Alma Mater Studiorum – Università di Bologna
In collaborazione con LAST-JD consortium:
Università degli studi di Torino
Universitat Autonoma de Barcelona
Mykolas Romeris University of Vilnius
Università di Lussemburgo
Tilburg University

DOTTORATO DI RICERCA IN

Erasmus Mundus Joint International Doctoral Degree in Law, Science and Technology

Ciclo 28 – A.Y. 2012/2013

**Settore Concorsuale di afferenza: 12H3**

**Settore Scientifico disciplinare: IUS20**

# Legal Ontology for Nexus: Water, Energy and Food in EU Regulations

**Presentata da:** **Md Mizanur Rahman**

**Coordinatore**

**Monica Palmirani**

**Relatore**

**Monica Palmirani**

**Relatore**

**Leon van der Torre**

**Esame finale anno 2016**

Alma Mater Studiorum – Università di Bologna
in partnership with
University of Turin
Universitat Autònoma de Barcelona
Mykolas Romeris University
University of Luxembourg
University of Tilburg

PhD Programme in

Erasmus Mundus Joint International Doctoral Degree in Law, Science and Technology
Cycle 28 – a.y. 2012/13

**Settore Concorsuale di afferenza: 12H3**

**Settore Scientifico disciplinare: IUS20**

# Legal Ontology for Nexus: Water, Energy and Food in EU Regulations

**Submitted by:** **Md Mizanur Rahman**

**The PhD Programme Coordinator** **Supervisor**

**Monica Palmirani** **Monica Palmirani**

**Supervisor**

**Leon van der Torre**

**Year 2016**

PhD-FSTC-2016-5.
The Faculty of Sciences, Technology and Communication

University of Bologna
Law School

# DISSERTATION

Defense held on 29/01/2016 in Bologna
to obtain the degree of

# DOCTEUR DE L'UNIVERSITÉ DU LUXEMBOURG

# EN INFORMATIQUE

# AND

# *DOTTORE DI RICERCA*
# *in Law, Science and Technology*

by

MD MIZANUR RAHMAN
Born on 19 NOVEMBER 1980 in COMILLA (Bangladesh)

# LEGAL ONTOLOGY FOR NEXUS: WATER, ENERGY AND FOOD IN EU REGULATIONS

## Dissertation defense committee

Dr Leon van der Torre, dissertation supervisor
*Professor, Université du Luxembourg*

Dr Monica Palmirani, dissertation supervisor
*Professor, Università degli Studi di Bologna*

Dr Adam Wyner, Chairman
*Professor, University of Aberdeen*

Dr Michal Araszkiewicz, Vice Chairman
*Professor, Jagiellonian University*

Dr Tom van Engers
*Professor, Amsterdam University*

Dr Sonia Bergamaschi
*Professor, University of Modena*

## Abstract of the thesis

Objectives of the thesis are – (a) to identify the problems in water-energy-food nexus from ICT and Law point of view and to propose theoretically a legal knowledge framework for water-energy-food nexus in order to reduce those problems technologically, (b) to construct and implement legal ontology for nexus extracted from EU water, energy and food Regulations in OWL 2 language, which is a part of the grater work of implementing legal knowledge framework for water-energy-food nexus proposed through the compilation of objective (a).

Considering these objectives, this thesis presents total five chapters. Chapter 1 is dedicated to fulfill the requirement of objective (a) and the rest chapters are devoted for objective (b). More particularly chapter four presents technical descriptions of the legal ontology for nexus, while chapter two and three articulate methodological aspect of it. Chapter five evaluates legal ontology for nexus. Additionally, besides the list of references, annex 1 delivers all asserted restrictions used in this ontology and annex 2 provides the links of all modules and documentations of legal ontology for nexus.

## Acknowledgment


I would like to express my special appreciation and thanks to my supervisor and tutor Professor Monica Palmirani, you have been a tremendous mentor for me. I would like to thank you for encouraging my research, for all of your support, hard work, guidance and for allowing me to grow as a research scientist. Your advice on both research as well as on my career have been priceless.

I would also like to specially thank my co-tutor Professor Leon van der Torre, for his administrative and research support during my stay in University of Luxembourg.

Indeed, I am truly grateful to LAST-JD program which financially supported this doctoral project and especially to Ms Dina Ferrari and Ms. Tazia Bianchi and everyone who is involved in this program. More particularly those who provided supports and cooperation during my research mobility in University of Bologna, University of Turin, Autonomous University of Barcelona and University of Luxembourg. Thank you so much.

I would also like to thank my committee members, professor Dr Adam Wyner, professor Dr Michal Araszkiewicz, professor Dr Tom Van Engers, professor Dr Sonia Bergamaschi and professor Dr Leon Van der Torre for serving as my committee members even at hardship. I also want to thank you for letting my defense be an enjoyable moment, and for your brilliant comments and suggestions, thanks to you.

A special thanks to Ms Florence Jacqué and all of her family members and to my mother. Words cannot express how grateful I am to them for all of the sacrifices that they've made on my behalf. Your love, kindness, supports and prayer for me were what sustained me thus far.

Last but not least, all errors in this doctoral work are solely mine and, for further correspondance for this work, I will be available at mizanur3 at gmail dot com. As the legal ontology for nexus is dynamic in nature, I would be happy to upgrade it time to time on the basis of reader's adequate feedback which will be highly appreciable.

## Table of Content

## Chapter 3: Methodology for Legal Ontology for Nexus: Water, Energy and Food in EU Regulations……………….104

## Chapter 4: Legal Ontology for Nexus: Water, Energy and Food in EU Regulations…………………………………...135

## Annexes

# Introduction

In 1996, the "*Rome Declaration on World Food Security and World Food Summit Plan of Action*[1]" by FAO declared the access to adequate food is a human right where water for human consumption is considered as food too. Following that declaration, since the beginning of 21st century, policy debate on food vs. fuel[2] has raised public demonstration throughout the world, particularly in Brazil, US and Europe due to the dilemma regarding farmland use changes by rising biofuel production which reinforce negatively the food supply. That worldwide concern regarding Water-Energy-Food nexus has led controversy within the existing international and regional legal systems such as policy harmonization debates between EU and her member states regarding water, food and energy domains even though food as a sub-domain of common agricultural policy was predominately a common concern at the EU level since its origin. Concurrently, in 2010, UN Resolution 64/292[3] explicitly recognized human right to clean drinking water and German Federal Government initiated, for the first time as such, an on-line resource platform[4] for Water-Energy-Food Security nexus funded by EU and in partnership with World Economic Forum, WEF and IFPRI. Subsequently Bonn Conference 2011 on '*The water Energy Food Security Nexus – Solutions for the Green Economy*' recognized the nexus perspective and provided the guiding principles for the nexus which drawn outstanding policy discourse in the UN Conference on Sustainable Development held in Rio 2012. Consecutively, in 2012, US National Intelligence Council published their report on '*Global Trends 2030: Alternative Worlds*'[5], where the nexus is declared as the fourth out of five most emerging global trends. Since then, subsequently, many governments like US, Germany, Brazil etc. as well as regional and international organizations like EU, UNWater and OECD have started policy discourse on how to recognize nexus and manage nexus resources using innovation and technology while there is no legal definition of such nexus. Very recently, on 25 September 2015, UN Resolution 70/1 on '*Transforming Our World: the 2030 Agenda for Sustainable Development*' declared 17 sustainable development goals where goal 2, 6, and 7 deals with food, water and energy security respectively. In addition, paragraph 16 of the said Resolution explicitly specified the need to bridge digital divide and to develop knowledge society using ICT as a means using following sentence[6] -

---

1 T. E. Downing (eds), Climate Change and World Food Security, NATO ASI Series. Yol. 137, Springer·Yeriag Berlin Heidelberg, 1996. And the entire Rome Declaration 1996 is available at http://www.fao.org/docrep/003/w3613e/w3613e00.htm

2 G, Jeffrey and A Goettemoeller. Sustainable Ethanol: Biofuels, Biorefineries, Cellulosic Biomass, Flex-Fuel Vehicles, and Sustainable Farming for Energy Independence, Prairie Oak Publishing, Maryville, Missouri, p. 42, 2007.

3 Available at http://www.un.org/en/ga/64/resolutions.shtml

4 http://www.water-energy-food.org/

5 Available at http://gt2030.com/

6 Available at https://sustainabledevelopment.un.org/post2015/transformingourworld

"*The spread of information and communications technology and global interconnectedness has great potential to accelerate human progress, to bridge the digital divide and to develop knowledge societies, as does scientific and technological innovation across areas as diverse as medicine and energy.*"

This utterance of the said UN Resolution is coherent with the EU Decision 456/2005/EC[7] which clearly emphasised to make digital content in Europe more accessible, usable and exploitable. However, in the case of nexus, following major problems are not in favour of implementing mentioned UN Resolution and EU Decision -

- First of all the nexus domains are isolated and managed by segregated institutional settlement. For example, European Food Safely Authority is established by EU Regulation 178/2002 in order to only deal with common food issues in EU level, but not with water or energy issues. Therefore digital content of such authority is not shared with digital content of other counter parts like water or energy related institutions, vice versa, for detail see chapter 1.

- Secondly, there are a number of legal information databases related with nexus domains such as FAO-Lex, ECO-Lex, Eur-Lex, WISH, Food in open data, and legislative.gov.uk but these data-bases are not inter-connected as well as their information is not inter-operable and semantically searchable, for detail see chapter 5.

- Thirdly, there is a number of water and food related ontologies such as AGROVOC. SESAME-S, CUAHSI, SSN, SWEET, Towntology and hydrology, but they do not represent legal definition neither of water nor food nor ontological connection among nexus domains, more discussion is given in chapter 3.

These mentioned problems in nexus domains create knowledge gaps in the nexus. For example, there is a lack of nexus detection mechanisms, lack of cross-compliance check among rules that affects and reinforces nexus domains and some of those rules are mutually exclusive in the nexus context. More discussion of such knowledge gaps are given in chapter 1. In order to minimize these problems and knowledge gaps in nexus, this doctoral thesis build legal ontology for nexus, explained in chapter 4, which is in line with the EU Council's conclusions inviting the introduction of the European Legislation Identifier (ELI) (2012/C 325/02)[8]. Because the annex 2 of the said EU notice specifies that -

---

[7] Available at http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1446837195759&uri=CELEX:32005D0456

[8] As a form of Notices from European union Institutions, Bodies, Offices and Agencies, published in EU Official Journal on 26.10.2012

"*...........Ontology is an 'explicit, formal specification of a shared conceptualisation' and represents a formal description of a set of concepts and the relationships in a given domain. By describing the properties of legislation and their relationships between different concepts, a shared understanding is made possible and ambiguities between terms can be avoided. Being a formal specification, it is directly machine-processable.............*" [9]

And it also explicitly mentions that

"*..... (2) Properties describing each legislative act*

*While a structured URI can already identify acts using a set of defined components, the attribution of additional metadata established in the framework of a shared syntax will set the basis to promote interchange and enhance interoperability between legal information systems. By identifying the metadata describing the essential characteristics of a resource, Member States will be able to reuse relevant information processed by others for their own needs, without having to put into place additional information systems.......................*"[10]

Considering the above contexts, the legal ontology for nexus is intended to provide following benefits –

a) It provides a legal definitional understanding for nexus that is machine processable and a formal specification of a shared understanding for nexus based on legal concepts those are laid down in the EU regulations.

b) It can be used as a basis to promote interchange and enhance interoperability between legal information systems related with nexus domains.

c) It can be reused by the Member States of EU for their own needs. That might decrease the total cost of developing nexus related legal information system.

d) It can be used to support case-based comparisons and testing different hypothesis of nexus.

e) Nexus query model can be formulated using this ontology.

f) It can be used to verify the legal mapping of nexus used to integrate data from multiple sources.

g) It can be used to support storage and management of linked nexus data.

---

[9] Available at http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1446837354309&uri=CELEX:52012XG1026(01)

[10] Ibid, annex 2.

h) It also can play intermidate role in the process of applying logic rules in nexus related legal documents, discussed in chapter 5.

i) By adding parametric values of water, energy and food quality in the existing legal ontology for nexus, it can be useful to detect WEF nexus using sensor technology in real time and space.

j) In addition, the methodology of it, explained in detail in chapter 3, can be applied to model legal ontology for other domains as well as jurisdictions.

The thesis is consisted with total five consecutive chapters. First chapter investigates current start of art of nexus in order to identify (1) major knowledge gaps in the nexus and (2) ontological existence of the nexus in the EU regulations, particularly in the legal definitions accommodated in EU Regulations and Directives associated with nexus domains. It also rationalizes the need for legal ontology for nexus. Second chapter evaluates existing perspectives and methodologies available for constructing legal ontology. The purpose of such evaluation was to select correct perspective and methodology for constructing legal ontology for nexus. It, at the end, justifies the need for developing new methodology for constructing the legal ontology for nexus. Third chapter explains the methodology used for engineering legal definitional knowledge extracted from the selected EU regulations in order to construct the legal ontology for nexus. Fourth chapter explains in detail the legal ontology for nexus while fifth chapter evaluates legal ontology for nexus. In addition, conclusion of the thesis shares critical issues faced throughout this doctoral thesis work. Furthermore, annexes contain a list of all formulas of restrictions implemented in legal ontology for nexus and links of all modules of legal ontology for nexus. LODE documentation of the legal ontology for nexus is available at http://codexml.cirsfid.unibo.it/post-doctoralresearchers/mizanur-rahman/.

# Chapter 1

## Water-Energy-Food Nexus: Domains, Problems and a Solution

*"A Nexus approach helps us to better understand the complex and dynamic interrelationships between water, energy and food, so that we can use and manage our limited resources sustainably. It forces us to think of the impacts a decision in one sector can have not only on that sector, but on others. Anticipating potential trade-offs and synergies, we can then design, appraise and prioritise response options that are viable across different sectors."*

- Food and Agriculture Organization of the United Nations (FAO), Rome, 2014.

## 1 Context: What is Water-Energy-Food Nexus?

Global resource scarcity has been pushing our civilization into an unconventional legal structural crisis. Let's consider following two snapshots from current state of art –

- If the legal structure in water, energy and food sectors remains the same, the increasing global population will need more about 70% of the current agricultural demands by 2050 and 50% more of current energy supply by 2035 [1,2,3].
- The increasing new bottom billion[11] neither has secure food supply nor proper access to clean water, and sustainable sources of energy [4,5,6,7].

Such scenarios would have affect and reinforce dramatically particularly on the water and land resources. In addition, changes in climatic patterns are likely to accelerate the pressure and scarcity of resources and hence to add vulnerability to human civilization and ecosystems, specifically on water scarcity and its affects over food and energy sectors due to following two reasons –

- Food and energy sectors are heavily dependent on the water resources [8,9,10]. For instance, fresh and clean water is required for producing food and energy [10].

[11] In 2007, Paul Collier, Economic Professor in University of Oxford, wrote his book – The Bottom Billion: why the poorest countries are failing and what can be done about it. In the book, he explained how bad governances structured by weak laws and legal institutions have been producing development traps, like legal-goal conflicts between institutions, of those causing resource scarcity and misuses. Furthermore, in 2010, Andy Sumner, a research fellow in Institute of Development Studies, in his work – 'Global poverty and the New Bottom Billion: three-quarters of World's poor live in Middle-income country' claimed that the most responsible factor of the bottom billion is to have proper policy concern, hence the lack of adequate legal structure for resources management. This has been affecting independently and inversely on water, energy and food sectors.

- Historically the legal structure and institutions designed for managing the water, energy and food service and resources are sectorial and domain-oriented [2]. For example, food and energy industry do not consider water as an economic input, as still they consider water resource is abundant and naturally available for usages [11].

Even though by nature water, energy and food are interdependent resources, by the rules of law and policy, they are domain-oriented and sectorial. Consequently, a nexus approach among water, energy and food sectors is fundamentally required in order to establish a unique legal structure for managing nexus resources, which might support climate mitigation measures favoring 'water smart strategy', climate adaptation measure to be based on sustainable and renewable energy initiatives, and to evade negative consequences of current and future food production due to water scarcity [12, 13, 14].

Considering the nexus contexts, this chapter first explains different perspectives of nexus – legal, non-traditional security, strategic cooperation, digital city, sustainable development, and globalization and geo-political perspectives. Then it manifests the guiding principles of the nexus approach and legal contextual understanding of water-energy-food nexus with a number of legal cases. It emphasizes the legal structure of water, energy and food sectors in EU and their institutional and jurisdictional limitations. Subsequently it articulates 17 major limitations, naming as knowledge gaps, of water-energy-food nexus from Information Communication Technology (ICT) and Law perspective. In conclusion, it proposes a potential solution based on a legal knowledge framework for managing and detecting WEF Nexus.

## 2 Nexus Perspectives

The origin of the word 'Nexus' is rooted in classical Latin, which means tie, combined group, the action of binding or bonding. The usages of the word 'Nexus' in different fields are very emerging since 1963, when Robert Boyle, a natural philosopher, in his book, '*Some considerations touching the usefulness of experimental natural philosophy*' indicated that nexus as juncture made out of their parts [15]. From that time, it has been meaningfully used in the fields of fiction and film[12], computer game[13], music[14], publishing, science, cell biology[15], technology, transport, philosophy

[12] Henry Miller wrote Nexus as the final novel in The Rosy Crucifixion, Mike Baron and Steve Rude wrote comic book named Nexus in 1981. Another famous writer Ramez Naam published his latest novel Nexus in 2012.

[13] There are many types of computer games are available in the market with the Nexus word. Most notably, in 2004 the real-time tactics based computer game came into market with the name 'Nexus: The Jupiter Incident'.

[14] There are a number of popular musical brand published

[15] In 1962, M. M. Dewey and L. Barr, in Science published at 31 Aug. 671/3, explained the term Nexus as an area where plasma membranes are fused out of two excitable cells.

and law. Since early of twenty first century, it became increasingly popular in public policy discourses particularly with the issue - water-energy-food nexus [16, 17,18].

In the current state of art, there are many perspectives available on the term Nexus such as philosophical, legal, non-traditional security, strategic thinking, digital city, sustainable development[16], globalization, and geo-political perspectives. Even though each of the perspectives has different articulations and manipulations of the term Nexus, there are also common understandings of it. A brief discussion of each of these perspectives has given below -

### 2.1 Philosophical perspective

The nexus as a term contributed vividly in the process philosophy [19, 20]. Alfred North Whitehead, a Harvard Professor in metaphysics and process philosophy[17], in his book *Science and the Modern World* (1925), articulates ontology in metaphysical perspective is consisted with two types of existence of entity – actual and abstraction entity [21]. He describes that actual entity that shows fundamental realities that characterize all things and abstract entity resulting from and based on its actual entity. Then Whitehead's ontology outlines nexuses of actual entities, which emphasizes the basic natures of Nexus – some aspects of the actual entities are either emphasized or de-emphasized in order to form the new set of characterizes of the Nexus.

The term Nexus is coined by Whitehead to articulate the networks of actual entities those exist in the universe. The example of Nexus, he gives, is known as 'enduring physical object', which allows changes and explorations of the actual entities during the course of its existence. Each enduring physical object is consisted with two types of members – a temporally earliest and a temporally last member. In addition, he also proposes following features of the Nexus -

- Every member of a Nexus is a causal consequences operated by the earliest member of the nexus.
- There is no spatial separation between the members of the Nexus.
- Within a Nexus there exist many overlapping Nexuses.
- Each group of Nexuses includes earliest and last member of the enduring physical object.

Whitehead's term Nexus and theory of process philosophy also contributed in psychology and postmodern cognitive science. Psychological perspective of the theory of mind also focuses on the eternal objects of the thoughts and their formations of Nexus [22, 23]. In addition, Michel Weber has generated an open forum named 'Whitehead Psychology Nexus' dedicating it for investigating similarities and differ-

[16] See Tilton, J.E. 1996. Exhaustible resources and sustainable development: two different paradigms. Resources Policy. Vol.22: 91-97.

[17] The thematic area of the process philosophy is identification of metaphysical realities with change and development. Whereas other branches of philosophy claim that true reality is based on permanent substance, timeless characteristic and consider change as an accidental, process philosophy in contrast supports that change is the cornerstone of the reality.

ences of Alfred's process philosophy and Nexus in lieu with various conceptions of contemporary psychological fields[18] [24].

### 2.2 Legal Perspective

The theory of Nexus-of-contracts is first demonstrated by a number of legal commentators and economists like Michael Jensen, William Meckling, Frank Easterbrook [25, 26, 27]. The principal idea of the Nexus-of-contracts theory is that a collection of contacts between and among various parties, like primary and secondary stakeholders, directors, employees, customers, suppliers and other involved parties, makes corporation. Therefore, any dispute arises in corporation must be resolved by interpreting contracts through identifying legal obligations of different involved parties that arise from those agreed contracts [28].

The Nexus-of-contracts theory is featured by both descriptive and prescriptive natures of Nexus. It is descriptive, on one hand, because of Nexus of all contacts of corporation shapes and formulates the legal nature of the corporation. On the other, it is prescriptive because of that corporation becomes a 'legal fictions' constructed by the Nexus of all contracts for minimizing the 'contracting costs' and 'the cost of monitoring compliance' those are mainly associated with various conflicting interests of the parties involved in the Nexus of contracts [25][28].

The theory is useful in order to enhance 'corporate plausible deniability'. Because it argues the validity of a chain of contractual obligations of corporates derives from the Nexus-of-contracts [29]. The theory also transcends the border of the state by emphasizing that the body of corporate laws varies between 'micro-social contracts' of different state governments [30]. That supports the notions of descriptive relativism, legal realism, and constructs the basis of universal human rights by incorporating the ideas of business ethics into the formulation process of the Nexus of contracts, even though theory needs to provide clear ideas on the relationship between – power and knowledge, position of interest of agents and principles, distinguishes between legality and morality, the 'is-ought gap' [28].

### 2.3 Non-traditional Security Perspective

The rise of non-traditional security, also known as human security [31], was the creation of conjunction of multiple factors at the end of the Cold War and is an emerging discipline of the security studies aiming to understand the vulnerability in global perspective, not in only state perspective [32]. In contrasts with traditional security, it refers the individual as the subject of security rather than state. The legal arguments of it is based on following international legal instruments – UN Charter 1945, UN Declaration of Human Rights 1948 and it related covenants 1966, and various conventions based on genocide, right of women, refugees and racial groups [33].

In particular, Holger Hoff presented background paper[19] for the Bonn 2011 Conference on understanding Water, Energy, Food (WEF) security Nexus[20], where he

[18] For more information - https://chromatika.academia.edu/MichelWeber

demonstrated in details about the substantial interactions between and among water, energy and food [2]. With his arguments and evidences, he shows that water is used for mining, refining, processing, extraction of fossil fuels, growing feedstock for generating electricity as well as bio-fuel. Statistic shows that agriculture uses average 70% of total fresh water consumption by human; it means food production is the principal consumer of global fresh water [5][8][10].

Moreover, the definitions of Water, Energy and Food security also help us to understand their sectorial and domain-oriented characters. These are given below in brief –

- The definition of water security [21] is given in Millennium Development Goals (MDGs), where it defines as 'access to safe drinking water and sanitation' [34]. Very recently both became human rights [35].
- The energy security is defined by UN Secretary General's Advisory Group on Energy and Climate Change (AGECC) as 'access to clean, reliable and affordable energy services for cooking and heating, lighting, communications and productive uses' [36, 37]. The definition also includes 'uninterrupted physical availability of energy at a price which is affordable, while respecting environmental concerns'.
- The definition of food security is designed by Food and Agricultural Organization, where it says 'food security means availability and access to sufficient, safe and nutritious food to meet the dietary needs and food preferences for an active and healthy life'[38]. It is also established as a human right recently [39].

However for following reasons none of these definitions represents the nexus perspective of WEF.

- Water security [22] definition does not mention about the necessity of availability of and access to water for various usages of ecosystems and human other than drinking. It generally represents the idea of water as services, but does not articulate the security of water as resource.
- Energy security definition promotes economic and usages aspects of services that energy sector provides [23]. However, even though the definitions clearly mentions 'respecting environmental concerns', it does not prescribe about the water as input

[19] See - Hoff, H. (2011). Understanding the Nexus. Background Paper for the Bonn2011 Conference: The Water, Energy and Food Security Nexus. Stockholm Environment Institute, Stockholm.

[20] See World Economic Forum. 2009. Thirsty Energy: Water and Energy in the 21st Century, update 2009, World Economic Forum in partnership with Cambridge Energy Research Associates (CERA), January 2009, at http://www3.weforum.org/docs/WEF_WaterAndEnergy21stCentury_Report.pdf

[21] See WWC, 2012. A pact for water security. World water council 2013-2015 Strategy.

[22] See Asit K. Biswas. (2001). Water Policies in the Developing World. Water Resources Development, Vol. 17, No. 4, 489–499, 2001

[23] See Peter P. Rogers. (2013). The Food-Water-Energy Nexus and the Challenge to Sustainability. Water Lecture Series. Radcliffe Institute for Advanced Study at Harvard University.

and output at the various phrases of energy productions. Furthermore, it also does not advocate about the food as input for the bio-fuel production as well as about the land-use changes due to bio-fuel production.

- Food security definition emphasizes on the food intakes of human being, but not the way it is made. More precisely, the water and energy as the inputs for food production is fundamental but not been considered in the definition.

### 2.4 Strategic Thinking Perspective

Strategic thinking, as a cognitive activity, is a way of thinking in order to achieve success in endeavors. It is intended to create future opportunities through creating comparative advantages [40]. It's critical questions do not relay on conventional 'What?', but 'How?' and 'Why?'.

In 1963 General Andre Beaufre mentioned in his article '*An introduction to Strategy*'[24] that strategic thinking has two components – analysis, that is to accumulate data collectively in a whole on which diagnosis is performed, and synthesis, that to choice between alternative courses of action comes from the results of diagnosis at the end of analysis. In the field of strategic study, it is well accepted condition that for executing strategy better requires strategic thinking in order to comprehend the motions of chain of nexuses of events that shape future for defining the strategic opportunities and sustainable future. In 1998, in addition, Jeanne Liedtka articulated following five major characters of strategic thinking competencies in practice[25] -

- Systems perspective that enables to articulate the implementing results of strategic actions in a whole, not partly. This also considers the identification and application of nexus arising from a diverse set of actions or different domains or sectors.
- Intent focused that allows being engrossed on the finding comes out of system thinking as a whole.
- Thinking in time that permits to fill the gap between today's reality and the critical intent for the future.
- Hypothesis driven that facilitates to visualize the critical intent for the future applying scientific methods into strategic thinking.
- Intelligent opportunism that means of being responsive towards the strategic opportunities. This competency allows understanding all alternatives and their influences over changing the environment.

Jeanne Liedtka also enunciated the differences between strategic thinking and planning by indicating that in contrasts with strategic planning, strategic thinking is bottom-up and interactive approach in order to understand the system as a whole for shaping the future by adding critical values into the system [41]. Additionally, Fiona

[24] See Beaufre, Andre (1965). An Introduction to Strategy. Frederick A. Prager. LCCN 65014177

[25] Jeanne Liedtka,(1998), "Linking Strategic Thinking with Strategic Planning", Strategy and Leadership, 26(4), 30-35.

Graetz in his article '*Strategic Thinking versus Strategic Planning: Towards Understanding the Complementarities*'(2002), proposed a model that holds that strategic thinking is required for adequate strategic planning, otherwise strategic planning might produces traps like development traps and/or rigidity traps [42].

It is evident that WEF domains are based on strategic planning; whereas WEF Nexus should be based on strategic thinking. Considering above five competencies of strategic thinking, however, the following table answers of why Nexus perspective is necessary –

**Table 1.** Relationship of strategic thinking and planning with WEF domains and nexus

| ***Evaluative Component*** | ***Strategic Thinking*** | ***Strategic Planning*** | ***WEF Domains*** | ***Nexus*** |
|---|---|---|---|---|
| Vision | Shape the future as a whole | A future that is predictable in detail. | Based on a future that is predicated in economical details. | Needs to be designed as a whole |
| Approach | Bottom-up | Top-down | Top-down | Bottom-up |
| Formulation and implementation | Interactive | Divided based on theory of strategic management | Divided based on the theory of strategic management | Interactive and iterative |
| Controlling mechanism | Relies on the process of whole and monitor from above. | Control through measurement system | Control through measurement system | Need to be controlled and monitored as a whole. |

### 2.5 Digital City Perspective

Digital city, also known as smart city, is based on information technologies motivated by major challenges increasingly emerging from climate change, aging populations, economic reformation, raising on-line life styles and multiple pressures on public finance in order to promote low cost efficiency, speed, performance and wellbeing [43]. The current idea of this perspective includes a number of sectors such as energy, water, waste, health care and transport [44]. Even though yet there does not exist the Nexus perspective of those sectors, it foundationally promotes transactional relationship with its citizens through using advanced ICTs by implementing following characteristics [45] –

- Efficiently supporting technology based development on economic, social and cultural sectors. Even though, at this stage, it does not support the ICT based legal infrastructure, artificial based legal industry has been growing faster too.

- Enabling technologies to learn, adapt, and innovate in order to respond in real time manner to the changing circumstances. That might open the opportunities of automatize the Nexus perspective of various sectors, mainly WEF sectors.
- Promoting e-participation and co-design through connecting digitally bottom-up, top-down and middle-out approach.
- Enhancing creative industry in order to consider the result as a whole.

Kimninos, in his conference proceedings 'The architecture of Intelligent Cities (2006)', proposed following three dimensions of the digital city [46][49] –

- Artificial intelligence rooted in communication infrastructure and physical environment. It also includes problem-solving digital tools for all.
- Collective intelligence for enabling connected knowledge based cooperation and innovation. It proposes such knowledge infrastructure that involves various innovative mechanisms like integration, collaboration and differentiation.
- Creative city where intelligence, creativity and resourcefulness of each citizen will be connected with city's knowledge hub in order to organize orders collectively.

These all above mentioned characters and dimensions of digital city directly and indirectly promote the nexus perspective. For example, without collective intelligence and artificial intelligence based infrastructure [47, 48], application of Nexus perspective will remain theoretical policy discourse. Because in the case of Nexus, it is required to analysis data that comes from satellite, GIS, and other ICT based environmental technologies in real time manner.

In addition, ARUP group projected that by 2020 global market value of digital city services will exceed $400 per year [49]. Furthermore, since the beginning of this century, EU has been constantly initiating strategies for achieving smart urban growth. One of such initiatives is FuturICT initiative 2012[26]. However, what is missing in the features and dimensions of the digital city is lack of concerns on developing artificial intelligence based legal infrastructure.

### 2.6 Sustainable Development Perspective

In 1713, the German term '*nachhaltiger Ertrag*' became a generic forestry term 'sustained yield', from which the concept 'sustainability' and 'sustainable development' came into being. Then, in 1970s, the concept sustainability came into practice as an economic term in order to enhance economics in an equilibrium way for ensuring ecological support systems [50, 51]. Then, in 1972, Dennis and Donella Meadows, in their classic report on the 'Limits to Growth' presents a model of sustainable world system compromising two elements – (a) without unexpected and unrestrained

[26] FuturICT projects aims to develop participatory computing for our complex world. One of the fundamental goals of this project is to manage complex interactive systems maintaining sustainability and resilience, which also includes nexus approaches. More detail see at http://futurict.inn.ac/whos-involved/

downfall, and (b) capable to provide fundamental material needs of all people [52, 53, 54]. IUCN forwarded sustainable development as a global priority in 1980 and UNWCN in 1982 came with five principles of establishing environmental justice by recognizing the nature affected by human's performance is subject to be judged [55, 56]. Successively, in 1987, Brundtland Commission's report '*Our Common Future*' exposed the significance of the term 'sustainable development' with the meaning – 'meets the needs of the present without compromising the ability of future generations to meet their own needs' [57, 58].

The year 1992 was very remarkable year for promoting sustainable development for two particular reasons – UN conference on Environment and Development declared (a) The Earth Charter and (b) The action plan Agenda 21. Most importantly chapter 38, which indicates International Institutional Arrangements, and chapter 39, which specifics International Legal Instruments and Mechanisms, of the Agenda 21emhapshized on balancing between environmental and development concerns, minimizing the legal gap between environmental, social and economic agreements and international legal instruments, and enhancing legal technical capacities for promoting environmental laws in lieu with UN systems and international arrangements [59, 60]. Consequently Millennium Declaration 2000 forwarded significances of conservation and management of resources for development.

Till 2012 even though it is evident that international instruments on sustainable development did not use the term Nexus, these instruments directly advocate on combining three perspective together – economic, social and environment, for promoting any types of public and private initiatives. In 2013, however, sustainable development has reframed by rearranging its interconnected domains – ecology, economics, politics and culture, while Nexus perspective concerns on connecting water, energy and food domains.

## 2.7 Globalization and Geopolitical Perspective

The term globalization is originated from the word globalize, which means promoting international networks of economic systems [61]. The current state of art defines globalization as a dynamic process for increased interconnectedness at economic, technological and societal scales. Since WW2 mainly two sectors re-energized the globalization process. They are – the financial market and the media [62, 63]. However, David Held, Anthony McGrew, David Goldblatt and Jonathan Perrator, in their book, Global Transformation, articulated following three perspectives of globalization [64, 65, 66] –

- Hyper-globalist perspective is featured by limiting significance and authority of nation-states, denationalized economics by interpreting global market through economic logic.
- Skeptical perspective argues that current approach of globalization is fragmented and regionalized where multi-national corporations plays bigger roles and which is based on neo-liberal economic strategy for benefits West.

- Transformationalist perspective, in contrasts with other two perspectives, claims that the dynamic and multidimensional process of the globalization is neither determined nor based on single cause. Because this process is consisted with spatial rearrangements and re-structuration of economic, political, cultural and military powers. Thus globalization can be viewed as a process of transformation in the scale of shared-power and resource management.

Furthermore the political and economic aspects of globalization process affect and reinforce the geopolitics, which an approach to comprehend, analysis and envisage international and regional political behaviors by examining and evaluating various geographical variables such as natural resources, climate change, demography, migration due to globalization process. It also explains foreign policies and international policies in relations of geography, space and resource – the size, locations and resources of places. In Oyvind Osterud's words[27] –

> 'In the abstract, geopolitics traditionally indicates the links and causal relationships between political power and geographic space; in concrete terms it is often seen as a body of thought assaying specific strategic prescriptions based on the relative importance of land power and sea power in world history... The geopolitical tradition had some consistent concerns, like the geopolitical correlates of power in world politics, the identification of international core areas, and the relationships between naval and terrestrial capabilities.'

The Former Secretary of State of USA Henry Kissinger[28] articulated that –

> *'by geopolitical, I mean an approach that pays attention to the requirements of equilibrium.'*

Historically globalization and geopolitics walk side by side, even though they work with different variables, scopes and capacity. On the one hand, globalization mainly works with variable related with economic, social and cultural integration [67]. On the other, geopolitics focus on world conflicts due to various geographical variables. Because, in-between these two disciplines, environmental variables play an important role to bridge these two influential approaches together. One of the fundamental reasons of it is that environmental degradation and depletion mainly caused by various industrial applications for meeting increasing supplies and demands coming from the progressive globalization processes and that primarily affect all geopolitical variables [68]. For example, polluted water[29] caused by massive food and energy production

[27] Osterud, Oyvind. "The Uses and Abuses of Geopolitics," Journal of Peace Research, no. 2, p. 191, 1988

[28] Kissinger, Henry. Colin S Gray, G R Sloan. Geopolitics, Geography, and Strategy. Portland: Frank Cass Publishers, 1999.

[29] See Tortajada, C. (2010). Water Governance: Some Critical Issues. (C. Tortajada & A. K. Biswas, Eds.)International Journal of Water Resources Development, 26(2), 297–307. doi:10.1080/07900621003683298

and that flows through the territory of one sovereign state to another and then eventually it affects the citizens of other country. This type of incidence involves both globalization and geo-political variables.

Consequently, Nexus is a concern of globalization as well as geo-political. Because these three approaches have following similar variables to be concerned -

- Water, energy and food – these sectors are consisted with shard-resources[30]. For instance, water is required in energy and food production, but water is not considered as an economic input to the energy and food industry. Energy is required for waste water treatment, water and food transfer, and food production. Many food substances are used for producing bio-fuel. However, these shared-resources are managed and directed in isolation by separate legal instruments and institutions nationally as well as globally.
- Detection of conflicting Nexuses that exist within water, energy and food sectors.
- The institutional and policy rearrangements for managing water, energy and food Nexuses.

## 3 WEF Nexus Approach and it's Guiding Principles

The foundation of Nexus approach is based on interdependency of water, energy and food security and also their associated natural and legal resources that affect and reinforce that security such as soil, land, legal and socio-economic structures etc. The aim of it is to detect trade-offs and synergies in order to produce shared-legal infrastructure for managing those shared-variables in a sustainable way. In order to achieve this goal, following guiding principles are proposed in Bonn 2011 Conference on The Water, Energy, and Food Security Nexus [2] –

- Investing to sustain ecosystem services – On one hand, the eco-system services contribute to human well-being – defined by UNEP. For example, many livelihoods of the poor come from these services. On the other, the fundamental principles of the Green Economy as well as Circular Economy are guided by eco-systems services that include water, food, bio-fuels etc. Among various types of eco-system services, regulating services are consisted with climate and water regulations, which has very close link with hydrological cycle and natural water infrastructure often disturbed by manmade activities and artificial hard infrastructure, e.g., Fukushima Daiichi nuclear disaster 2011. Besides, transforming into green agriculture and bio-fuel might decreases the damages caused to eco-system services due to food and energy production. In addition, Payments for Ecosystem Services (PES) currently lack Nexus approach, because it is based on single sector and service like carbon sequestration.

[30] See WWAP (World Water Assessment Programme), 2012. The United Nations World Water Development Report 4: Managing Water under Uncertainty and Risk, vol. 1 (Paris: UNESCO, 2012), 25.

- Creating more with less – Resources use-efficiency[31] and increased sectorial resources are two fundamental requirements of the Green Economy. However, in case of measuring efficiency, productivity is calculated with mainly kilograms, kilocalories and kilowatts for food and energy respectively. But the productivity is not based on calculating water consumed by per unit of food and energy production, while food and energy production consumes the highest amount of the water consumed by human. The role of Nexus might lead an important contribution in increasing productivity rate of food and energy by reducing average waste and negative effects caused by one sector over other. It may also reduce greenhouse gas emissions, sectorial foot-prints and also pressure on the resources.

- Accelerating access and integrating the poorest – On one hand, environmental degradations and depletions due to food and energy affect negatively on the eco-system services[32], which eventually affects the livelihood and lives of the poorest as they have less responsive capacity towards the risks and hazards[33]. On the other, it is likely that the poorest people have the direct field experiences of why and how one sector affects other, as their livelihood is based on mainly eco-system services[34]. For example, how water is collected and used for the food production is best known by a farmer and how power plant affects the land fertility of its surroundings is also best known by the local community people whose livelihood is based on the eco-system services that are in the location of that power plant. Therefore, Nexus primarily is based on bottom-up approach that ensures the access and participations of the local people, especially the poorest, into the process of the Nexus detection and policy formulations.

Even though these three guiding principles seem very useful for formulating Nexus, they are grounded on the approach of strategic planning. Because they do not answer the non-conventional questions 'How?', rather they are only based on the conventional question 'what?'. For example, the applicability of the third principle 'accelerating access and integrating the poorest' is not fundamentally possible, if the characteristics of the digital city perspective are not implemented at all levels of public administration and service management.

These principles neither support legal nor strategic thinking nor digital city perspectives, but supports non-traditional security, sustainable development, globaliza-

31 See Gerbens-Leenes, W., Hoekstra, A.Y. and Van der Meer, T.H. (2009): The water footprint of bioenergy, PNAS, 106 (25): 10219-10223

32 See World Economic Forum. 2011a. Water Security: Water-Food-Energy-Climate Nexus. The World Economic Forum Water Initiative. Edited by Dominic Waughray. Washington D.C., USA. Island Press.

33 See Bizikova L., et al. 2013. The Water–Energy–Food Security Nexus: Towards a Practical Planning and Decision-Support Framework for Landscape Investment and Risk Management. Winnipeg, Canada: International Institute for Sustainable Development (IISD).

34 See Cook, C. and K. Bakker. 2012. Water security: Debating an emerging paradigm. Global Environmental Change. Vol.22: 94-102.

tion and geo-political perspective[35]. The following in *Table 2* shows the summary of whether these principles satisfy various Nexus perspectives –

**Table 2.** Relationship of principles of Nexus approach and various Nexus perspectives

| ***Nexus perspectives*** | ***Investing to sustain ecosystem services*** | ***Creating more with less*** | ***Accelerating access and integrating the poorest*** |
|---|---|---|---|
| Philosophical | Not support fully the ideas of Nexus in the process philosophy. | | |
| Legal | No | No | No |
| Non-traditional security | Yes | Yes | Yes |
| Strategic Thinking | Are based on Strategic Planning, not Strategic Thinking, as there is no explanation of how to implement these principles. | | |
| Digital city | No | Yes [from technological aspects of 'creating more with less'] | No |
| Sustainable development | Yes | Yes | Yes |
| Globalization and geo-political | Yes [the transformational perspective of globalization | Yes | Yes |

## 4 Understanding Water-Energy-Food Nexus

Water, energy and food systems are interconnected and interdepended in our ecosystem services, industrial and agricultural sectors as well as in maintenances of our daily life activities[36]. For instance, water is required to extract energy and produce electricity, energy is essential to treat and transport water, and both water and energy are fundament requirement to grow food [2][69]. The increasing global population, advanced level of prosperity and technological development will add up the global demand for energy, food and water supplies in coming times [70,71,72]. This necessitates identification of their complex relationships, which is known as water-energy-food nexus [72].

[35] See ADB (2013). Thinking About Water Differently: Managing the Water-Food-Energy Nexus. Asian Development Bank (ADB). Mandaluyong City, Philippines.

[36] See Karlberg, L. and Hoff, H. (2013). Using a Nexus Approach to Support Development and Environmental Planning in Ethiopia. SEI Discussion Brief. Stockholm Environment Institute.

## 4.1 The Nexus Sectors

The nexus sectors are consisted with water, energy and food[37]. A brief introduction of each sector is drawn below in the light of their roles in the Nexus.

- Water - The principle role in Nexus[38] is played by water, which is non-interchangeable in any types of biomass production [73]. Despite the fact, the biomass is primacy and fundamental resource for producing energy and food under Green Economy umbrella. It functions like two types of variables in Nexus – (a) as a state variable that helps to describe its mathematical state in the WEF Nexus system and hence it determines the future behavior of the Nexus system, and (b) as a control variable of change, which strongly influences the internal quality values of the interactions that happens among water, energy and food [74, 75].

  There exist two types of water with different set of functionalities. They are – (a) green water, available in the soil for supporting agricultural and natural ecosystems, is maintained through land usages and farming, (b) blue water, available in rivers and lakes for municipal usages like sanitation, domestic water supply, irrigation for agricultural production, and industrial purposes, and managed by water infrastructure and can be recycled. Each of these waters has different trade-offs in Nexus context and most importantly they are typically managed by the different institutions and legal structure [2][69][74].
- Energy – Fossil fuels, non-renewable resources, are the primacy sources of energy. Two points to consider about Fossil fuels are – firstly it has adverse effects in Green Economy, and secondly the entire amount of Fossil fuels is going to end by coming decades [76,77]. Therefore, the renewable bio-fuels have much significance in the Nexus context. EU Directive on Renewable Energy gives a solid target of increasing 20% of total energy supply from renewable bio-fuels by 2020 [76].

  However, these increasing non-renewable bio-fuels also have hostile externalities on other sectors of Nexus. For instance, unit production of bio-fuel consumes more fresh water than unit production of energy from fossil fuels. It means that increasing production of bio-fuels will accelerate the demands of fresh blue water which is one 3% of total global water [2]. Production of bio-fuels has also been increasing the land-use changes since last decade. Because now corn, which previously used for human consumption, grows for bio-fuel production [78].
- Food – Green Revolution[39] has pushed food production ahead during last few decades mainly for two reasons – (a) by expending the agricultural lands – mostly due to deforestation and conversation of landscapes into farm land, and (b) by intensi-

[37] See UNECE (2014). Workshop on Water-Food-Energy-Ecosystems Nexus Assessment in the Sava River Basin. Unece Water Convention Draft Methodology.

[38] See Stein, C. (2013). How Understanding Social Networks Can Help to Govern the Nexus: A Case from the Blue Nile Basin. SEI siscussion brief. Stockholm Environment Institute.

[39] See Ponting, Clive (2007). A New Green History of the World: The Environment and the Collapse of Great Civilizations. New York: Penguin Books. p. 244. ISBN 978-0-14-303898-6.

fying existing agricultural systems through adding large inputs of energy, fertilizers and water [79,80,81,82].

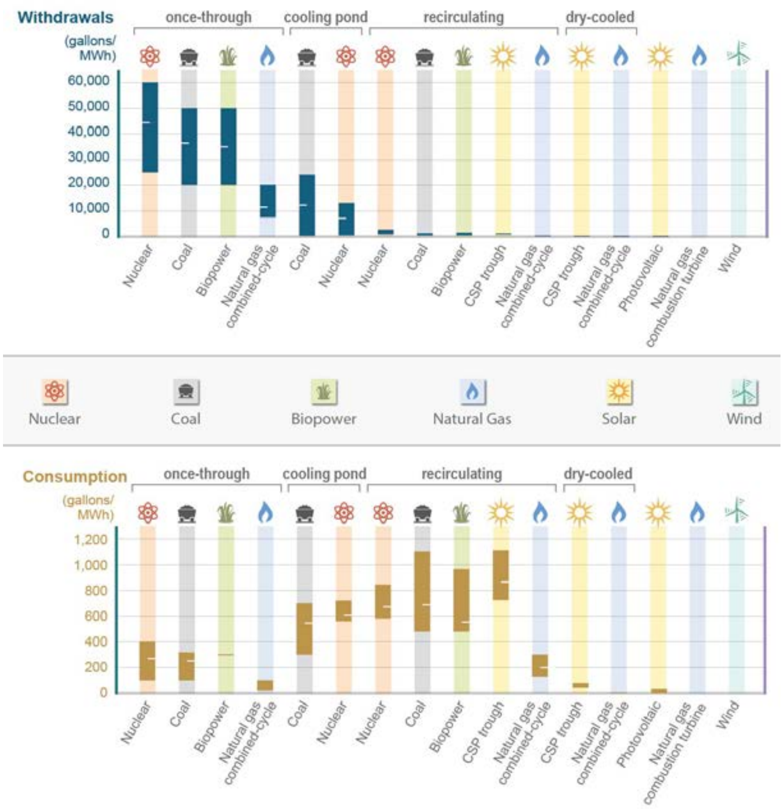



**Fig.1.** Water use for electricity generation by fuel and cooling technology[40]

This advancement in food production has a number of side-effects on other sectors of Nexus[41]. Some of them are [2][69] [83,84,85,86] – (a) it increase water and energy consumption per unit of food production, (b) excessive fertilizer caused soil pollution, hence water pollution that increased the cost of waste water treatment, (c) through deforestation and land-use changes, carbon storage decreased and that eventually affects the global warming and changes climatic patterns, (d) through modern agricultural technology, water productivity has increased in food production process while energy productivity remained at the same place, (e) uneven repeated pressures from over-agricultures affects eco-system services, particularly the carrying capacity of eco-systems.

[40] For detail see http://www.globalchange.gov/browse/multimedia/water-use-electricity-generation-fuel-and-cooling-technology

[41] See UN-ESCAP (2013). Water, Food and Energy Nexus in Asia and the Pacific. Discussion Paper. UN-ESCAP. Bangkok.

## 4.2 Interfaces among Water-Energy-Food Sectors

The interfaces among WEF sectors can be viewed from four different angles – (a) water for energy, (b) water for food, (c) energy for water and (d) energy for food [2][75][87]. A brief explanation of these interfaces has been illustrated below with relevant cases –

- Water for energy - Energy consumes 8% of global water withdrawals [2][87]. In some industrial countries of Europe, the figure is 45% of total water withdrawals of that country [76]. From ‘fossil fuels conversation’ to ‘energy uses for transportation’, water is used as control variables generally in the process of mining, extraction, refining, processing and disposal of fossil fuels, and for growing biofuels and producing electricity [75][88]. In the process of these activities, water also gets polluted. Production of bio-fuels requires more water consumption than the amount of water consumed by fossil fuels [89]. For instance, 10,000 to 100,000 liters per GJ of energy. In addition, producing gas and oil consumes 1 to 10 liters and 100 to 1000 liters of water per GJ of energy respectively. However, the *Figure 1* shows the requirement of amount of water for electricity generation by fuel and cooling technology. It is scientifically accepted fact that the amount of water is required for producing food for one day is equivalent to the water needed to produce 1 litter of liquid bio-fuel.

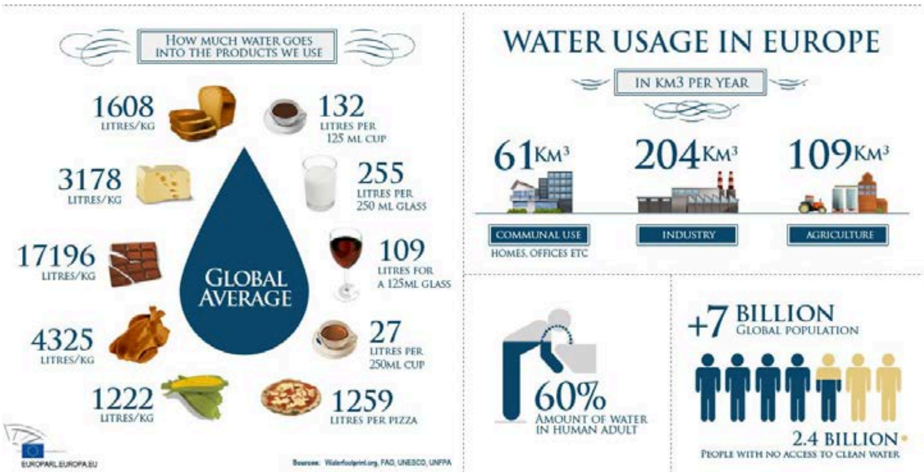



**Fig.2.** Water footprints and global production[42]

- Water for food – There are generally two types of interconnectivity between water for food – one is water requires for food production and other is effects of food production over the water quality system [90]. Form the water requires for food production’s point of view, globally 80 to 90% of consumption of blue water is performed by food production as well as terrestrial eco-systems use a large amount

[42] See http://one-europe.info/eurographics/enough-clean-water-for-all-of-us

of green water [2]. This does not mean that water productivity is same at every usage of it. Generally water productivity depends on a number of factors like type of soil and crops, farming methodology, climates, type of fertilizers used for agriculture and other water quality related factors[43]. However, it is scientifically accepted fact that one calorie of food takes average one liter of water [91]. *Figure 2* shows the average water consumption rate of the food people eat regularly and sector-wise average water consumption in Europe. From the reverse point of view, there are a number of adverse effects of food production over the water system such as degraded land and soil formation due to over-irrigation affects the quality of water and changes the run-off [92,93]. It also has negative impacts on groundwater recharge and effectiveness of ecosystem services [94]. In addition, it reduces water storage capacity of soil and causes siltation in the water reservoirs. That eventually affects the water capacity and availability for the electricity generation from hydropower plants [91][95].

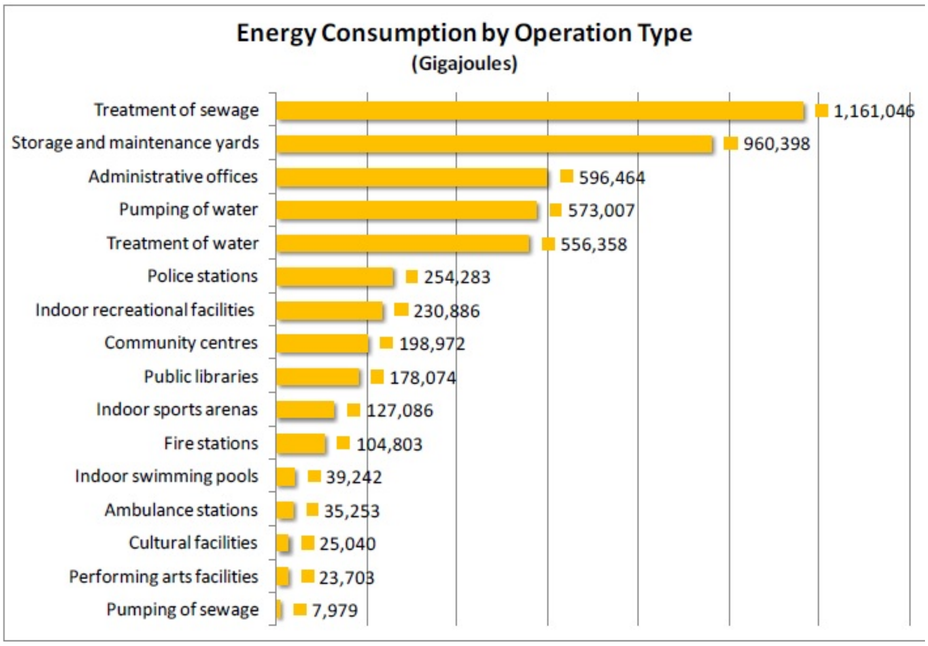



**Fig.3.** Average energy consumption by operation type in an urban community[44]

- Energy for water – Water is lifted, moved, treated and distributed by energy [2][69]. The rate of energy consumption for water related operation is depended on many factors such as source of water, quality and quantity of water as well as the

[43] See FAO. 2003. World Agriculture Towards 2015/2030: An FAO Perspective. Food and Agriculture Organization-Earthscan; Rome and London.

[44] See http://www.toatmosphericfund.ca/2013/11/06/first-annual-benchmarking-report-on-city-facilities/

purpose of water operation etc [96]. Figure 3 shows the average energy consumption[45] by operation type in an urban community. It draws clear alarming calculation that a typical city spends maximum amount of its energy supplies - 1,161,056 Gigajoules for only treating sewage. In addition, 573,007 and 556358 gigajoules are used for pumping and treating water respectively.

However, highly energy intensive water sources are generally non-conventional ones such as desalinated seawater and reclaimed wastewater, which takes 2.6 to 4.3 and .66 to .87 kWh respectively per cubic meter of clean water produced. Furthermore, the irrigation water that comes from ground water is more energy intensive than irrigation performed by surface water. Statistics show that in few countries it takes 40% of the total energy usage for pumping water from the ground [94][97,98].

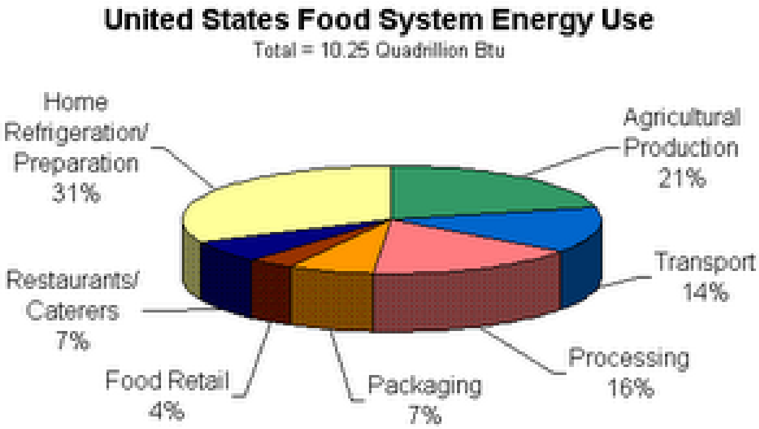



**Fig.4.** Energy uses in food system in US[46]

- Energy for food – Energy is required for every stages of agricultural production such as transporting, processing and packaging. It also is used for food retails, restaurants and caterers, food preservation at domestic level [97]. Statistics shows, given in the *Figure 4* that home refrigerators consume maximum energy used for food system in US, which is 30% of the total. While agricultural production, transporting and processing food consumes 21%, 14% and 16% of the total energy consumption respectively.

  Energy productivity[47] of irrigation and desalination is increasing constantly as these are essential for food production [99]. Drip irrigation consumers relatively

[45] See Marta, A. D., F. Natali, M. Mancini, R. Ferrise, M. Bindi, and S. Orlandini. 2011. Energy and water use related to the cultivation of energy crops: a case study in the Tuscany region. Ecology and Society 16(2):2.
[46] See https://attra.ncat.org/attra-pub/viewhtml.php?id=281

more energy than rain-based agriculture [100]. The lack of fresh water might lead demand of energy much higher in order to fill the gap and vice versa [2][75]. For instance, while there is electricity gap due to erratic power supplies in the process of crop cultivation, over-irrigation becomes very useful. That affects negatively both blue and green water.

Technology based current agriculture system even though increased crop harvesting but labor market of agricultural sector became fragile [101,102]. In this context, in order to run all machines used for farming increased energy inputs expressively, mainly for land preparation, executing irrigation and other inputs. The agriculture and food manufacturing is, hence, heavy energy intensive, which affects and reinforces prices of crop and oil. This also makes particularly agricultural sector earns less profits after burning the greater energy costs. Another statistics show that 30% of the total global energy is consumed by food production [102].

### 4.3 EU water-food-energy domains and their legal jurisdictions

In EU nexus perspectives in environmental issues and eco-system services are not only limited to the nexus. As a result, in 2012, EU first officially reported nexus among water, energy and land. That also includes other associated sectors related with these three domains such as soil. Very recently EU has initiated many projects based on public-private partnership for understanding better the nexus. However, these all initiatives are subjects of different sub-polices supported by isolated public funds [103, 104, 105, 106]. Because there is no legal structure yet installed in EU for dealing with such Nexus issues. To understand the legal structure of each of WEF domains, a brief overview of these domains are given below –

- EU water domain and its legal arrangement – For the past 30 years, EU has established a number of directives for regulating water resource management and its quality standards. The first wave of water related legislations took in place in 1970s with Drinking Water Directive and Legislation covering certain polluting economic activities, known as IPPC Directive. However, all of these legislation can be categorized into three broad groups – (a) legislation for protecting water and water bodies, (b) legislation for controlling economic activities that affects the water quality, and (c) legislation for regulating municipal's responsibilities for water and waste water management. The most important directives are discussed below briefly –

  - The Surface Water Directives 75/440/EEC [48] fully dedicated to express the quality standards and pollution protection guidelines for surface water, but it

[47] See U.S. Department of Energy. 2006. Energy demands on water resources: report to congress on the interdependency of energy and water. Sandia National Laboratories, Albuquerque, New Mexico, USA.

[48] Of 16 June 1975 concerning the quality required of surface water intended for the abstraction of drinking water in the Member States

does not say anything about the ground water. However, this Directive eventually embedded into the EU Drinking Water Directives 1998.

- Dangerous Substance Directive 76/464/EEC[49] focuses on pollution protection in the aquatic environment mainly caused industrial chemical release. This Directive is considered as the interface between industrial and environmental policies for next 25 years. It provided a Black list for eliminating dangerous substances and a Grey list allowing member states to introduce other dangerous substance that locally pollutes water and implements those guidelines within the framework of local legal jurisdiction. However, this legislation did not achieve much success in practice, because only 18 out of 129 Black list substances were regulated, but not all.
- Ground Water Directive 80/68/EEC[50] provides two lists of dangerous substances that affect ground water adversely.
- Bathing Water Directive 76/160/EEC[51] is the first fully water-related legislation of EC, which has been in force for 25 years and amended by the scientific knowledge into the Water Framework Directive and revised version of bathing water standards are further given in Bathing Water Directive in 2002.
- The Nitrates Directive, officially known as Council Directive 91/676/EEC[52] concerning the protection of waters against pollution caused by nitrates from agricultural sources, is considered as a complementary legislation of Urban Waste Water Directive aiming to reduce levels of nutrients that affects adversely drinking water and food production activities.
- The Pesticide Directive 94/414/EC[53] is placed to mainly protect the plants that is affected by the contaminated water supplies.
- The IPPC Directive, official known as Council Directive 96/61/EC[54] on Integrated Pollution Prevention and Control, is one of the most important legislation that bridges the industrial and environment legislations. It provides a list of 30 EU industrial sectors and their integrated approving procedures for installing their industrial functions.
- The Drinking Water Directive 98/83/EC[55] provides quality standard of water intended for human consumption, which is considered as the guiding legislation for water service and supply related industries. This legislation fundamentally summarized the legal experiences occurred through the market and societal respond towards the Drinking Water Directive 1980. This legislation also has giv-

[49] Of 4 May 1976 on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community

[50] Of 17 December 1979 on the protection of groundwater against pollution caused by certain dangerous substances

[51] Of 8 December 1975 concerning the quality of bathing water

[52] Of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources

[53] Of 15 July 1991 concerning the placing of plant protection products on the market

[54] Of 24 September 1996 concerning Integrated Pollution Prevention and Control (IPPC).

[55] Of 3 November 1998 on the quality of water intended for human consumption

en a proper legal definition of water intended for the human consumption and included water used in food manufacturing is the subject of this Directives.

- The Urban Waste Water Directive (UWWD)[56] has provided legal requirements of waste water treatment which promoted massive investments throughout all member states of EU and helped to establish a massive waste water treatment infrastructure in urban settlements. However, still water quality is directed by the EU Drinking Water Directive 1998.

Generally during 1970s and 1980s, there were very limited legal influences over the water industry and urban water management. In principle, these legislations helped to protect the water bodies in better way, but did not affect much on the management of water resources, especially when water used in other sectors like food and energy as resource input. As a result, even though there are a number of water protecting legislation, water of EU is degraded and depleted during 1980s, 1990s and even till today.

- EU food domain and its legal arrangement – In EU food legislation is mainly based on general principles and umbrella requirements for food law, which is laid down in Regulation (EC) 178/2002[57]. The aim of this legislation is to provide a general framework for promoting common rules for internal market integration for food safety, food/feed production and distribution. It also officially established Food Safety Authority in 2002. In addition, in 2010, Commission started the 'fitness check of food chain' exercise aiming to evaluate entire body of legislations for detecting the legal loopholes, overlaps, gaps, inconsistencies those exist among the legislation from the point of view of food safety and promotion.

  The entire process of food safety is categorized into three group tasks – (a) risk assessment, (b) risk management, and (c) risk communication articulated in Article 3 of the No 10 of the Regulation. In the legislation, food assessment is comprehended as an examination process of identifying risks by applying scientific methodologies. The assessment also includes social and economic aspects of food in order to incorporate it into the process of risk management. However, legislation does not ensure public participations and transparency in the food assessment and risk management and communication process.

- EU energy domain and its legal arrangement – The body of EU energy laws are very comprehensive and complex with multi-layers of institutional arrangements. Generally EU energy laws cover the taxation and usages of energy both renewable and non-renewable through various legislations, case laws, statues, rules, regulations and edicts. In addition, EU energy formally policies articulate European politics over various issues of energy. The practices of EU energy laws involve with general guidelines for its member-states of legal requirements of extraction, in-

[56] Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment

[57] Of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety

stalling energy industry, and getting licenses for ownership-rights as well as attainments in oil and gas under the soil. It also expresses harmonizing mitigation guidelines if conflicts rise related with those rights mentioned in the vest body of energy laws.

EU energy laws also based on legal instruments for handling temporary disruptions occurs to the energy supply among its member states. The first generation of electricity and gas directives, known as the Price Transparency Directive[58] tracked by the Electricity and Gas Transit Directive, expressed common rules for EU's internal market integration in particularly electricity and gas in order to promote transparency in the common energy markets. Since then, EU has installed vast energy infrastructures through following major legislation –

- Major external energy treaties include Energy Charter Treaty 1994[59] with 54 signatories concerning various trades of energy products, Energy Community Treaty 2006 between Balkan states and EU, and The Energy Star Agreement, which become law by Council Decision 2006/1005/EC. In addition, The EU Energy Policy also concerns about international cooperation.
- The laws related with electricity and gas sectors are covered by Third Energy Package containing mainly following legislations – Regulation (EC) 714/2009, Regulation (EC) 715/2009, Directive 2009/72/EC, Directive 2009/73/EC, Regulation (EC) 713/2009. These legislations concern on access of electricity and gas through cross-boarders.
- The main legislations related with renewable sources and efficiency of energy are: Directive 92/42/EEC providing efficiency rates of energy produced by hot-water boilers, Directive 2004/8/EC promoting internal energy markets, Directive 2006/32/EC enhances energy service improvement, Directive 2009/28/EC promoting generating energy from renewable sources, Directive 2009/31/EC regarding carbon capture and their storage, Directive 2009/125/EC providing a framework for legal requirements of eco-designs of energy related products, Directive 2010/30/EU indicates labeling requirements of products coming from energy sector, Directive 2010/31/EC mentioning energy efficiency of building, Directive 2012/27/EU based on Energy Efficiency Plan 2011 provides guidelines for promoting energy efficiency in EU.
- The principle legislations related with oil and petroleum sectors are: Directive 94/22/EC based on requirements for hydrocarbons licensing, Directive 98/70/EC for fuel quality, Directive 2009/119/EC focusing on the management oil and petroleum supplies, and Directive 2013/30/EU provides safety related regulations of offshore oil and gas operations.
- Coal related legislations are: Regulation (EC) 1407/2002 provides state aid mechanisms for coal industry but expired in December 2010, The Council Deci-

[58] Council Directive 90/377/EEC of 29 June 1990 concerning a Community procedure to improve the transparency of gas and electricity prices charged to industrial end-users

[59] Council and Commission Decision 98/181/EC, ECSC, Euratom of 23 September 1997 on the conclusion, by the European Communities, of the Energy Charter Treaty and the Energy Charter Protocol on energy efficiency and related environmental aspects.

sion 2010/787/EU on state aids for uncompetitive coal mines, Regulation (EC) 405/2003 enhancing monitoring requirements in coal inputs within the EU zone.
- Legislations related with EU energy tax measures are: Directives 92/81/EC and 92/82/EEC direct the excise duties over the mineral oils, Directive 2003/96/EC is Energy Taxation Directive that provides maximum taxation rates on electricity, gas and oil,

### 4.3.1 EU Water-Food-Energy Related Case Laws

In the present state of art of EU legal cases, there is no such case filed with Nexus. However, there are a number of legal cases where judgments were directly and indirectly related with some parts of Nexus. Few such type of legal cases are given below in brief –

- *Guerra and others v. Italy (no. 14967/89)*[60] –An accident causes in a chemical factory that produces fertilizers for agricultural farming. As a result, a big chunk of toxic arsenic substances mixed with local water caused 150 local people to admit to hospital due to intensive arsenic poisoning. The applicants complained that it affected their right to live and physical integrity. The court held that Article 8 of the Convention was not ensured by Italy as health problems caused by water pollution directly related with people's well-being and restrict them to enjoy their private and family life.
- *Commission of the European Communities v. Ireland (case C-396/01)*[61] – the case is related with protection of water against any pollution may occurred by nitrates from agricultural sources, which is the subject of Directive 91/676/EEC. The court held that the member states of EU are obliged to identify water in three different ways – (a) water is affected by pollution, (b) waters that could be affected by pollution, and (c) waters that is intended for human consumption. The court also mentioned that all fresh ground and surface water which has nitrate concentration more than 50 mg/l shall be taken under obligation to take care of it.
- *Commission of the European Communities v. French (case C-266/99)*[62] – the related legislation of the case is Directive 75/440, Art 4(1)(2) and Art. 4(2) focusing on to ensure quality of the water by reducing harmful substances including nitrates. The court held that member states are responsible to achieve removal of dangerous substances in the surface water in order to make it humanly consumable. The judgment also indicates that merely qualitative and quantitative prescription of the water is not the intent of the Art. 4(2) of the Directive 75/440, rather member states must ensure the quality of the water as it is prescribed in the Directive.

---

[60] See http://www.hrcr.org/safrica/environmental/guerra_italy.html

[61] See http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1421518976805&uri=CELEX:62001CJ0396

[62] See http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1421518976805&uri=CELEX:61999CJ0266

- *European Commission v. Federal Republic of Germany (case C-525/12)*[63] – the judgment provides a clear concept of the ‘water service’ under Art 2(38) and 9 of the Directive 2000/60/EC. The court held that Germany has failed to fulfill the obligation under Directive 2000/60/EC, because the concept of the ‘water service’ also includes water uses for hydroelectric power generation, irrigation and industrial purposes, navigation and flood protection as well as personal consumption.
- *European Commission v. French (case C-258/00)*[64] – the principle subject-matter of the judgment is to identifying water that is affected by pollution. It says that there is certain types of water containing phosphorus might be incompatible to recognize it as polluted water under the Directive 91/676, Art. 3(1) and (2). The court shows following three reasons on behalf of their final verdict – (a) the role of phosphorus in water may play very important role to give rise of different organisms which are the essential part of the aquatic eco-system, (b) in order to balance inconsistency between Art 3(1) and (2) of the Directive, and (c) in order to give a wider discretion to the member-states to identifying polluted water with the proper respect the objectives of the Directive.

### 4.4 Institutional and Jurisdictional Limitations and Complexity

Considering Nexus, the scope and capacity of institutional and jurisdictional dimensions of each of WEF domains are limited and complex mainly for following reasons –

- ***Domain oriented institution and jurisdiction*** – historically each of WEF domains is based on their own sectorial institution and jurisdiction arranged by a number of legally complex institutional mechanisms. For example on one hand legal authority food and energy domain still do not consider water as economic inputs in their production layers. On the other legal aspects of water related institutions are mainly focused on providing water services, but not protecting water resources.
- ***Lack of bridge between ‘interpretative guidance of courts’ and ‘domain’s jurisdiction’*** – even though traditionally WEF domains are sectorial, the justice system is not. Therefore, whenever appropriate and competent court makes a judgment regarding any of WEF issues, they fundamentally make their sentences based on interpretative perspective of Convention and other related legislations. That arises level of complexities at the execution level of those legal decision due to the institutional limitation of WEF sectors.
- ***Lack of integrated resource management*** – the resource management of WEF is segregated. As a result, different institution is responsible for different part of the same resource. For example, generally blue and green water resources are managed by different institutional setups. Similarly, in the case of energy and food sectors,

[63] See http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1421518976805&uri=CELEX:62012CJ0525
[64] See http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1421532511868&uri=CELEX:62000CJ0258

different types of energy and food resources are promoted by different institutional arrangement.

These fundamental legally created institutional and jurisdictional restrictions have been affecting and reinforcing a number of knowledge-gaps that need to be well managed in order to promote the Nexus. Few important such knowledge-gaps have been discussed in section 5.

### 4.5 Ontological Existence of Nexus in their Legal Definitions

Even though, on the one hand, the existing legislations of WEF sectors don't address Nexus and, on the other, existing environmental legal cases did not legally establish the direct legal inter-dependency over resources of WEF sectors. For example, in *European Commission v. Federal Republic of Germany (case C-525/12 )* even though the court established the linkages between the concept of 'water services' and 'water used in energy and food production', it did not give clear links between resource inter-dependency over WEF resources.

However, there is an ontological existence of Nexus under considering legal definitions of 'water', 'food' and 'bio-fuels' that are given in following respective legislations –

- Article 2 of Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption defines 'water intended for human consumption' as

> "'For the purposes of this Directive:
>
> 1. 'water intended for human consumption' shall mean:
>
> (a) all water either in its original state or after treatment, intended for drinking, cooking, food preparation or other domestic purposes, regardless of its origin and whether it is supplied from a distribution network, from a tanker, or in bottles or containers;
>
> (b) all water used in any food-production undertaking for the manufacture, processing, preservation or marketing of products or substances intended for human consumption unless the competent national authorities are satisfied that the quality of the water cannot affect the wholesomeness of the foodstuff in its finished form.'"

- Article 2 of Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport, defines bio-fuel as

> "'1. For the purpose of this Directive, the following definitions shall apply:

(a) ‘biofuels’ means liquid or gaseous fuel for transport produced from biomass;
(b) ‘biomass’ means the biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste,
(c) ‘other renewable fuels’ means renewable fuels, other than biofuels, which originate from renewable energy sources as defined in Directive 2001/77/EC (2) and used for transport purposes;
(d) ‘energy content’ means the lower calorific value of a fuel.

2. At least the products listed below shall be considered biofuels:

(a) ‘bioethanol’: ethanol produced from biomass and/or the biodegradable fraction of waste, to be used as biofuel;
(b) ‘biodiesel’: a methyl-ester produced from vegetable or animal oil, of diesel quality, to be used as biofuel;
(c) ‘biogas’: a fuel gas produced from biomass and/or from the biodegradable fraction of waste, that can be purified to natural gas quality, to be used as biofuel, or woodgas;
(d) ‘biomethanol’: methanol produced from biomass, to be used as biofuel;
(e) ‘biodimethylether’: dimethylether produced from biomass, to be used as biofuel;
(f) ‘bio-ETBE (ethyl-tertio-butyl-ether)’: ETBE produced on the basis of bioethanol. The percentage by volume of bio-ETBE that is calculated as biofuel is 47 %;
(g) ‘bio-MTBE (methyl-tertio-butyl-ether)’: a fuel produced on the basis of biomethanol. The percentage by volume of bio-MTBE that is calculated as biofuel is 36 %;
(h) ‘synthetic biofuels’: synthetic hydrocarbons or mixtures of synthetic hydrocarbons, which have been produced from biomass;
(i) ‘biohydrogen’: hydrogen produced from biomass, and/or from the biodegradable fraction of waste, to be used as biofuel;
(j) ‘pure vegetable oil’: oil produced from oil plants through pressing, extraction or comparable procedures, crude or refined but chemically unmodified, when compatible with the type of engines involved and the corresponding emission requirements.’”

- Article 2 of the Food definition from Regulation (EC) no 178/2002 of the European Parliament and of the Council of 28 January2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety.

  “Definition of ‘food’ For the purposes of this Regulation, ‘food’ (or ‘foodstuff’) means any substance or product, whether processed, partially processed or unprocessed, intended to be, or reasonably expected to be ingested by humans.

> ‘Food’ includes drink, chewing gum and any substance, including water, intentionally incorporated into the food during its manufacture, preparation or treatment. It includes water after the point of compliance as defined in Article 6 of Directive 98/83/EC and without prejudice to the requirements of Directives 80/778/EEC and 98/83/EC. ‘Food’ shall not include:
>
> (a) feed;
> (b) live animals unless they are prepared for placing on the market for human consumption;
> (c) plants prior to harvesting;
> (d) medicinal products within the meaning of Council Directives 65/65/EEC (1) and 92/73/EEC (2);
> (e) cosmetics within the meaning of Council Directive 76/768/EEC (3);
> (f) tobacco and tobacco products within the meaning of Council Directive 89/622/EEC (4);
> (g) narcotic or psychotropic substances within the meaning of the United Nations Single Convention on Narcotic Drugs,1961, and the United Nations Convention on Psychotropic Substances, 1971;
> (h) residues and contaminants.’”

Considering the above mentioned legal definitions, following arguments can be drawn in favor of Nexus –

- Water definition addresses clear resource inter-dependency between ‘water intended for human consumption’ and ‘water used for food manufacture’. It says that water used in any phrases of food manufacture must be the water legally qualified by the water definition.
- Food definition clearly mentions that water is food and the water used in the food production must be the water without compromising the wholesomeness of the food and the quality standard mentioned the drinking water Directive.
- The biomass from agricultural sector in bio-fuel definition makes linkages with the food substance, if the food substance is taken after the harvesting, where the fresh water is used to produce. This makes triangular dependency over the resources of Nexus.
- In addition, there are few types of bio-fuels mentioned in the bio-fuels definition have direct resource dependency over the food resource and hence it depends on water resource too. For example, ‘pure vegetable oil’ is one type of the bio-fuel as well as is one type of food commodity for domestic usages and as it is a food product, it has direct resource dependency of water.

There also exist other types of meta-ontological nexus among WEF domains from legal definitional point of view and those discussed in detail in chapter 4.

# 5 Knowledge Gaps in the Water-Energy-Food Nexus

In 1970 Phillip J. Tichenor, George A. Donohue, Clarice N. Olien first suggested the significances of knowledge gap hypothesis[65], where knowledge is considered as a form of wealth. In the context of Nexus, due to the institutional and jurisdictional limitations those mentioned in section 4, there exist a number of knowledge gaps in the collective form of WEF domains' knowledge, which is required to understand in order to detect and implement the Nexus. This section is intended to demonstrate following knowledge gaps that exist within the nexus.

## 5.1 Isolated jurisdictions

Jurisdiction generally deals with the power of an official body in order to handle a particular matter and also expresses the scope and approach of institutional performances [107]. The right of the jurisdiction only exists whenever the subject of the jurisdiction has been authorized. This authority can be given or distributed to and/or among institutions created by law. But when the authority is distributed and/or incomplete in any certain context or subject-matter, jurisdiction becomes isolated and thus such jurisdiction generates gaps in legal and/or collective knowledge creation, management and distribution [108, 109].

In the case of Nexus, resource and service management of each of these sectors are authorized with a set of procedural law based jurisdiction to different institutions. For example, Regulation (EC) no 178/2002 of the European Parliament and of the Council of 28 January2002 presents the general principles and requirements of food law as well as it established the European Food Safety Authority which deals with food safety measures mentioned in the legislation. Therefore, it produces a vast body of knowledge related with the subject-matters of food safety. The same happens in energy and water sectors. However, in the context of nexus, it is required to collect and keep all of this knowledge in a place so that it will be easier to detect and analysis, possibly by machine as well, the Nexus among these sectors efficiently and semantically.

## 5.2 Lack of detection mechanism

The implication of legal textual provision of one domain of nexus, generally, affects and reinforces other domains, which is not easy to detect. In order to detect such implications, it is essential to connect different terms, concepts, sub-concepts and their associated properties of one domain to another. For example, EU water definition established the links between 'water intended for human consumption' and 'water used for food manufacture', but did not produce any link between the concept of 'drinking water' and 'water used for energy production, even though in both cases, they use fresh water, which is only 3% of the total Earth's water [2][110]. As a result,

[65] See Tichenor, P.A.; Donohue, G.A. & Olien, C.N. "Mass media flow and differential growth in knowledge". Public Opinion Quarterly 34 (2): 159–170. doi:10.1086/267786

food sector is legally responsible to maintain the quality standard of drinking water mentioned in EU Water Directive, but not the energy sector. However, therefore from legal reasoning perspective, it is important to know whether the water is used for food maintains the natural and chemical quality of the drinking water mentioned in the Directive, which is not an easy task to do it manually. Consequently Nexus requires a detection mechanism in order to detect the implication of textual provisions of one sector over the others.

### 5.3 Difficulties to maintain the rules of policies and/or legislations

There are always a number of rules of one policy documents and legislations have legal relationship with other aligned policy documents and legislations. But generally these rules are subject of different institutions to implement and to prepare necessary financial allocations. That plays an important role to arise up level of difficulties and complexities in the process of detecting nexus. For example, on one hand, the purposes of bio-fuels legislations are to promote renewable energy for transportation purposes, but do not address the issues related with land-use-changes from agricultural production to energy production due to using crops, e.g. vegetable oil, for bio-fuel production. On the other hand, bio-fuel is a legal concern of Agency for the Cooperation of Energy Regulators[66] and not the land-use-changes. So, in order to simplify the process, it is essential to maintain linked-rules of different policy documents and legislations.

### 5.4 Lack of mechanism for integrating

In the current state of art, there is lack of mechanism for integrating between ‘related institutional rules’ and ‘rules coming from policy-based legislations’ of WEF domains. The rules of the game of WEF domains are not only determined by policy documents and legislations, rather institutional rules play an important role in determining ideas, interests, process, content and what need to be done at the ground time to time of WEF domains. Hence making functional links between institutional rules[67] and rules coming from policy documents and legislations may help to coordinate legal knowledge of WEF domains more efficiently.

### 5.5 Lack of mechanism for cross compliance check among rules

There is also lack of mechanism for cross compliance check among rules (legal, institutional, social, cultural, ethical and technical) of WEF domains. For instance, as it

[66] Known as ACER, is an Agency of the European Union by the Third Energy Package in 2009 and established in 2010. It is situated in Ljubljana, Slovenia

[67] Scott, W. Richard in his book, ‘Institutions and Organizations: Ideas and Interests’, Los Angeles, CA: Sage Publications (2008), mentioned that institutional rules generally shape authoritative guidelines for social behavior which is different than the rules appear from law and policy document.

is shown in earlier section that EU biofuel Directives specifics that biofuel must be sourced from biomass in order to use for transportation. However, in reality, the biofuel can be used for other purposes too[68]. It simply indicates the gaps between legal and technical rules of using biofuel, which requires cross compliance check. However, cross compliance check between and within policy documents and legislations of WEF domains is not enough. Besides, it is also very crucial to have integrated mechanism for cross compliance checking among rules coming from different sources such as legal, institutional, social, cultural, ethical and technical perspectives of WEFC domains. These two types of cross compliance checking jointly are very requisite for detecting the nexus as well as for legal reasoning in favor of nexus.

### 5.6 Unresolved conflicting rules and laws

Conflicts between and among laws and legal rules are concerns of private international law [111, 112]. In the context of nexus, there exist many unresolved conflicting rules and laws not only based on their legal institutional jurisdiction [113]. Rather these conflicting rules and laws also are based on adverse effects over the resources of their own sector and/or effects of one sector over the others [114]. Detecting of conflicting rules within WEF domains might add another degree of efficiency in order to adopt most appropriate set of rules for nexus.

### 5.7 Lack of collective approach

Lack of collective approach based on multi-sectorial-linked-legal-rules of WEF domains is one of fundamental drawbacks towards forwarding policy agendas of nexus. Because on the one hand new legal rules appear few frequently from new legislations and case laws through the court's interpretation of legislations and on the other hand existing legal rules get its necessary changes through either new legislations or amendments. These legal rules of one particular domain of WEF might create goal-conflicts to the legal rules of the others. Hence it is necessary to have collective approach based on multi-sectorial-linked-legal-rules for detecting nexus in a synchronized way.

### 5.8 Absence of standardized and systematized documentation

Absence of standardized and systematized documentation of the contents and rules (legal, institutional, social, cultural, ethical and technical) of WEF domains may increase lack of correspondences and interoperability among the contents of different documents, e.g. legislation, scientific reports, policies or authority approved statistics. In the present context of WEF domains – all respective policy documents, legislations, authoritative reports and other legal documents are not systematically documen-

[68] In UK, biofuel can be also used, beside using it for the purpose of transportation, for generating power and heat ect. See http://biofuel.org.uk/uses-of-biofuels.html

tized in according to any international standard such as Akoma Ntoso[69] and by following any other semantic web standard. Hence it is very difficult to process mechanically the contents and rules of WEF domains, which can be considered as a fundamental obstacle for detecting nexus automatically.

### 5.9 Absence of implication of technical rules

Generally, but not always, technical rules are guided by legal rules within a specific domain of WEF. Hence traditional way of applying technical rules is limited to the respective domain. But, in order to detect nexus cautiously, technical rules of one domain must need to apply to the others in its appropriate scope and context. However, in the case of not having appropriate technical rules within the policy documents and legislations of one specific domain of WEF, it is necessary to include technical rules from scientific investigations and authority approved reports. Moreover, detecting contradicting technical rules is too essential for detecting nexus in most appropriate way.

### 5.10 Lack of mechanism for detecting contradicting technical rules

Scientific study based and authority approved technical rules is one of key contents of WEF domains. For example, methodologies and technical standard of testing water-quality are given in EU Directive on water Intended for Human Consumption. However, technical rules of one domain may contradict with technical rules of other domains. For instance, technical rules of measuring quality standard of 'water used in food' is not as same as the technical rules of measuring quality standard of 'water intended for human consumption'. Therefore, identifying the conflicting technical rules that exist among WEF domains is prerequisite for understanding the effects and those technical rules over nexus.

### 5.11 Lack of formalization of legal knowledge

Once standardized and systematized documentation of contents and rules of WEF domains are processed, it is required to formalize and model legal knowledge of WEF domains using computational ontology and the logic theory adopted that make the legal reasoning of nexus applicable in heterogeneous set of rules coming from WEF domains. It also may enable to detect the nexus spontaneously in real time application and with the feature of legal reasoning for detecting nexus. Lack of formalization of legal knowledge of WEF domains using computational ontology and semantic web approach is another fundamental requirement for not only ensuring Smart City in practice, rather it is an essential technical requirement for processing all knowledge of WEF domains coming from parliaments, legislative bodies, competent courts, satel-

---

[69] Akoma Ntoso, which means "linked hearts" in the West African Akan language, is to define XML based technology-neutral simple electronic representations format of parliamentary, legislative and judiciary documents. See http://www.akomantoso.org/

lite, geographic information systems and other environmental technologies in real time, space and legal manner.

### 5.12 Lack of legal knowledge network

Semantic knowledge management of WEF domains may enable to identify the contents of respective domains by it types as well as by the meaning of the documents through descriptive metadata executed by semantic web technologies such as XML, Ontology etc. It may provide following benefits in favor of detecting and analyzing nexus –

- Maintain the knowledge of WEF domains together in graph data format which can enable the technology to search for content efficiently as well as publish it in the desirable formats.
- All administration might operate the documents in the same time and acquire the right knowledge from the right department or authority in the least amount of time.

Existing networks of nexus's initiatives are neither based on Akoma Ntoso [115] and LegalRuleML standard [116] nor use computational ontology. These networks are merely preserving information in pdf or html format and also not independent from technology, language, machines and platform. Most importantly these networks are not designed for formalizing legal knowledge of WEFC domains. Therefore, usages of these networks are very limited.

Furthermore, In the WEF domains, there is no graph data-model or storage system of their contents. It may provide index-free adjacency in order to enclose a pointer to its data-elements without no index-lookups. It may enable to share memories and distributed environment among the contents of WEF domains. It is the prerequisite for developing semantic knowledge management of WEF domains as well as their nexuses.

### 5.13 Lack of rule-based simulation

Existing simulation techniques for Environmental Decision Support Systems (EDSS) are mainly based on mathematical models, but the rules of the game for WEF domains are based on mostly legal and institutional rules including other relevant rules such as social, cultural, ethical and technical. Therefore, in order to simulate nexus pragmatically with legal reasoning, it is required to simulate based on all available exiting and legally valid rules.

### 5.14 Lack of change management

Existing WEF domains, on the one hand, are mainly closed and non-adaptive in nature towards the changes transported by new rules coming from new legislation, institutional, social, cultural, ethical and technical requirements. On the other, there is no the best solution for detecting the nexus. However, one of the most appropriate approaches of detecting the nexus from Big Data[70] [117] is to execute a legal knowledge framework enable to perform various legal operations including legal reasoning on open-linked-data of WEF domains with the technical capabilities to adapt the changes that happens so often within the legislative and policy documents of WEF domains. The reason beyond it is that the rules of WEF domains get changes over time to time. Therefore, flexibility and adaptability must be ensured towards the new rules in order to update the detection of nexus.

### 5.15 Absence of ontological representation

There is a clear absence of ontological representation of the contents of WEF domains and their nexus. As a result, the same concept that exists in WEF domains has various implications with different meaning. For instance, the concept 'substance' and 'bio-mass' has different usages under the legal definition of bio-fuel and food, while chemicals that exist in the body of water do not consider as substance in the legal definition of 'water intended for human consumption'. Therefore, in order to systematize the concepts, sub-concepts and their associated properties and interactions of WEF domains and their nexuses, ontology can limit complexities and organize knowledge of nexuses for further problem solving.

### 5.16 Lack of detecting constitutive rules that come from legal definition

Fundamentally WEF domains are, on one hand, deterministic due to their sectorial, that is based on legal and structural governances, biasedness and, on the other hand, non-deterministic due to the unknown consequences originated from each of their legal biasedness over the others. These deterministic and non-deterministic natures of nexus, in combined, generate complexities in order to detect and understand the legal reasoning process of nexus. Because legal reasoning works like a complete circuit composed by legal rules as the point of departure from the source to the proof and supported by evidences throughout the proofing process back to the source. In the case of WEF domains, this legal reasoning circuit does not function completely. Because the most, if not all, of institutional rules of WEF domains are driven by the legal definitions and constitutive and regulative rules that appear from such sets of legal definitions those are by character limitedly expressive and operated by the respective authorities of WEF domains. This limited expressiveness of legal definitions coming from one domain is further compressed and challenged by the deterministic and non-deterministic natures of other domains. Consequently legal reasoning process

[70] Few perspectives of Big Data are mentioned here from 3Vs complementary characteristics of big data: Volume: big data doesn't sample. It just observes and tracks what happens, Velocity: big data is often available in real-time, Variety: big data draws from text, images, audio, video; plus it completes missing pieces through data fusion. Machine Learning: big data often doesn't ask why and simply detects patterns, Digital footprint: big data is often a cost-free byproduct of digital interaction. See Mayer-Schönberger, V., & Cukier, K. (2013). Big data: a revolution that will transform how we live, work and think. London: John Murray.

of nexus becomes paralyzed at some point of the legal reasoning circuits by their own legal biasedness.

In order to understand the role of constitutive rules[71] [118, 119, 120, 121] that appears from the legal definition of WEF, the following brief explanation is given followed by the Figure 5 and using following legal definitions of water, food and biofuel have considered for following explanation from – (a) EU Water Directive 98/83/EC[72] on the quality of water intended for human consumption, (b) Regulation no 178/2002[73] of the European Parliament and of the Council on food safety, (c) EU Directives 2003/30/EC[74] on Promotion of the use of biofuel or other renewable fuels for transport, please see complete definition at section 4.5 -

- Let's assume A, B and C represents legal definitions of water, energy and food respectively and each of them represents non-interacting system or interacting system in a very limited way.
- A2, B2 and C2 are corresponding constitutive rules of WEF domains coming from respective legal definitions of A, B and C. These constitutive rules also represent non-interacting system.
- I-1, I-2 and I-3 are legally accountable institutions responsible to implement respective constitutive rules A2, B2 and C2. By nature, there institutions are non-interacting systems too.
- A, B and C; A2, B2 and C2; and I-1, I-2 and I-3 are not a composite system. Consequently, they do not themselves produce composite constitutive rules.
- Institutions I-1, I-2 and I-3 are legally responsible to produce their own scientific evaluative report corresponding their own domains.
- All available knowledge coming from sensors, internet of things, satellite, GISs, environmental technologies and social web related with WEF domains are known as Big Data of WEF domains. These Big Data contains the evidence that is legally admissible for proofing legal reasoning of nexus.
- In order to realize the composite constitutive rules, P1, P2 and P3 need to be applied in the Big Data. P1, P2 and P3 represent precautionary principles, coherence of law and utility of law respectively.
- As the content of Big Data is unknown to anyone, the answer of any queries asked by applying P1, P2 and P3 is unknown too to everyone.
- Appling P1, P2 and P3 over the Big Data is intended to produce composite constitutive rules X.

---

71 "[R]egulative rules regulate antecedently or independently existing forms of behaviour […]. But constitutive rules do not merely regulate, they create or define new forms of behaviour. The rules of football or chess, for example […] create the very possibility of playing such games" - See Searle, J. R. (1969). Speech acts: An essay in the philosophy of language. Cambridge: Cambridge, University Press, pp 13.

72 See http://eur-lex.europa.eu/legalcontent/EN/ALL/?uri=CELEX:31998L0083

73 See http://eur-lex.europa.eu/legalcontent/EN/ALL/?uri=CELEX:32002R0178

74 See ec.europa.eu/energy/res/legislation/doc/biofuels/en_final.pdf

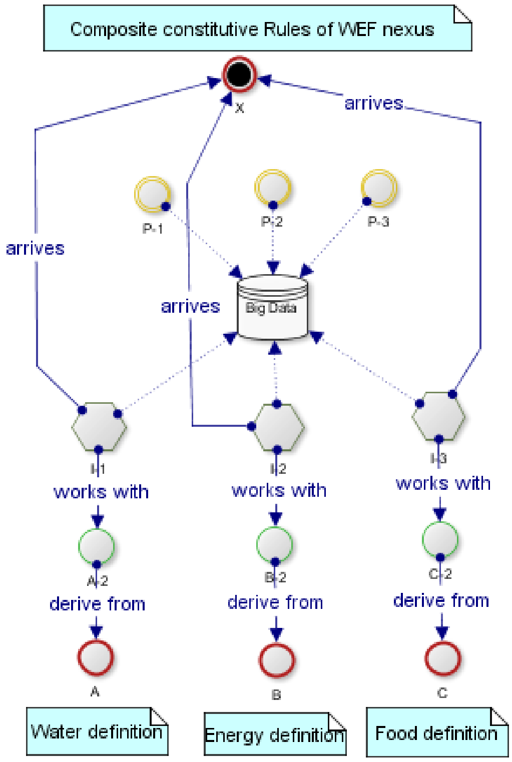



**Fig.5.** Legal reasoning framework of the nexus [from legal definition to legal reasoning]

- Once X as composite constitutive rules will appear, legal definition A, B and C may lose the reasons for their own legitimacy even though they might have their own legal validity. This state, X, can also be addressed as entangled-state of nexus.

The above mentioned scenario shows that one of the departure points of all legal reasoning of nexus is the legal definition, which is static in its legal nature. Therefore, it is an indispensable step to investigate the content of a legal definition through its various meta-ontological layers. Because constitutive rules appearing from the legal definition fundamentally depends on the meta-layers of its concepts, sub-concepts and their associated properties and inter-relationship with their relevant feeding evidences.

# 6 A Theoretical Proposal

In 2010, Corley and Scheufele examined many elements that may encompass the knowledge gaps[75]. They suggested that Web 2.0 can be a useful tool in order to close, if not then to reduce, the knowledge gaps that exist in the various sectors, domains, departments, public administration as well as at the various layers of our society. However, the knowledge gaps are still evident in the performances of Web 2.0 even though it provides interactive communication platform of all users due to its limitations on collaborating capacity and privacy [122]. However, the semantic web, also known as Web 3.0, has extended the positive hopes for minimizing the knowledge gaps. Tim berners-lee [123] says (2006) that

> *'People keep asking what Web 3.0 is. I think may be when you've got an overlay of scalable vector graphics – everything rippling and folding and looking misty – on Web 2.0 and access to a semantic Web integrated across a huge space of data, you'll have access to an unbelievable data resource…'.*

However, the Web 3.0 is based on following standardized and chronological stages –

- Identifiers and character set, that provides unique name of the entities [124] on the web and the character set in order to spell those entities and helps to communicate information about their content in XML format [125].
- Syntax, which sets the pattern of additional information in order to describe the entities on the web [126].
- Data interchange, in RDF, which establishes relations among different sets of entities on the web [127,128].
- Ontologies, which provides common meaning of the entities and introduces restrictions to the relationships among entities in order to validate the knowledge base that is free from errors and contradictions and based on common and shared understanding [129].
- Unifying logic, which performs complex reasoning on the knowledge base [130,131].
- Proof and trust, which ensures authentication, correct and up-date version of the knowledge base [132,133].

Considering 'the potentials and existing capabilities of Web 3.0 for reducing the knowledge gaps' and 'the context of knowledge gaps that exist in nexus as explained in section 5', following legal knowledge framework is proposed in order to reduce those knowledge gaps and for identifying nexus.

[75] Corley, E. A., & Scheufele, D. A. (2010). Outreach gone wrong? When we talk nano to the public, we are leaving behind key audiences. The Scientist.

## 6.1 Legal Knowledge Framework for Identifying nexus: Main Pillars and Features

The proposed legal knowledge framework is based on three main standards:

- *Akoma Ntoso standard*[76], that is a machine readable and technology neutral XML standard for digital representation of substantive and institutional regulations and policy based legislation and documents [134]. It is for systematizing documentation of related legal and Para-legal contents of WEF domains.
- on a *Computational Ontology based on OWL Full standard*[77], that is to represent the main concepts and relationships [135] of the WEF domains, and
- *LegalRuleML standard*[78], that is for modeling rules for formalizing legal knowledge related with WEF domains using logic-based theory of legal and evidence-based hybrid reasoning. It is also intended to use for legitimizing the identifications of nexus by proving legal reasoning. It is based on following features - isomorphism, defeasible logics, semantic of negations, legal temporal parameters and legal deontic operators, and jurisdiction and authority of legal reasoning [136].

This framework is also intended to provide the following features:

- *A Knowledge network*[79], that is for connecting legal texts relevant in WEF domains aiming to create a knowledge network that could help the legislator and policy makers to maintain updated legal knowledge of WEF domains over time[80] in a coordinated way;
- *Identification of nexus*, that is by ontological modeling of legal concepts [137] and their relationships of WEF domains, which is not immediately explicit in their respective legislative texts, for detecting nexus;
- *Evidence based hybrid reasoning* that is for using non-monotonic logic reasoning (defeasible logic) [138] in order to manage the conflicts among the above mentioned rules and to provide different scenarios where the decision maker and the policy maker could use for evaluating the impacts on the nexus.

---

[76] See Vitali, F.: Akoma Ntoso Release Notes. 1997. Available at: http://www.akomantoso.org.

[77] See http://www.w3.org/TR/owl-features/

[78] See https://www.oasis-open.org/committees/tc_home.php?wg_abbrev=legalruleml

[79] See Hayes, M.; Walsham, G. (2003). "Knowledge sharing and ICTs: A relational perspective". In Easterby-Smith, M.; Lyles, M.A. The Blackwell Handbook of Organizational Learning and Knowledge Management. Malden, MA: Blackwell. pp. 54–77. ISBN 978-0-631-22672-7.

[80] To understand temporal aspects of legal knowledge system, see Palmirani, M., Ognibene, T., Cervone, L.: Legal rules, text, and ontologies over time. In: Proceedings of the RuleML@ ECAI 6th International Rule Challenge, 2012.

## 6.2 Methodology

The methodology for proposed legal knowledge framework for nexus can be compartmentalized into following three major segments, where each of these segments has its own objectives and desired models and languages to be used, as it is illustrated in Table 3.

### 6.2.1. Documentation Stage followed by Akoma Ntoso Standard

In order to documentize formally and systematically legal, policy and other relevant documents of WEF domains by using Akoma Ntoso standard, following technical features are suggested. Some of these features are already incorporated into Akoma Ntoso.

- Functional requirements for bibliographic records (FRBR)[81] system based URI (Uniform Resource Identifier) is intended to be used to identify a uniform name of a web resource of each targeted legal documents [139], e.g. article, section, which will enable interactions between content of each resources over the proposed knowledge network using specific protocols of World Wide Web (WWW)[82].
- XML (EXtensible Markup Language) that is to transport and store data and its related metadata of respective targeted legislations in a software-and-hardware independent and machines understandable way, and XML schema that is to describe the structure of the targeted legislation [140].
- RDF (Resource Description Framework) that is to describe resources of target legislative documents on the web written in XML, and RDF schema (RDFS) that is to extend RDF vocabularies [127] in order to allow describing taxonomies of classes and properties of targeted legislative documents [141, 142].

**Table 3.** Methodology for proposed Legal Knowledge Framework for identifying nexus

| ***Major Stages*** | ***Objectives of the methodology*** | ***Desired Models and Languages to be used*** | ***Expected Outcomes*** |
|---|---|---|---|
| Documentation stage based on Akoma Ntoso Standard | To documentize systematically the specific content of legislations of WEF domains. | URI, XML, XML Schema, RDF, RDF Schema, Akoma Ntoso, LIME editor[83] | Cross compliance check and simulation of nexus |
| Computational Ontology stage | To represent main concepts and relationships of WEF domains. | OWL (Web Ontological Language) | |
| Hybrid Rea- | To model defeasible logics | SPINDLE engine for | |

[81] See http://www.ifla.org/publications/functional-requirements-for-bibliographic-records
[82] See http://www.w3.org/
[83] See http://lime.cirsfid.unibo.it/

| | | | |
|---|---|---|---|
| soning stage | of legal rules, those exist in WEF domains, followed by LegalRuleML[84] standard. | hybrid reasoning [143] and simulation, and RAWE [85] (an editor for rule markup of legal texts) | |

- LIME, that is an open source based the Language Independent Markup Editor developed by CIRSFID at University of Bologna, can be used to structurize the targeted legislations maintaining Akoma Ntosao standard.
- Akoma Ntoso 3.0 Schema[86] can be used as the standard for documenting targeted legislations in an XML based document format.

It is noteworthy to mention that Akoma Ntoso already defines a methodology for URI of legal documents, legal concepts, etc, [134][144] which is suggested to be used in this framework even though other standards exist also for this purpose.

### 6.2.2. Computational ontological stage

OWL (Web Ontology Language) Full can be used for legal and technical knowledge representation of related terms and concepts of targeted legislations. That will help to use the predefined relevant vocabularies stored in RDF.

Even through the state of art of computational environmental ontology is very new and on-growing, there is no such computational ontology for nexus has been yet developed. In recent literature, following types of ontologies have been evolved for expressing environmental terms and concepts, but it is noteworthy to mention that all of these ontologies are based on specific purpose or sectorial wise which are far behind the nexus's terms and concepts:

- *XeO (XEML Environmental Ontology)* expresses terms and concepts related with plant in order to help plant scientists [145].
- *Ontologies for Energy Efficiency* is dedicated exclusively to the terms and concepts of energy supply chain [146].
- In *EcoLexicon*, the terms and concepts are structured by terminological knowledge base (TKB) which is hosted in a relational database. The basic environmental conceptual underpinning is taken from the environmental event (EE) which represents the location of conceptual sub-hierarchies [147].

[84] See very recent article on LegalRuleML written by Tara Athan, Guido Governatori, Monica Palmirani, Adrian Paschke, Adam Wyner. LegalRuleML: Design, principles and foundation. In Reasoning Web. Web Logic Rules - 11th International Summer School 2015, Berlin, Germany, July 31 - August 4, 2015, Tutorial Lectures. Lecture Notes in Computer Science 9203, Springer 2015, ISBN 978-3-319-21767-3

[85] See Monica Palmirani, Luca Cervone, Octavian Bujor, Marco Chiappetta, RAWE: a web editor for rule markup in LegalRuleML. Available at ceur-ws.org/Vol-1004/paper4.pdf

[86] See http://www.akomantoso.org/release-notes/akoma-ntoso-3-0-schema/

- *EnvO (the Environmental Ontology)* contains a comprehensive controlled and structured vocabulary of terms and concepts related with biomes, environmental features, and environmental materials [148].
- *Biome* articulates terms and concepts connected with particular patterns of ecological succession and climax vegetation [149].

These above mentioned examples give a strong observational result is that it is fundamental requirement to develop computation ontology for nexus. In the case of formalizing terms and concepts related with WEF domains, the differential ontological model [150] can be very insightful.

#### 6.2.3. **Evidence based hybrid reasoning stage**

In according to the Hermann [151], hybrid system is based on interactions between representing knowledge by human experts and machine learning mechanisms. Generally such system is executed by a fuzzy neural network enable to decoding knowledge into rules. For example, SPINdle is a scalable hybrid system based on an engine made out of defeasible logic with capability to check compliance between governing procedural rules and business rules [143]. Another example of such hybrid system is Drools[87] that is rule based business management system executed by rete algorithm [152]. Following LegalRuleML standard, RAEW editor [154] - a web editor for rule markup in LegalRuleML, and SPINdle engine can be used for evidence based hybrid reasoning for nexus for following reasons –

- From open texts to open rules for nexus [155] – the norms [156], textual provisions and rules in WEF domains are distinct. Because nexus norms are to provide abstract mandatory commands regarding rights and duties of WEF domains while textual provisions represents the sequences of legislative texts and nexus rules are to render of such text into the logical rules, shown in Figure 6[88]. Therefore these three conceptual layers for nexus must be processed separately. Because generally AI and law scholars, on the one hand, emphasis only rule modeling through foundational logical theory[89]. The core disadvantage of this approach is that it is lack of implementing isomorphism principle[90]. Simply it means the connections between and among these above mentioned conceptual layers have been neglected [154].

[87] The engine specifically relies on hybrid technology, see Sottara, D., Mello, P., Proctor, M.: A configurable Rete-OO engine for reasoning with different types of imperfect information. In: Knowledge and Data Engineering, IEEE Transactions on, 22(11), 2010, 1535-1548.

[88] The details explanation of these three conceptual layers are given at Palmirani M., Contissa G., Rubino R: Fill the Gap in the Legal Knowledge Modelling. In Proceedings of RuleML 2009, pp. 305-314, Springer, 2009.

[89] See Curry, Haskell, Foundations of Mathematical Logic p.48

[90] See Bench-Capon T. and Coenen F.: Isomorphism and legal knowledge based systems. Artificial Intelligence and Law, 1(1):65–86, 1992.

On the other hand, interpretations[91] of legislative textual provisions are modeled using logical formalism without established the connections between these three mentioned layers.

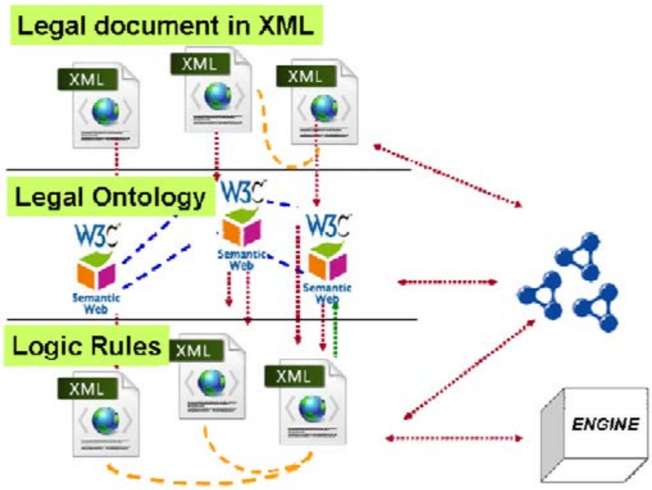



**Fig.6.** Relationships among different layers in the legal knowledge modeling [154]

In order to reduce this gap, the prevalent theory is, in current literature, oriented with hybrid reasoning[92] with N:M relationship among these three layers [154].

- The role of LegalRuleML in the hybrid reasoning of nexus – LegalRuleML can implement three groups of rules – prescriptive, constitutive and behaviors [116]. As previously described that the nexus is mainly based on constitutive rules, LegalRuleML allows prescribing and modeling correctly constitutive rules that coming from one domain and effects on others among WEF domains.
- The role of RAWE – is to synergy between Akoma Ntoso and LegalRuleML. As mentioned earlier, these two standards for modeling and representing legal documents with different technical features and functionalities. On the one side, Akoma Ntoso is to model legal document's structure and its respective metadata. It also can expresses ontological formalization containing multiple interpretation of the same legal concepts. On the other hand, LegalRuleML formalizes legal rules which can be further executed over the Akoma Ntoso legal documentation linking with respective legal ontologies. Under this new context of legal formalism, RAWE can coordinate the legal knowledge captured through implementing these two standards. That enables, in addition, end users to mark up legal rules using logic formal-

[91] United States of America v. William C. Scrimgeour 636 F.2d 1019 (5th Cir. 1981) discusses most aspects of statutory construction.

[92] See Sartor G.: Legal Reasoning: A Cognitive Approach to the Law. Vol. 5. Treatise on Legal Philosophy and General Jurisprudence. Berlin: Springer, 2005

ism that is enriched with temporal parameters. One of such tasks in RAWE editor is shown in Figure 7.

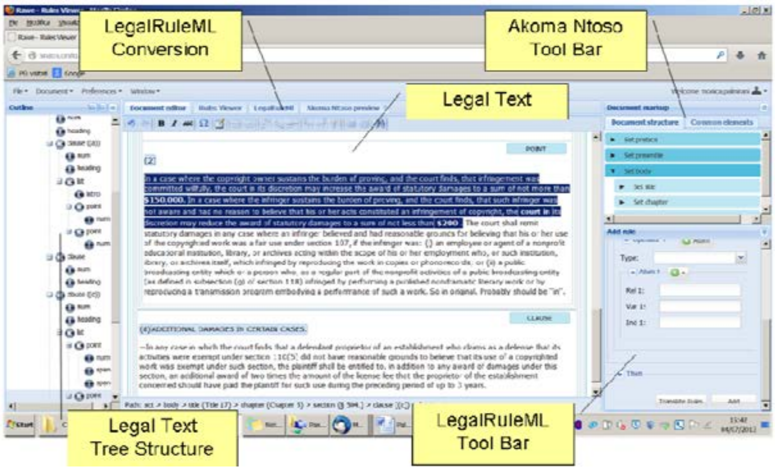



**Fig.7.** RAWE web editor for marking up legal texts and normative rules [154]

- The role of SPINdle – SPINdle is a scalable hybrid reasoning engine written in Java computes both basic and modal defeasible logics as well as detects anomalies. It also supports 'ambiguity propagation'[93] and 'well-founded semantics'[94] variants of such defeasible reasoning. It can handles inferences with thousands of rules within very short period of time. Its architecture consists with three main components – (a) I/O manager, that provides interface for end users, (b) theory normalizer[95], that transforms rules to regular form and provides superiority relationships among the rules, and (c) inference engine[96] provides resulting answers after executing all rules implemented into it performing a number of inference stages, shown in Figure 8.

---

[93] A literal is ambiguous if there is a chain of reasoning that supports the truth of the literal, and another that supports the truth of its negation, and the superiority relation does not resolve this conflict. For detail, see Stein, L. A.: Resolving ambiguity in nonmonotonic inheritance hierarchies. In: Artificial Intelligence 55(2-3), 1992, 259-310.

[94] Originally developed by Van Gelder in order to provide reasonable interpretation of logic program with negation, and has been applied to extended logic programs and non-monotonic reasoning. For detail, see van Gelder, T., Ross, K. A., Schlipf, J. S.: The well-founded semantics for general logic programs. In: Journal of ACM, vol. 38(3), 1991, 619–649.

[95] This approach is better explained in this paper - May CR, Mair F, Finch T, Macfarlane A, Dowrick C, Treweek S, Rapley T, Ballini L, Ong BN, Rogers A, Murray E, Elwyn G, Légaré F, Gunn J, Montori VM. Development of a theory of implementation and integration: normalization process theory. Implement Sci. 2009 May 21;4:29

[96] A tool from artificial intelligence, see Hayes-Roth, Frederick; Donald Waterman; Douglas Lenat (1983). Building Expert Systems. Addison-Wesley. ISBN 0-201-10686-8.

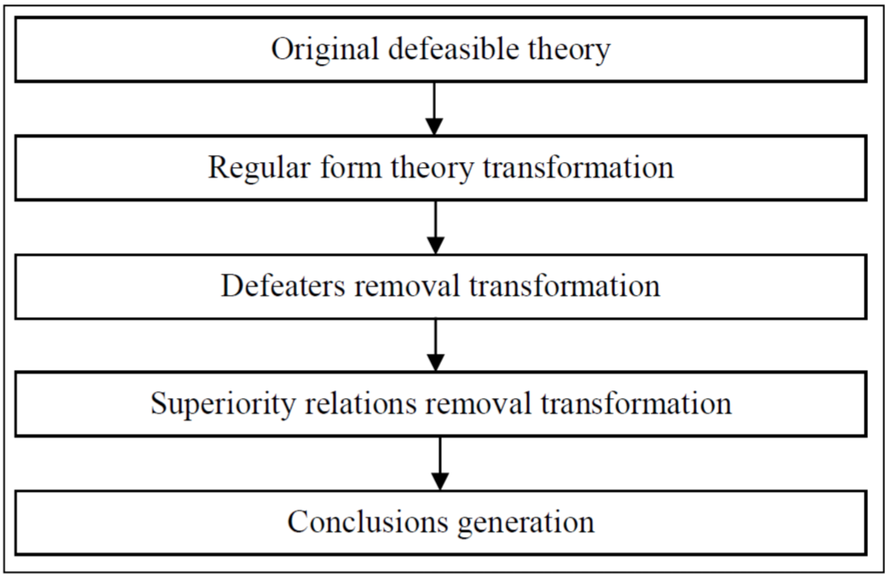



**Fig.8.** Defeasible theory inference process in SPINdle [143]

The defeasible theory[97] in SPINdle shares common structure like defeasible logic deals with – facts, rules, defeaters and superiority relationships between rules. It also can handle both direct obligation as well as the temporal dynamic treatment of obligations. Considering above features and functionalities of SPINdle as hybrid reasoning engine, it is very likely to be useful in the context of handling various rules of Nexus appearing from multiple WEF domains.

#### 6.2.4. Schema for the legal knowledge framework for ex-ante and ex-post of policy life cycle for nexus

The following, as shown in Figure 9, schema can be used in order to help the process that takes in place at every stage of the entire policy life cycle of WEF domains such as analysis of the requirement, draft of the policy, implementation of the policy, monitoring of the policy and then the refinement of the policy. This schema is to cove from standardized and systematized documentation to applying hybrid engine for reasoning to simulation of the multi-sectorial scenarios. The simulation and evidence based reasoning can jointly play a crucial role by using norms and rules coming from various sources at every stage of WEF domains in order to adopt the most appropriate rules and norms for policy.

[97] See for detail - Asher, Nicholas, and Michael Morreau, 1991, "Commonsense Entailment: A Modal, Nonmonotonic Theory of Reasoning", in Proceedings of the Twelfth International Joint Conference on Artificial Intelligence, John Mylopoulos and Ray Reiter (eds.), San Mateo, Calif.: Morgan Kaufmann.

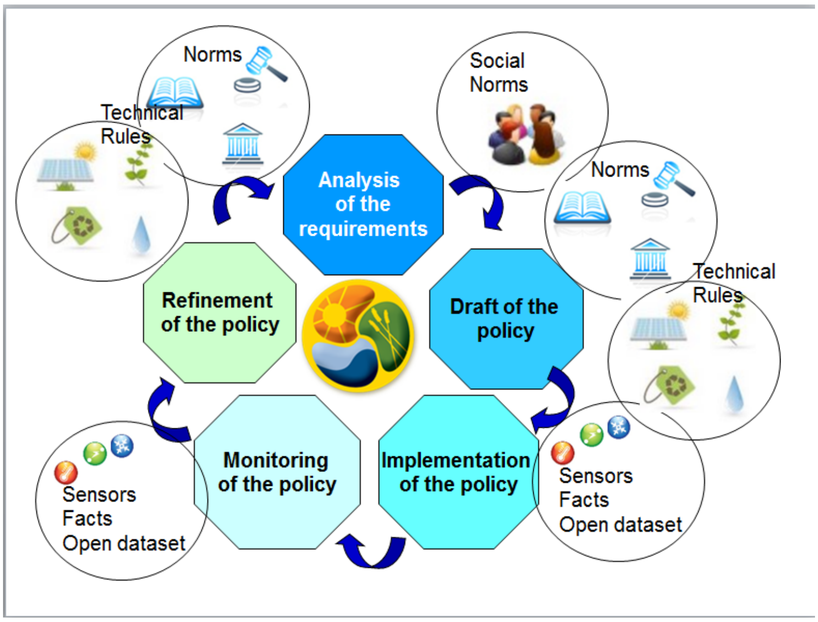



**Fig.9.** Proposed schema for legal knowledge framework for nexus[98]

The proposed schema for legal knowledge framework for nexus is consisted with five different layers of legal and para-legal documentation and their hybrid reasoning. Each of these layers has following different requirements and expectations to be fulfilled –

- Analysis of the requirements for nexus – in this stage, it is expected to complete documentation of all EU Directives and Regulations of WEF domains and respective technical reports coming from each EU member-states in Akoma Ntoso. These para-legal technical reports can be sources of social norms and technical rules that are associated with nexus and can be formalized by RAWE using LegalRuleML standard. The legal ontology for nexus is expected to be used to incorporate between those Akoma Ntoso documentations and LegalRuleML based rule modeling for nexus in order to execute hybrid reasoning for nexus in SPINdle architecture for detecting nexus. The legal ontology for nexus is also expected to ensure interoperability among legal, technical and social concepts and rules in the open texts and rules for nexus.
- Draft of the policy for nexus – once the detection of nexus is performed in the open texts and rules for nexus, it may enhance policy makers for preparing necessary policy regulations for nexus. It is also expected that the framework will help policy makers to understand the efficacy of new policy rules of nexus towards the existing legal structure by proving legal knowledge networks which is semantically coordinated and regulated.

[98] This schema is designed by Prof. Monica Palmirani. CRISFID, University of Bologna.

- Implementation of the policy for nexus – during this stage, a number of new documents and rules, both legal and para-legal, will be created such as country specific reports based on new sensors data and facts. All of these new documents and rules are expected to be formalized following the methodologies used in the first stage in order to detect the conflicting rules appearing from new phenomena. That will help policy makers in order to harmonize the legal rules for nexus in the light of new outcomes and emerging social and technical elements.
- Monitoring of the policy for nexus – once the formalization of all old and new legal and para-legal documents for nexus is performed, the framework is expected to be useful for monitoring semantic as well as satellite open data for monitoring nexus for further policy modification.
- Refinement of the policy for nexus –legal knowledge framework for nexus is also expected to handle temporal parameters of all legal and para-legal documents of nexus. That particularly would help to refine the policy for nexus without affecting their previous versions, formats and legal efficacy.

### 6.2.5. Decision Support System in WEF domains

In order to understand the potentials of the proposed legal knowledge framework for nexus, few important existing decision support systems used in WEF domains are discussed in this section. Even though in the state of art of Environmental Decision Support Systems (EDSS) there are many useful tools, they are very limited in scope and their functionalities in order to simulate scenarios of different policy decisions. These tools can be clearly distinguished from this proposed framework in following ways:

- Existing EDSS tools are based on mathematical models that do not comply with legal rules, and with other relevant rules, of WEFC domain. In some extend, EDSS also integrates geographic information systems (GIS), mathematical process models, monte carlo simulation, linear programing optimization, and expert systems etc [158].
- Human rules coming from legal, institution, society, culture, ethics and news scientific discoveries usually only considered in ad hoc ways. Therefore, historically, EDSS has very limited success despite considerable effort has been made in the development of EDSS during last 25 years [159].
- They are not independent from jurisdiction, machine, language and platform. Hence these tools are not useable as anywhere policy makers want to use [160].
- They are not designed for evolutionary and evidence-based hybrid logic reasoning and creating a knowledge network for WEFC domain [161].
- They are also not designed for standardized and systematized documentation of legal documents [162].

However, many important learning can be shared, in the development of this proposed legal knowledge framework, from “Fill the Gap” project organized, led and funded by CIRSFID-University of Bologna [134]. Because this project has designed an information system based on XML standards to store, in an integrated way, legal resources and rules in order to serve important roles for supporting legal knowledge engineers and end-users.

### 6.2.6. **Relationship between this framework and different perspective of Nexus**

The proposed framework has potentials to meet the demands appear from various perspectives of nexus discussed in section 2. The *Table 4* shows few fundamental relations of their mutual correspondence. Considering ontological alignment for nexus from the perspective of process philosophy, legal ontology for nexus can represent legal conceptual relationships that exist in nexus appearing from different legislative texts. Therefore it is expected to establish interoperability among WEF domains in order to detect and reason nexus in the light of law. In the case of legal perspective of nexus, Akoma Ntoso and LegalRuleML based formalization of legal contents of WEF domains may represent the nexuses of concepts and rules exist in WEF domains.

**Table 4.** Relations between leagl knowlegde framwork for nexus and different perspective of nexus

| ***Perspectives of nexus*** | ***Corresponding elements between framework and perspective*** | ***The relations between the framework and perspectives*** |
|---|---|---|
| Philosophical | Process philosophy and ontological alignment. | The process of conceptual relationship of nexus can be represented in ontology. |
| Legal | Nexuses of contracts and nexuses of concepts and rules. | Ontology and LegalRuleML can together manage the nexuses of concepts and rules that exist in nexus. |
| Non-traditional security | Involvement between public authority and individual, connection between policy and data coming from GISs, Satellite in real time and space manner. | The framework may facilitate the automatized process based on ontology and hybrid reasoning system in order to link various rules with the data that appears from GISs, Satellite in real time and space manner. |
| Strategic Thinking | Linking between ‘bottom-up approach’ and ‘forward thinking’ | The framework may help for initiating strategic thinking on WEF nexuses with reasons. |
| Digital city | Collaboration between collective knowledge | The framework may provide all necessary internal legal procedural mechanism in order to collaborate the collective knowledge of WEF domains for further analysis as desired. |
| Sustainable development | Linking knowledge of ecosystem services and domain | Ontological representation of WEF domain related concepts and nex- |

| | | |
|---|---|---|
| | based resource management | us's rule based hybrid engine can combine the knowledge of eco-system services and domain based resource management together. |
| Globalization and geo-political | Border-free knowledge transfer and enhancing knowledge-based global society | The framework may facilitate jurisdiction-free knowledge platform for nexus and help the policy makers by detecting the nexus issues in real time, space and legal manner. |

From the non-traditional security perspective of nexus[99], the proposed framework can facilitate hybrid reasoning for nexus among various rules coming from multiple legal and para-legal sources in connection with semantically formalized social norms and rules. That might help to ensure non-traditional security aspects of nexus. Considering strategic thinking perspective of nexus, the prospered framework may establish connection between 'bottom-up approach[100]' and 'forward thinking' by implementing the schema shown in Figure 9 and explained in section 6.2.4. Furthermore, on the one hand, collaboration between collective knowledge among WEF domains can be implemented through this proposed framework by formalizing procedural rules of nexus policy[101] initialization, implementation, monitoring and refining. That will affect make Digital City perspective a step ahead. On the other hand, proposed framework can implement knowledge linkages among concepts and rules coming from both – eco-system services and domain based resource management, which may help policy makers to manage nexus in the light of sustainable development framework[102]. Last but not least, the proposed framework can be useful to ensure border-free knowledge transfer for nexus which is semantically linked and interoperable.

[99] See Hussey, K., and A. Schram. 2011. Policy integration and the energy–water nexus: accounting for, and managing, the links. Pages 245-268 in P. Winand and G. Pearman, editors. Securing sustainable energy futures in Europe and Australia. PIE–PeterLang Publishers, Brussels, Belgium.

[100] See Malik, R.P.S. 2010. Water-Energy Nexus in Resource-poor Economies: The Indian Experience. International Journal of Water Resources Development. Vol.18: 47-58

[101] See Scott, C.A. , Pierce, S.A. , Pasqualetti, M.J., Jones, A.L. , Montz, B.E and J.H. Hoover. 2011. Policy and institutional dimensions of the water-energy nexus. Energy Policy Vol.39 (10): 6622-6630.

[102] See Weitz, N., Nilsson, M., Huber-Lee, A., Davis, M.and Hoff, H. (2014). Cross-Sectoral Integration in the Sustainable Development Goals: A Nexus Approach. . SEI discussion brief. Stockholm Environment Institute.

# Chapter 2

## Evaluating Perspectives and Methodologies of Legal Ontology for Water-Energy-Food Nexus

*"...........Ontology is an 'explicit, formal specification of a shared conceptualisation' and represents a formal description of a set of concepts and the relationships in a given domain. By describing the properties of legislation and their relationships between different concepts, a shared understanding is made possible and ambiguities between terms can be avoided. Being a formal specification, it is directly machine-processable............."*

- Annex 2 of EU notice 2012/C 325/02, published in EU Official Journal on 26.10.2012

## 7 Overview of Evaluating Perspectives and Methodologies of Legal Ontology

Ontology engineering [163], known as a sub-field of knowledge engineering[103] in information science[104] as well as computer science, is a formal way of defining concepts, sub-concepts, properties and their interrelationships. In order to handle complexity and organize knowledge orderly of a particular domain or multi-domains, many fields have been increasingly engineering ontologies such as systems and software engineering, artificial intelligence, library science, information architecture and legal informatics [164,165]. One of main objectives of ontology engineering is to elucidate the interoperability problems that exist in semantic web[105]. Likewise, legal ontology provides conceptual networks and their interoperability for various legal applications, e.g. legal information retrieval, legal reasoning etc [166]. It also deals with sources of knowledge from which concepts and terms extract, formalities whether the legal ontology is highly axiomatic or language-oriented, a wide ranges of methodologies for developing legal ontologies [167]. Nevertheless, on one hand, following reasons pose inconsistencies among different methodologies and theories in legal ontology –

[103] See Schreiber, August Th.; Akkermans, Hans; Anjewierden, Anjo; Dehoog, Robert; Shadbolt, Nigel; Vandevelde, Walter; Wielinga, Bob (2000), Knowledge engineering and management: the CommonKADS methodology (1st ed.), Cambridge, MA: The MIT Press, ISBN 978-0-262-19300-9

[104] See Emard, J. P. (1976). "An information science chronology in perspective". Bulletin of the American Society for Information Science 2 (8): 51–56.

[105] See Benjamins, V. R., J. Contreras, and O. C. A. G´omez-P´erez. 2002. Six challenges for the Semantic Web. Presented at Semantic Web Workshop, at the Eighth International Conference on Principles of Knowledge Representation and Reasoning (KR2002), Toulouse, April 22–25, 2002.

- Lack of interfaces between language and legal ontology [168].
- Lack of automated extraction from the natural languages for constructing formal models of the law [169].
- Lack of connectivity between core and domain legal ontologies and their representations [170].
- Lack of epistemological justifications in defining legal knowledge [171,172].
- Lack of using content patterns for legal knowledge framework [173].

On the other, in the context of developing legal ontology for nexus based on legal definitions of water, energy and food from their respective EU legislative texts, the above mentioned points plays big roles. Therefore it is noteworthy to find out the appropriate perspective and methodology for developing such legal ontology for nexus. From the above mentioned foundational understanding, this chapter is divided into following sections and discussions –

- Section 8 – Describes ontology development criteria that require being fulfilled for ontology engineering of legal definitions and their nexus with the example of EU water, energy and food legislations.
- Section 9 - Explains different perspectives of legal ontology such as cognitive science, legal theory multi-layer legal information, linguistic, legal documentation, computational, legal service science and legal knowledge management perspectives.
- Section 10 – Discusses about the major methodologies used for legal ontology engineering such as NORMA, LKIF, Hafner's semantic network for legal concepts, frame-based and functional ontology of law, CLIME ontology, dynamic interconnected system, Mommer's knowledge based model of law, LRI-Core, JurIWN and CLO, Lame's ontology of French law, and SAMOD etc.
- Section 11 - Provides the summary of an evaluative survey of those perspectives and methodologies in order to find the appropriate perspective and methodology for developing legal ontology for nexus from respective EU Directives and Regulations. The evaluative elements used in the survey are based on those criteria discussed in section 8, which need to be fulfilled in order to develop such ontology.

# 8 The criteria for ontology engineering of legal ontology for nexus

In order to engineer ontology of legal definitions of EU water, energy and food legislations and their nexus, two sets of criteria[106] are developed on the basis of content and nature of the legal definitions in conjunction with the purposes of developing this ontology. First set of criteria is based on two types of knowledge acquisition – explicit

[106] These criteria and evaluative questions are taken from the paper - Visser, P. R. S., and T. J. M. Bench-Capon. 1998b. A comparison of four ontologies for the design of legal knowledge systems. Artificial Intelligence and Law 6:27–57.

and implicit knowledge acquisition. The second set of criteria is based on three components of the constructing ontology – epistemological adequacy, operationally and reusability. This section is divided into two sub-sections [174]. First sub-section introduce the legal definitions that is the main subject matter for ontology, and the later section discusses about two sets of criteria that must be met throughout this ontology development in light legal definitions of EU water, energy and food.

## 8.1 Introducing legal definitions of EU water, energy (bio-fuel) and food

Following legal definitions[107] of 'water', 'food' and 'bio-fuels' are the explicit subject matters for engineering the legal ontology for nexus –

- Article 2 of Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption defines 'water intended for human consumption'.
- Article 2 of Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport, defines bio-fuel.
- Article 2 of the Food definition from Regulation (EC) no 178/2002 of the European Parliament and of the Council of 28 January2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety, defines food.

## 8.2 Two sets of criteria: for knowledge acquisition and ontology construction

Developing ontology generally guided by the purposes for which it is made of [175]. Because it is a very generic case that every ontology project is based on two-fold tasks management. First, it starts with articulating normative purposes and then all later stages are designed and completed in order to fulfill its purposes [176]. However, as the intention of this doctoral project is to develop ontology of legal definitions and their nexus, generally referred as legal ontology for nexus, there is very limited scope to formulate more concert task and method oriented purposes, other than this singular purpose. Therefore, in order to do that, two sets of criteria have developed as a guideline for knowledge acquisition and ontology construction, followed by [174]. These criteria have been discussed below in the light of above mentioned EU legal definitions of water, bio-fuels and food.

### 8.2.1 Criteria for knowledge acquisition from the legal definitions

In order to represent and manage knowledge through ontology, one of the fundamental requirements is to have precise and adequate knowledge acquisition [177]. In particular, when legislative documents are the subject-matter of the ontology, the

[107] All of EU definitions are mentioned in chapter one and available at http://eur-lex.europa.eu/homepage.html?locale=en

technique of knowledge acquisition is very fundamental. Common senses based knowledge acquisition become back-dated and crisis a lot of drawbacks [178]. Hence, legislative-texts itself can be the principle sources of knowledge acquisition, which can be performed into two stages – explicit and implicit knowledge acquisitions [179]. These are discussed below in the light of above mentioned legal definitions -

#### 8.2.1.1 Explicit knowledge acquisition from legal definition

It helps to extract terminological knowledge from the legislation [180]. For example, in the water definition, the noun phrase – '*water intended for human consumption*' explicitly qualifies the category of water the legislation is concerning about through its normative lexical relationships[108] among the words of this noun phrase. Particularly in the case of implication of the notion of light ontology[109], it also guides to not be redundant and irrelevant with quantity of the legal terms and concepts.

#### 8.2.1.2 Implicit knowledge acquisition from legal definition

The implicit knowledge, on the one hand, is required in order to make meaning of explicit knowledge [181]. On the other, constitutive rules, as proposed in following papers by Searle, J.R. [182], are appearing from the explicit knowledge [183] of a legal definition need implicit knowledge, which is not given or mentioned in the legal definition, in order to incorporate evidence as an inference with the meaning of explicit knowledge. This is how constitutive rules bridge the explicit and implicit knowledge. For example, in the food definition, it says ''*Food' includes drink, chewing gum and any substance, including water, intentionally incorporated into the food during its manufacture, preparation or treatment*'. The explicit knowledge acquisition from this part of the definition, in order to make a lexical relationship between food and water, can be –

…Water that used in food manufacture, preparation and treatment is food too---(E1)

This explicit knowledge might be a false knowledge, because the noun '*water*' in the food definition does not qualify the category of water it is concerning about as it is explicitly done in the water definition. Therefore, the constitutive rule plays a role here like putting following question forward -

What kind of water can be used in the food manufacture, preparation and treatment? …..(C1)

---

[108] Normative lexical relationships collectively expresses lexical semantics, see Grandy, Richard E. (2012). "Semantic Fields, Prototypes, and the Lexicon". Frames, Fields, and Contrasts: New Essays in Semantic and Lexical Organization. Routledge. pp. 103–122. ISBN 9781136475801.

[109] See John Davies (2010): Lightweight Ontologies. In: Theory and Applications of Ontology: Computer Applications, 2010, pp 197-229. DOI 10.1007/978-90-481-8847-5_9

In order to produce the answer of this question, it requires looking for available applicable and admissible implicit knowledge that is not written in this particular legislative text. Hence, now the explicit knowledge of the water definition says that

'*all water used in any food-production undertaking for the manufacture, processing, preservation or marketing of products or substances intended for human consumption unless the competent national authorities are satisfied that the quality of the water cannot affect the wholesomeness of the foodstuff in its finished form*'…..is……. '*water intended for human consumption*'.

Incorporating explicit knowledge of water definition for answering the C1 and making precise meaning of E1 is simply entering implicit knowledge into the food definition from water definition. Regarding the relationships between knowledge acquisitions and constitutive rules, more description is given in chapter 3, 4 and 5.

### 8.2.2 Criteria for ontology construction

In the state of art of the ontology engineering, there are many criteria available for ontology construction. However, for this doctoral project purposes, the main three criteria are – epistemological adequacy, operationability, reusability. Each of these criteria has been discussed below in the light of the EU legal definitions of water, energy and food.

#### 8.2.2.1 Epistemological adequacy

From the ontological perspective, epistemological adequacy aims to provide the representation of cognitive understanding of human problems in such a way that can meet that demand of a lawyer by putting the legal concepts and their relations easily distinguishable in the ontology [184,185]. It is divided into five following sub-criteria:

##### *8.2.2.1.1* Clarity

Epistemological clarity mainly intended to provide clear and unequivocal meaning of the concepts used in the ontology [186]. For instance, the concept "*water*" mentioned in the Article 2 of Council Directive 98/83/EC defines the "*water intended for human consumption*", but the concept "*water*" mentioned in the Article 2 of the Regulation (EC) no 178/2002 indicates "*food includes water when it is intentionally incorporated into the food during its manufacture, preparation or treatment. It includes water after the point of compliance as defined in Article 6 of Directive 98/83/EC and without prejudice to the requirements of Directives 80/778/EEC and 98/83/EC*".

#### *8.2.2.1.2* **Intuitiveness**

Epistemological intuitiveness [187] ensures the representation of the concepts and their relationships [188] in such a way that articulates individually as well as collectively the intuition of the experts of the domains. For example, Article 2 (1) of Directive 2003/30/EC says that

> "*(a) 'biofuels' means liquid or gaseous fuel for transport produced from biomass;*
> *(b) 'biomass' means the biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste,*"

In this definition, the intuitiveness of the concept "biofuel" is based on mainly its relationships with other three main concepts such as "liquid or gaseous fuel", "transport" and "biomass". On one hand, the biofuel produced for other purposes except transportation cannot be considered as biofuel and on the other hand biofuel must be produced from biomass as it is described in the Article 2(1)(b).

#### *8.2.2.1.3* **Relevance**

Epistemological relevance[110] checks whether the modeling of the ontology satisfies the purposes of ontology construction [174]. It also supports the legal reasoning tasks and methods[111]. For example, if the purpose of developing ontology of legal definition of water is to make nexus with the legal definition of food, then it requires establishing conceptual relevancy between the concepts and properties coming from the both legal definition.

#### *8.2.2.1.4* **Completeness**

Epistemological completeness provides the legal concepts and their relationships in such a way that can be useful for performing legal reasoning tasks in a combined way [189]. For example, in order to facilitate automated legal reasoning of nexus between water, energy and food, it does not only require establishing the conceptual nexus that exist among legal definitions of water, energy and food. Rather it also requires establishing consistent relationship between legal conceptual nexuses and reality through

[110] See Hjørland, Birger (2010). The foundation of the concept of relevance. Journal of the American Society for Information Science and Technology, 61(2), 217-237
[111] See Rissland, E. L. 1985. Ai and legal reasoning. In Proceedings of the International Joint Conference in Artificial Intelligence (IJCAI85), 681–687, Los Angeles.

initiating corresponding relationships between concepts of TBox and instances of ABox[112].

#### *8.2.2.1.5* Discriminative power

Epistemological discriminative power[113] helps to distinguish ontological independent tasks from one another [174]. For example, even though ontology can help to recognize and detect the nexuses among legal definitions of water, energy and food, a good ontology with its capacity of discriminative power can execute its different components independently through its own iterative processes.

### 8.2.2.2 Operationality

Ontological operationality signifies the functional capabilities of the representation of concepts and their relations in a representational language [190]. It also deals with whether the ontology is capable to operate the legal tasks following legal methodology [174]. It is comprised with following sub-criteria:

#### *8.2.2.2.1* Encoding bias

It deals with the symbolic ontological choices [174]. Particularly, encoding bias happens when entire ontological representation is based on the suitability of any particular approach or method of notation and/or implementation [191]. For example, cognitive perspective of ontology might provide a certain set of operationality based on its common sense approach, which might be very different from the outcomes of any ontology based on LAMP,s approach of legal knowledge acquisitions.

#### *8.2.2.2.2* Coherence

Coherence in the ontological Operationality [192] is established when a meaning of a concept is inferred from a legal definition in such a way that is consistent with the meaning of other legal definitions.

[112] The reasoning between TBox and ABox has been described in De Giacomo, G., Lenzerini, M.: Tbox and Abox reasoning in expressive Description Logics. In: Proc. 5th Intl. Conf. on Principles of Knowledge Representation and Reasoning, pp. 316–327 (1996)

[113] The importance of epistemological pluralism and the revaluation of the concrete has been discussed by Sherry Turkle and Seymour Papert, which can be found in the Journal of Mathematical Behavior, Vol. 11, No.1, in March, 1992, pp. 3-33; Constructionism, I. Harel & S. Papert, Eds. (Ablex Publishing Corporation, 1991), pp.161-191; and SIGNS: Journal of Women in Culture and Society, Autumn 1990, Vol. 16 (1).

##### *8.2.2.2.3* **Computationality**

Computationality deals with adequacy of the computation of the concepts and their relationships represented in the ontology [174]. More particularly it handles the computationability of the both contents – Tbox and ABox, in a combined manner.

#### 8.2.2.3 Reusability

The reusability of ontology mainly deals with whether ontology is usable, partially or completely for another legal tasks which is not intended in the development of the existing ontology [193]. It also deals with extendibility of the ontology by adding other legal concepts and their relations for performing other legal tasks independently and/or for supporting other ontology. This can be sub-divided into following two criteria :

##### *8.2.2.3.1* **Task and method reusability**

It expresses the reusability of ontology based on their tasks and method by extending or subtracting the concepts and relations required for performing other legal tasks [194,195].

##### *8.2.2.3.2* **Domain reusability**

It makes the ontology capable to use for the purposes of other legal domains with compromising the internal coherence of the existing ontology [196].

# 9 Perspectives of legal ontology

Traditionally ontology as a branch of philosophy analyze the fundamental categories which makes the world's object in combine through examining linkages between essence and existence, intrinsic and extrinsic properties of objects etc. However, in 1970s, Artificial Intelligence (AI) researchers realized that developing ontologies as computational model qualify AI for some kinds of automated reasoning. In 1980s, they started creating ontology a core component of knowledge systems [197]. In 1990s, Tom Gruber in his paper '*Towards principles for the design of ontologies used for knowledge sharing*' recognized ontology as a technical term in computer science [198]. He says -

> '*Ontology is a description (like a formal specification of a program) of the concepts and relationships that can formally exist for an agent or a community of agents. This definition is consistent with the usage of ontology as set of concept*

*definitions, but more general. And it is a different sense of the word than its use in philosophy*[114]'.

Since then, the ontology has been using in information and computer science as an integral core component for engineering knowledge system and management. However during the twenty first century, on the contrary of research-driven AI based ontology engineering, legal ontology engineering is driven by need of developing computer applications in such way that can meet the legal requirements as well as fulfill the demands of users [199]. That need pushed researches to design legal ontologies in order to embed it into the core architectures of any legal knowledge or information systems.

However, at present there are sixty different legal ontologies have been developed and many perspectives are available for legal ontology engineering [200]. A number of such perspectives are listed below –

**Table 1.** Different perspective of the legal ontology enginnering and their main profounders[115]

| ***Different perspectives of legal ontology engineering*** | ***Notable persons who supported it*** |
|---|---|
| The scientific perspective | Barry Smith |
| The philosophical perspective | Maurizio Ferraris |
| The formal perspective | Nicola Guarino |
| The computational–ontology perspective | Aldo Gangemi |
| The legal–theory perspective | Giovanni Sartor |
| The sociolegal perspective | Pompeu Casanovas, Nuria Casellas |
| The comparative–law perspective | Gian Maria Ajani |
| The cognitive–science perspective | Joost Breuker, Rinke Hoekstra |
| The linguist's perspective | Mariangela Biasiotti, Daniela Tiscornia |
| The case–based–reasoning perspective | Kevin Ashley |
| The knowledge-engineering perspective | Enrico Francesconi |
| The complex–systems perspective | Daniele Bourcier, Paul Bourgine, Pierre Mazzega |
| The electronic-institutions perspective | Marco Schorlemmer |
| The legal–technology perspective | Tom Van Engers, Radboud Winkels |
| The multilingual–legal– | Guido Boella |

114 See Gruber, T. (2001). "What is an Ontology?". Stanford University.

115 This list of perspectives have been collected from Sartor, G., P. Casanovas, M. Biasiotti, and M. Fern´andez-Barrera. 2011. Approaches to legal ontologies. Theories, domains and methodologies. Number 1 in law, governance and technology series. New York/Heidelberg: Springer.

| | |
|---|---|
| information–system perspective | |
| The document-standard perspective | Monica Palmirani, Fabio Vitali |
| The large–legal–database perspective | Angel Sancho, Jos´e Manuel Mateo – Wolters Kluwer–la Ley |
| The legal–multimedia perspective | Xavier Binefa, Ciro Gracia, Emma Teodoro, Nuria Galera |

Every legal-ontology is influenced by different perspectives that affects and reinforces the content and uses of those ontologies. For instance, while Metaphysical ontology deals with reality; systematic terminologies are the subject-matter of Information Science, terminological knowledge is the fundamental concern of AI, terms and concepts related with knowledge bases are the focusing area of Knowledge Engineering, semantic nature of ontology is the priority for Information Management, and concepts of common sense as the content of the knowledge instincts is dealt in the heart of ontology development by Cognitive Scientist. One of the best examples of Cognitive Science based legal ontology is LKIF-Core [201], which is mainly based common-sense based core ontology for general purposes used in legal domains [202]. Furthermore, the utility of structuring legal concepts must deals with degree of stability for making it contextually independent, proving embedded relationship between the legal concepts and its corresponding documents, which was not the case in LKIF-Core. Therefore, this section describes eight different perspectives of developing legal ontology that will provide background understanding of how and why legal ontology is shaped by the perspective researchers use to engineer the ontology for legal purposes and/or services.

### 9.1 A cognitive science perspective

Cognitive science has started with work of Plato’s *Meno*[116] and Aristoetle’s *de Anima*[117], even though they used other types of tools and concepts, in to articulate philosophical dimensions of mind and their application, than the way modern cognitive scientists do. For example, in 1930s and 1940s McCulloch and Pitts modeled what is known as artificial neural networks – a computational model by following the biological mental networks [203]. In 1940s and 1950s, Alan Turing and John von Neumann introduced the theory of computation and the digital computer, both as a representation of human mind and cognition, which played fundamental contributions from cognitive science [204]. In 1973 formally cognitive science was created by Christopher Longuet-Higgins and formulated ‘then-current’ state in the application of AI [205]. In 1970s and 1980s Marvin Minsky articulated formal characterization of hu-

[116] See Klein, Jacob. A Commentary on Plato's Meno. Chapel Hill: University of North Carolina Press, 1965.
[117] See J. Barnes, M. Schofield, & R. Sorabji, Articles on Aristotle, vol. 4, 'Psychology and Aesthetics'. London, 1979.

man being in their decision making and problem solving process [206]. He mentioned in his book '*The Society of Mind* (1987)[118]' that –

> '*The "laws of thought" depend not only on the property of brain cells, but also on how they are connected. And these connections are established not by the basic, "general" laws of physics... To be sure, "general" laws apply to everything. But, for that very reason, they can rarely explain anything in particular. ...Each higher level of description must add to our knowledge about lower levels.*'

Marvin's work inspired to create artificial mind which is also known as symbolic AI. Then in 1985 Pat Hayes in his paper '*Naïve physics manifesto*[119]' says that basic ontology is developed by small sets of concepts coming from the common sense view of the world. Later on CYC in 1995, SUMO and DOLCE in 2002 were developed as upper ontology based on common senses. In 2011, Joost Breuker and Rinke Hoekstra in their paper '*A cognitive science perspective on legal ontologies*' described following two perspectives to illustrate the road from cognitive science to ontology engineering [200] –

- The knowledge and semantic is not one thing. Therefore formal machine learning as well as the architecture of human cognition should be driven by ontologies in order to treat the knowledge and semantic separately but simultaneously.
- The basic concepts should be based on human's deep common sense.

In 2007 both of these perspectives have been used in the LKIF-core – ontology for legal domains based on common sense [207]. There are a number of ways cognitive perspective of ontology engineering has been used during last decade. For example, in 2011 J.A. Turner and A.R.Laird, in their paper 'Cognitive paradigm ontology: design and application[120]' proposed the fundamental structure of Cognitive Paradigm Ontology (CogPO) which is consisted with three elements – (a) demonstration of actual experimental conditions, (b) the instruction given, and (c) response requested. The ontological representation combining with these three elements may provide advanced techniques of data retrieval by searching both –similarities and dissimilarities in even multiple ontologies.

However, there are two central roles of the top ontology from cognitive science perspective. The first role is to structure the class of the domain in such way so that this class can be addressed as sub-class. That improvises detailed architectural modeling of the ontology. The other one is by inheritance define properties can be reused. That helps to check inconsistencies within the domain ontology. These roles together enhance the ontological architecture based on common sense [200].

---

[118] See Minsky, Marvin. The Society of Mind. Simon and Schuster, New York. 1986 . ISBN 0-671-60740-5

[119] See The naive physics manifesto in Michie, Donald (1979). Expert systems in the micro-electronic age. Edinburgh: Edinburgh University Press. ISBN 0-85224-381-2.

[120] See Neuroinformatics. 2012 Jan;10(1):57-66. doi: 10.1007/s12021-011-9126-x.

## 9.2 The legal theory perspective

Fundamentally, the legal theory is a theory discusses about what law is and should be. From ancient to till the date, many profound personalities contributed in order to obtain a deeper and constructive comprehension of the nature of law, its reasoning mechanisms and related institutions such as Aristotle, Saint Thomas Aquinas, Hugo Grotius, Thomas Hobbes, John Locke, Thomas Jefferson, Emile Durkheim, Mas Weber, Terence Irwin, Lon Fuller, Joel Bakan and others [200,208]. There are many branches of the legal theory explain the formations and functions of the law differently, for example few of those perspectives are given in the *Table 2*.

**Table 2.** Diffenernt branches of legal theory and their take on law

| ***Name of different branches of legal theory*** | ***Their perspective on law*** |
|---|---|
| Critical legal theory[121] | Law is not neutral and value free and it is attached with politics. |
| Legal positivism[122] | Authority creates law. |
| Legal realism[123] | Nature of law is based on how law is practiced. |
| Natural law[124] | Law is set up nature and therefore it is applicable anywhere. |
| Positive Law[125] | Law derives from government and the body who administers them. |
| Deontology[126] | Law is consisted with rules and duties. Ethics helps to determine good or right by scrutinizing acts. |

However, each of these legal theories has a clear lack of methodological coherence as they are often full of ambiguities in their claims. That is what is needed to be improved in order to engineer legal ontologies from legal theory perspectives. Therefore, in order to decrease this level of methodological coherence, Maritxell Fernandez Barrera and Giovanni Sartor in their paper '*The legal theory perspective: doctrinal conceptual systems vs. computational ontologies*' claimed that [200] legal ontology is the formal description of legal-domain-based-discourses that can identify following ways

---

[121] See Andrew Altman, Critical Legal Studies: A Liberal Critique, Princeton University Press 1990

[122] See Gardner, John (2001) "Legal Positivism: 5 ½ Myths," 46 American Journal of Jurisprudence 199.

[123] See Green, Michael Steven, Legal Realism as Theory of Law. William & Mary Law Review, Vol. 46, pp. 1915-2000, 2005. Available at SSRN: http://ssrn.com/abstract=761007

[124] See Haakonssen, Knud. 1996. Natural Law and Moral Philosophy: From Grotius to the Scottish Enlightenment. Cambridge, UK: Cambridge University Press.

[125] See Murphy, James Bernard (2005). The philosophy of positive law: foundations of jurisprudence. Yale University Press. ISBN 978-0-300-10788-3.

[126] See F. M. Kamm (2006). Intricate Ethics Rights, Responsibilities, and Permissible Harm Rights, Responsibilities, and Permissible Harm. Oxford University Press. ISBN 0-19-534590-8.

– (a) laws and regulations, (b) judgments, (c) systematizing legislators and judges, and (d) any legal works [200]. In addition, they proposed following three dependency-characters of law –

- The legal concept is depended on legal norms.
- The legal norm is depended on the legal terms written in authoritative documents.
- The interpretation of legal norms is depended on the context in which legal norms can be applied.

These dependency-characters of law arise level of complexity in the process of representation of legal concepts in ontologies. And therefore then they claimed that these semantic and topological characters of legal concepts can be solved through legal-ontology building.

### 9.3 Multi-layered legal information perspective

Law is static for a specific period of time, but not the legal knowledge as law evolves over time [134]. Because legal knowledge itself represents a formal knowledge-producing process consisted with many legal documents and authorities like constitution, legislations, institutional practices, judgments etc [209]. The process also includes socio-economic and political forces that play influential role in the formation of law and its changes. It means legal information itself is multi-layered as well as multi-leveled [210], where the semantic meaning of 'the layer' is to add something towards its core and 'the level' defines something independent in order to express its own meaning in its own rights. However, both – layer and level, provide 'formation ties within the architecture of the system as a whole' [134, 211].

For instance, contemporary constitutions in European countries have multi-layered structure. This can be easily understand by looking at British constitutional layers where all multi-leveled layers are based on fundamental parliamentary acts such as European Communities Act, Human Rights Act, Devolution Act. This multi-layered legal structure may vary in according to the political arrangements of any countries within EU. About the multi-level government, John Morison says[127] -

> "*Ideas of multi-level government have evolved from a simple recognition that there are layers beyond the national state to more sophisticated ideas of how power is dispersed into a multiplicity of sites, constituting nodes in a hierarchical network rather than layers in a hierarchical pyramid, which operate in a relationship of mutual influence rather than control*''.

In the case of European integration, multi-level system has been widely used in recent times. Particularly in Germany Gunnar Folke Schuppert, Rainer Wahl and Udo Di Fabio supported concept of multi-level constitutionalism [200].

[127] See Morison, J., E-Democracy: On-Line Civic Space and the Renewal of Democracy?. Canadian Journal of Law and Jurisprudence, Vol. 17, No. 1, pp. 129-142, January 2004. Available at SSRN: http://ssrn.com/abstract=528202

However, Guido Boella and PierCarlo Rossi in their paper ‘The multi-layered legal information perspective’ [200,212] proposed a lightweight ontology considering the context of engineering legal ontology of multi-layered and multi-leveled legal knowledge, which is consisted with following four major ontological layers –

- The first layer – represents information based on legal interpretation of legal content such as legislation. This interpretative information generally comes from legal domain experts. For example, Legal Taxonomy Syllabus is light-weight ontology of legal concepts and terms of particular domains, like legal concepts related with consumer, of EU.
- The second layer – characterizes service ontology that includes the definition of roles and duties of respective authorized agents of those particular domains represented by the first layer.
- The third layer – expresses ontological relations between first and second layers, which permit conversation of concepts from service ontology to domain ontology, vice versa.
- The fourth layer – organizes core concepts from the outcomes of intentional semantics originated from first, second and third layers. This layer provides a set of orthogonal concepts which consequently make the foundational basis for addressing the legal process. Even though it produces complex simulations of legal process, but it is independent from application.

In the case of legal interoperability[128], ontology must engineer all concepts and their related instances in such a way so that the designed legal knowledge model can ensure the inter-connectivity and correspondences among them. Under this context, Guido Boella and PierCarlo Rossi claimed that the multi-layers legal information perspective is also potential to ensure all features of interoperability that exist within the legal knowledge base.

## 9.4 Linguistic perspective

The main proposition of this perspective is that law and language are strictly connected. Even though they co-exist autonomously but they together represent similar structure and system. They both together not only construct the entire substantial and procedural legal system, rather they also guide the evolution, the paradigms of consistency, and temporal aspects of the legal system. They dynamically arrange and rearrange contents of the legal system in connection with socio-economic, political and cultural contexts [213].

It also says that the connection between law and language is not symmetrical [214], because law fundamentally communicates through their verbal and non-verbal ex-

[128] See Allen, D. K., Karanasios, S., & Norman, A. (2013). Information sharing and interoperability: the case of major incident management. European Journal of Information Systems, 10.1057/ejis.2013.8.

pression. Maria Angela, Biasiotti and Daniela Tiscornia, in their paper '*Legal ontologies: the linguistic perspective*' [200] described following characteristics of law –

- As legislative language is considered as the primary source of positive law, it is the object language of the law. The orthodox meaning of the legal concepts may derive from the rational interpretation of legislative content.
- As judge play the central role to interpret the legislation like a legitimate and authoritative operator, the norms originated from the legal language get its application into the concrete cases. Therefore the linguistic demonstration of legal concepts connects normative and abstract legislative statements.
- Manipulations and reformations of legislative and jurisprudential languages create new legal concepts that help to understand and analysis universe of legal discourses. It also provides the semantic manipulations of the legal theory.
- The formation and structure of legal theory is independent form the metaphysical reality and they are in their core syntactic. Because these legal theories organize the rules and regulations of the society.
- The creative roles of legal translation and interpretation of legislative contents also play an important role to understand the complexity of multi-leveled legal systems. For example, legal terminologies that express the constructive relationships between EU and non-EU entities do not only deal with representing legal concepts rather they also explicitly and implicitly reflects differences among the legal systems and their sub-systems.
- There exist gaps between the text and knowledge. Therefore, legal text does not necessarily always represent the legal knowledge. Consequently, in order to engineer ontology for legal knowledge modeling, legal ontologies must bridge the gaps.

Under considering above mentioned characteristics of law, they proposed a bottom-up methodology for legal ontology building consisting following two layers –

- The lexical layer – this is a lower layer of legal terms and concepts manipulated in semantic lexicons, where lexicon draws the essential mapping of words onto the legal concepts. One of the examples of this type of ontological work is LOIS database, which is consisted with 3500 concepts in 5 different languages and where the concepts are expressed by a synset – the atomic unit of their respective semantic net.
- The ontological layer – this is the top layer based on the lexical layer and composed of following two sub-layers –
    - The concept layer contains lists of synset linked with a number of relational nodes with other lexical layers. They aim to provide extension-ability of the concepts even though they themselves do not carry any semantic inherent characteristics.
    - The ontological layer formulates the interpretational meaning of the core elements of the legal domain. It also validates the correspondence takes in place between lexical and concept layers.

Through this methodology, they claimed, different expressions of legal concepts can be extracted from legislative documents. Besides, it also can handle the constraints that exist between legal text and knowledge, between legal concepts and systems.

### 9.5 Legal documentation perspective

The practical way of comprehending law is to examine the law as it is. The legal documentation perspective for legal ontology engineering has much to offer in the sense that it considers legal resources as a whole and as it is. Monica Palmirani, Luca Cervone and Fabio Vitali, in their paper – '*A legal document ontology: the missing layers in legal document modeling*' proposes that legal system is designed by a complex and multi-layered legal informative architecture, where every single legal document is consisted with following five layers [200] –

- Legal text, the vital component of any legal document formally approved by legitimized competent authority.
- The structure of the legal text, that organizes the texts in order to make a meaningful legal document.
- Legal metadata that is implicitly attached with the legal document but not explicitly approved by the authority. It can appear in many forms such as keywords, workflow, lifecycle, and/or identifications of the legal documents.
- Legal ontology deals with any information or network of information about the reality where the legal document acts its role. It also provides semantic interdependencies and inter-operability that exist internal and external environments of the legal documents.
- Legal knowledge representation manages the modeling and interpretation of the meaning of the text.

The layers of a legal document have ontological links with the layers of other many legal documents, which arises level of legal complexities and difficulties to manage inter-operability, granularity and cardinality of relationships and changes over time that exists within and outside of any legal documents. Therefore, the role of engineering legal ontology from legal documentation perspective might help to reduce these multi-layered complexities [134].

### 9.6 Computational legal ontology perspective

The computational legal ontology attempts to tie between the fundamental structures of legal knowledge and computational ontology. On one hand, it says that legal knowledge is based on knowledge of physical and social world in order to create a novel layer over the social world. Therefore, legal knowledge has autonomy as well as dependency on knowledge of both physical and social world, which together form like a frame in order to address the legal reasoning process. One of the examples of such frames is *Norm* ↔ *Case* means when there is violation of legal norm, it may become the subject of a legal case. However, this frame expresses the unit of a meaningful cognitive reality. Therefore, it is the cognitive agent who uses such type of frames in order to interpret the involved environment for producing legal reasoning. In this perspective, the frame also contains the meaning of the context.

On the other hand, in the computational science, ontology is artifact consisting structure, function and life cycle. The structure of ontology carries vocabulary, linguistic and formal features that also include logical and semantic features. The function of ontology is to encrypt the reality of a world for specific purposes. Besides ontology also has its life cycle like artifact due to its cycle of creation, evaluation, fixation and usage. Therefore, ontology is dedicated to deal with both domain and its tasks. All of these are performed by representing concepts and sub-concepts of the domain and by exhausting relations and attributes that are related with those concepts. Subsequently task of ontology limits its expressivity and helps to achieve certain goals.

Aldo Gangemi, Valentina Presutti and Eva Blomqvist, in their paper 'The computational ontology perspective: design patterns for web ontologies' [200] addressed following advantages of using computational ontology in legal domain –

- Inter-subjective agreement that helps to perform a task for discovering consensus about the meaning of legal terms and concepts.
- Legal knowledge reengineering and extraction by using legal knowledge patterns from database, documents and other relevant legal documents.
- Legal conformity checking provides verification results that appears from the interactions between social situation and legal explanation written in different legislations.
- Representation of both contexts and constraints from any legislative documents in a homogeneous language with high-order logics.
- Legal norm comparison that includes conflict checking in a set of norms, discovering hidden relationships among norms.
- Legal norm rephrasing when there are many legal norms with same meaning but in different legal terms.
- Contract management and excitation
- Change management of legislation[129] includes temporal as well as legal amendment.

Based on these above mentioned structures of legal knowledge and computational ontology, computational legal ontology perspective proposes that legal knowledge engineering can use the 'frame' directly or as 'legal knowledge pattern[130]'. Even

---

[129] See Palmirani M.: Legislative Change Management with Akoma-Ntoso, in Legislative XML for the Semantic Web, Springer, Law, Governance and Technology Series Volume 4, 2011, pp 101-130.

[130] See Presutti, V., A. Gangemi, S. David, G. A. de Cea, M. C. Su´arez-Figueroa, E. Montiel-Ponsoda, and M. Poveda. 2008, February. A library of ontology design patterns: Reusable

though ontology design pattern based on frames is not yet popular in the web ontology and/or link data development and practices, this could be very fruitful for handing complexity of legal domain adequately. Because complexity of legal knowledge engineering of some legal cases proves that formal consistent model is not sufficient enough, rather it requires precise design of the legal content and personalized with tasks for developing cognitively conceivable applications.

### 9.7 Legal service science perspective

Legal services, which are known as ‘bespoke’ product[131], have been modified and advanced by technological improvements. In the current state of art on legal service science[132], there are following five suggested stages in order to transform traditional to technology based legal services –

- Bespoke legal service is the traditional way to provide legal services mainly offered by professional lawyers.
- Standardized legal service aims to provide harmonized conceptual understanding among various interacting legal systems.
- Systematized legal service aims to digitalize the services including corresponding responsibilities, duties, rights and obligations of the service providers.
- Packaged legal service focuses to produce software based applications for specific legal services.
- Commoditized legal service targets to covert legal service as the legal economy.

In order to achieve all objectives of these five stages, it is required to combine many different advanced technologies and knowledge systems where computation ontology of legal service may play very fundamental roles. However, on the other hand, one of the fundamental objectives of legal informatics, and AI and law is to deliver legal services through various technologies where transferability of services includes two aspects – transferability of right as well as duty [200]. However, every single service is a complex event, which is featured by its legally layered structure, temporal and spatial location and participants, consisting with following five components –

- Service commitment is generally guided by legal procedural rules and by-laws.
- Service presentation expresses the outputs of service commitments in order to service building.

solutions for collaborative design of networked ontologies. Deliverable D2.5.1, NeOn Project, http://www.neon-project.org

131 See Deb, B. (2012). "Towards a Framework for Service Ontology Evaluation". International Journal of Computer Applications 48: 12–15. doi:10.5120/7343-9986.

132 One of the examples of such work can be found in Liebwald, D. 2009. An ontology for the implementation of the eu services directive. In Legal knowledge and information systems – JURIX 2009: The Twenty-Second Annual Conference on Legal Knowledge and Information Systems, Rotterdam, 16–18 December 2009, ed. G. Governatori. Frontiers in artificial intelligence and applications. Vol. 205, 100–105. Amsterdam: IOS.

- Service acquisition includes three performances such as service discovery, service negotiation, and service activation. This stage is depended on the performances of first two components.
- Service process provides service context monitoring, customized delivery planning, coordination and production. The customized service production basically deals with four types of actions. That are – supporting action, core service, enhancing, and follow-up actions.
- Service value exchange notably depends on producer's and customer's sacrifices and exploitation.

Most importantly the performances of each of these components are structurally layered in laws, where responsibility, rights duty and obligations play fundamental roles. Many service science scholars, like Steven Alter, consider the responsibility is the central of the service science consisting with following attributes –

- Agent is a party who play the central role to deliver the services.
- Theme/patient is also considered as the subject-matter of the services who goes through the event where theme does not get changes but the patient might change its state.
- Goal is to direct the event based on a certain states of desired performances.
- Recipient or beneficiary is the party who receives the results from the service
- Instrument is used to produce performance in order to accomplish the event.
- Location is the spatial place where the event is performed.
- Time and/or duration help to calculate the temporal status of the event.

Under considering above mentioned components of service responsibility and service science, it is possible to arrange these layers orderly in the computational ontology development. In addition, Roberta Ferrario, Nicola Guarino, and Meritxell Fernandez-Barrera, in their paper, 'Towards an ontological foundation for service science: the legal perspective' provides few core reasons of why legal ontology should be designed from the point of view of legal service science [200] –

- The legal perspective of service science requires considering the world where international economic and political institutions interacts with different legal systems for ensuring mutual understanding of legal methodologies and measures for their appropriate services. In this context, lack of unified conceptualization of legal terms, concepts and their associated properties of all interacting service providers may lead costly judicial procedures. That can be avoided by developing adequate computation ontology of their services.
- The service is one of the central features of both public and private laws. Therefore, foundational ontology of services may create opportunities to analyze conceptual interdependency and interoperability.

## 9.8 Legal knowledge management perspective

Legal knowledge is well-structured and written in exclusive and restrictive textual corpuses[133]. There are complexities in the formation, acquisition and distribution of legal knowledge by following ways described by Bourcier and Mazzega – (a) legal knowledge is created by interacting knowledge component, (b) legal conceptual links are very dynamic and changes through time and their evolutions, (c) limited and structural expressibility of the legal concepts and their inter-relationships with other legal concepts, terms and principles, and (d) the meaning of the properties is also depended on observation of contextual reality [200]. In order to manage these complexities of legal knowledge management, it is required to have common ontological platform, by which it is possible to handle diversities of cognitive patterns and conceptual implicitness that exist in the legal knowledge.

Furthermore, legal corpuses[134] itself is formulated by a complex but semantic network of conceptual interrelationships which play vital role in the legal reasoning process. Therefore, ontological mapping of legal corpuses may provide following advantages –

- It may create conceptual interrelationships like a tree-like structure with limited expression and relations of each concept with other concept, which may provide a sophisticated graph-data of legal corpuses. That can also be useful to enhance inter-operability among various legal knowledge systems.
- It may allow to retrieve legal links mechanically that exist within the legal corpuses as well as among multiple numbers of legal corpuses.
- It can be further used as weighted graph in order to add another informative layer.

Pierre Mazzega, Daniele Bourcier, Paul Bourgine, Nadia Nadah, and Romain Boulet, in their paper, 'A complex-system approach: legal knowledge, ontology, information and networks' [200] says, about the necessity of legal ontology for legal knowledge management, that

'*A legal ontology can be thus represented as continuous in dynamic networks such as semantic web. Then we should attempt to answer the two following questions – in what way and to what extend the meaning of the same expression are similar and different, according to the context given by the whole sentence? How can this meaning move through time? Human experts have remarkable skill to interpret the meaning of an expression depending on its context through long range interactions and on the date of the text. The increasing quantity of texts makes this encyclopedic*

[133] See van Engers, T. 2004. Legal engineering: A knowledge engineering approach to improving legal quality. In eGovernment and eDemocracy: Progress and challenges, ed. J. Padget, R. Neira, and J. D. Le´on, 189–206. Instituto Polit´echnico Nacional Centro de Investigacion en Computaci´on. ISBN 970-36-0152-9.

[134] See Cary Federman. 2006. The Body and the State: Habeas Corpus and American Jurisprudence. SUNY. ISBN 0-7914-6703-1.

*knowledge less and less tractable for human experts with bounded capacities of reading or memorizing.'*

# 10 Start of art on methodologies for legal ontologies

While computation ontology permits computer for interacting with each other with their corresponding semantic metadata, legal ontology by practice is different than other ontologies that have been using in medical or engineering fields. This is mainly for following reasons –

- While ontologies of other domains are based on common sense concepts of physical, abstract and/or social world, legal ontologies represent complex legal norms, rules and their interactions written in various legislative documents.
- Legal domain also needs to correspond with the activities of physical as well as social world, even though law itself is static in its own nature.
- The normative view of law and legal concept, mainly contributed by the American jurist Wesley Newcomb Hohfeld[135], addresses the central focus of law is with overt behavior of persons, where mental concepts like intention, honesty and predictability play important role in the process of legal reasoning justified by legal reason and evidence.
- Unlike ontologies of other domains, legal ontologies emphasis also epistemological issues of legal terms, concepts and their relationships, e.g. Core Legal Ontology, LRI-Core, Functional ontology for law etc.
- Unlike other domain ontology, legal ontology generally covers wide subject-matters of legal discourse from legislative documents to amendment of legislation to change and chain management of legal concept, content and knowledge.

Consequently, besides analyzing the law and legal concepts in its most applicable perspective for engineering legal ontology, it is also another fundamental requirement to consider the most appropriate methodology for doing so. Therefore, in order to understand the core principles of the legal ontology methodology, a number of such methodologies have been discussed below in brief -

## 10.1 Hafner's semantic network of legal concepts

Wesley Hohfeld (1913)[136], a legal positivist, claimed that all legal affairs can be articulated by four fundamental relations – rights, duties, powers and liabilities. Later on, similarly, Carole D. Hafner, in his article 'Representation of knowledge in a legal

[135] See Vatiero, Massimiliano (2010), "From W. N. Hohfeld to J. R. Commons, and Beyond? A "Law and Economics" Enquiry on Jural Relations", American Journal of Economics and Sociology 69 (2): 840–866, doi:10.1111/j.1536-7150.2010.00724.x.

[136] See Hohfeld, Wesley Newcomb: Some Fundamental Legal Conceptions as Applied in Judicial Reasoning, 23 Yale Law Journal 16 (1913).

information retrieval system (1980)[137]' introduced Legal Research System (LRS) that is a knowledge based system for retrieving information of court cases and statutes. LRS is mainly consisted with four kinds of knowledge – functional, structural, semantic and factual [216].

In the case of functional knowledge, the description of data contains – an information function and an explanation of legal concepts. In his paper, Hafner describes following eight types of legal information functions –

- (PLAINTIFF D) -- The plaintiff of a case was a 'D'. D must describe a party -- for example, the payee of a cheque.
- (DEFENDANT D) -- The defendant of a case was a 'D'.
- (CAUSE-OF-ACTION D) -- The legal basis of a case was 'D' – for example, negligence.
- (EXAMPLE D) -- The fact situation of a case was an example of 'D' -- for example, a forged promissory note.
- (HYPOTHETICAL EXAMPLE D) -- A case or statute describes a hypothetical situation that is an example of 'D'.
- (CRITERIA D)--A case or statute defines criteria for a situation to be an example of 'D'.
- (LEGAL-EFFECT D) -- A case or statute describes the legal consequences of 'D'.
- (RULE D) -- A case ruled that the situation before the court was an example of 'D'.''

The need of legal researchers determines the corresponding information function. In the case of structural knowledge, there are two types of relationships. First, dependency relationship aims to establish inter-dependency between the structures and the second, identify relationship helps to identify the involved parties who participate in the process of structural knowledge. The semantic knowledge of the LRS is to build inferences about the queries' meaning. In order to do that it uses -

- Nodes for defining concepts, and
- Nodes are linked by the atomic structure of the semantic knowledge
- Collection of nodes and their associated links can build complex semantic network of legal knowledge.

There are six types of semantic links in LRS such as set/member, constituent, super and sub class, attribute, role and event-condition links. Among these links, role and even-condition links express most complex semantic networks of the legal knowledge. This can be used for giving meaning of the words, sentences as well as subject-matters of the legal knowledge [217].

However, the networks do not represent the knowledge directly, but they express the factual relationship, such as implies or unless, which is considered as factual

[137] See Hafner, C. D. (1981). An Information Retrieval System Based on a Computer Model of Legal Knowledge. Ph.D. Thesis, The University of Michigan. UMI Research Press: Ann Arbor, MI.

knowledge in LRS. Because legal rules generally vary from context to context and all strict legal rules also have their own exceptions. This factual knowledge helps to handle inconsistent information. In addition, LRS deals with descriptive deductions through applying quantification and extension mechanisms.

However, Jerome Frank (1948)[138], a legal realist, exposed contrary argument to Hafner's position by saying that formal system cannot deal with law as slight changes in facts may affect and reinforce the legal decision in different direction and unpredictable. For example, legal open-textured concepts such as the legal concept of recklessness, which do not have clear direction and applicability, always based on human experience and common sense. That makes the law irregular in its application.

### 10.2 Language for legal discourse

L. Thorne McCarty, in his paper '*A language for legal discourse I. basic features*', presented the architectural model of legal for legal discourse (LLD) [219]. About the fundamental arguments in favor of LLD, he says -

> *''There are many common sense categories underlying the representation of a legal problem domain: space, time, mass, action, permission, obligation, causation, purpose, intention, knowledge, belief, and so on. The idea is to select a small set of these common sense categories, the ones that are most appropriate for a particular legal application, and then develop a knowledge representation language that faithfully mirrors the structure of this set. The language should be formal: it should have a compositional syntax, a precise semantics and a well-defined inference mechanism. The semantic interpretation of the common sense categories should be intuitively correct, that is, it should generate exactly those entailments that ordinary people (and ordinary lawyers!) generate in similar situations. The inference mechanism for the language should be complete and sound, in principle, but, in practice, completeness and soundness would often be sacrificed for computational tractability, just as they are in ordinary human (and ordinary legal!) reasoning. Clearly, if a language of this sort could be developed, it would provide a uniform framework for the construction of a legal analysis/ planning/retrieval system, and a solid foundation for further theoretical work.''*

The principle component of the LLD consists with atomic formula, rules and proofs, and usages of different modalities. The atomic formula in LLD is featured by reified relationships, sorts and sub-sorts and count and mass terms. It is based on internal and surface syntaxes with different functionalities. Internal syntax is used by the proof mechanism and surface syntax is used to manage communication with external users [218, 220]. In LLD, every atomic relationship is either constant or variable, which is considered as reified relationship. That is to understand the changes that happen in the interactions of legal and real world, which is similar notion of Kow-

[138] See in Neil Duxbury 1991: "Jerome Frank and the Legacy of Legal Realism", in Journal of Law and Society, Vol.18, No.2 (Summer 1991), pp. 175–205.

alski's ‘holds’ formalism. All the count, e.g. person, and mass terms, e.g. cash, stock, used in LLD are sorted and sub-sorted, which is respected by unification algorithm.

There are two sides of the rule represented in the LLD. They are – (a) the left-hand side, which carries the conjunction of atomic formulas based on Horn clause, and (b) the right-hand side, which contains the compound expression in either the form of negation or embedded implication or default expression that includes both default rules and proofs. That proves that LLD is based on intuitionistic semantic, not classical. In addition, even though it does not permit disjunctive assertions, but can be achieved by utilizing the functional capacity of prototypes and deformations. These all rules features are essential for representing legal rules semantically.

Furthermore, deontic logic is used to handle the modalities found in the different legal rules and concepts like time, permission, obligations, causation, purposes, knowledge, belief, and intention etc. This is also based on intuitionistic semantic in order to support unique models and definite substitutions of answers. Besides, the proof procedures in LLD are designed by first-order language in order to simply overall performance of the system by managing both action and deontic languages.

## 10.3 NORMA

Traditional symbolic logic system is based on concepts like identity, truth etc. That was not appropriate in order to handle the expressivity of legal knowledge appears from legal rules and concepts. Therefore, Ronald Stamper says, classical logic's frame of reference is not good enough for legal knowledge management [221,222]. And then he proposed NORMA, means logic of norms and affordance, is based on few central ontological concepts – agents, behavioral invariants, and realizations[223].

The NORMA was not primarily concerned with norms and affordance, while Samper was working with LEGOL – a project aiming to model computerized representation of law. Then subsequently he added the notion of norms, which was coined by Von Wright, and the notion of affordances, which was coined by Gibson, into his project LEGOL and named it as NORMA [224].

In NORMA, an agent is considered the central focus of the reality which can regulate and changes the world by acquiring knowledge and applying them accordingly. The agent is responsible for its own undertaken actions in the form of omission as well as commission of a single task. Furthermore, the conceptual formation of an agent mainly depends on the architecture of the NORMA system, because this concept can be extended as other forms of legal personalities like state or cooperation.

In addition, legal knowledge is characteristic by such some features that are invariant over some time, for example all legislation has its starting and ending time. And most importantly these characters are evident in the behaviors of entity. This invariant behavior is handled in NORMA by putting a description of a context in which behavior or features are invariant. The description of the context also expresses knowledge of legal as well as social world consisting with an object or state of affairs [225].

When agent performs any action, it goes through a context associated with its invariant behaviors. Therefore, the realization depends on an agent and its invariant behavior. In NORMA it is written as Ax, where A and x represents agent and behavioral invariant respectively. Furthermore, composite realization can be formed by a set of agents and their behavioral variants.

### 10.4 CABALA semantic network

Laws are often heterogeneous, multi-layered and multi-leveled. In many cases, all available laws cannot be detected easily under any particular legal discourse[139]. One example of such laws is environmental laws, where sectorial and segregated legislation can hardly recognize all polluting factors under one corresponding institution's rule based roles[140]. However, these fundamental but sectorial laws have been affecting the roles of institutions very adversely. Moreover, the information related with these vast bodies of environmental laws is situated at various institutions documentation centers. That pushes following fundamental challenge to get the access to that legal information –

- Diversity of environmental law related data banks.
- Structural inconsistency of that information and data banks.
- Not standardized linking mechanisms among the information exist in different data banks.
- Different search languages arise the complexity
- Tools for conceptual retrieval are diversified.

In order to overcome above mentioned challenges, CABALLA ((Consultazione Assistita di Basi di Dati di Leggi Ambientali) [226] was proposed with four features – defining search strategy, construction of queries, managing dialogues with external users, and navigating semantic network. It has following three independent functional pats, but they communicate among each other through messages - query generator, data base query manager, and data bases. The query generator, which is to enable users for initiating query from both legal and common sense point of view, is further sub-divided into three parts – the navigator, query constructor, and query evaluator. The navigator and query constructor together use the knowledge that exists in the semantic network.

This semantic network of CABALLA contains legal terms and concepts represented as the nodes in the network. Both the navigator and query constructor can recognize relationships between the nodes by using Broader Term (BT) relation and Broader Term hierarchies. BT relation that nested in hierarchies is transitive and denotes legal concepts of the domain. BT hierarchies express the nodes of the semantic network in order to recognize the relations between the nodes. It also uses Related Term

---

[139] See Brachman & Levesque, 1985] Brachman, R.J. and H.J. Levesque, A fundamental Tradeoff in Knowledge Representation and Reasoning. In: Brachman, R.J. and H.J. Levesque (eds), Reading in Knowledge Representation, Kaufmann, Palo Alto, CA, 1985.

[140] See Guidotti, P., L. Lucchesi, P. Mariani, M. Ragona and D. Tiscornia, A simple intelligent Interface to Data Bases on Environmental Law. In: Database and Expert Systems Applications, DEXA '90, Springer Verlag, 1990.

(RT) to recognize the interpretative knowledge that appears from the interpretation of various legal norms, rules and concepts[141].

The production rules has been used to formalized the strict part of the legal knowledge such as compliance check between values, granting authorization etc. by using if <condition> then <consequence> rule which has following features –

- Modularity, because it represent atomic parts of the independent legal knowledge[142],
- Adding capacity is the technical capacity of the system in order to add new rules
- Transparency is to facilitate the answers in according to the user's questions.

In addition, there are two types of rules used in Flex language used CABELLA, one is followed by Prolog clauses for backward reasoning purposes, and the other is followed by production rule format for forward reasoning. Together these rule-sets enable the system to determine the rules used in the query agenda, to define an approach for choosing appropriate rules, and to establish the approach for query agenda updates.

Flex, a toolkit for developing expert system, is used for developing CABELLA and frames is used for representing expert's knowledge of the domain. The frames in CABELLA enabled to represent complex legal concepts and other associated information of any entity.

### 10.5 Frame-based ontology of law

Few important ontological techniques for legal knowledge systems have been proposed by Van Kralingen and Visser [227][230]. Both of them acknowledged that conceptual as well as formal ontologies are very crucial in order to delimit inter-task-dependency of specifying legal knowledge. Even though there are dissimilarities between legal ontology proposed by Van Kralingen based on conceptual legal entity and by Visser based on formal legal entity, the similarities between these two approaches together made the Frame-based ontology of law (FBO) [228,229]. The main central focus of FBO is to model statute-specific legal ontology. In addition, in 1998, Visser and Bench-Capon proposed ONTOLINGUA for the legal ontology [233].

In FBO, legal ontology categorizes legal knowledge into three separate entities. They are norms, acts and concepts. The frame structure is used for formulating each of these entities. These entities are described below in brief [230, 231][234]–

- Legal norms appear from rules, standards and principles written in legislation that guide behaviors. In FBO, there are following eight elements of the norm –

[141] See Sergot, M., Representing Legislation as Logic Programs. In: Machine Intelligence, Oxford University Press, 1988, no. 11.

[142] See Doyle, J. and R. Patil, Two theses of knowledge representation: language restrictions, taxonomic classification, and the utility of representation services. In: Artificial Intelligence, 1991, no. 48, pp. 261-297.

- Norm identifier: it acts as a point of reference of each norm.
- Norm type: it helps to identify what type of norm legal ontology is dealing with, e.g. norm of violating contract.
- The source of the norm: it denotes the origin of the norm.
- The scope of the norm: it says about how and where to apply the norm.
- Conditions of applying norm: it specify the contextual circumstances where the norm can be executed.
- The subject of the norm: it answers of who is the targeted subject matter of the norm
- Legal modality of the norm: it denotes the 'ought' status of the norm.
- The act identifier for the norm: it helps to find out the legal references in the description of separate act.

• Acts helps to recognize two broad distinctions. First distinction is consisted with events and process, where event notifies the instant changes that happen between two states and process counts durations. The second distinction is related with institutional and physical acts, where institutional acts represent legislative physical acts as well as it qualifies the physical act to be performed. All acts have following thirteen elements –

- Act identifier: it does similar job as norm identifier but, in contrast, it acts as a point of reference for each act.
- Source of the act: it describes the root origins of such act.
- Scope of the act: it says where and how the act can be applied.
- Agent: who performs the act and it can be natural as well as legal person/s.
- Type of the act: it describes the categories of the act.
- Modality of means of the act: the physical objects that has been used in order to perform an act.
- Modality of manner of the act: it answers of how the performance has been executed, e.g. honesty or with bad intention.
- Temporal aspects of the act: it denotes the information about the performing time of the act.
- Spatial aspects of the act: it says about the specific location of where the act has been performed
- Circumstantial aspects of the act: it represents the contextual situation of the performed act.
- Causes of the action: it describes the reasons behind the performance of the act.
- Aim of the action: it points out the goals and objectives of the agent behind performing such act.
- The intentionality of the action: it focuses on the mental elements of the performed act.
- The final state of the act: it describes the outcomes of the performance.

• Concept description represents the meaning of the concepts. It can be derived from a legal definition or provisions as well as it can also represent a notion of legal friction. It also can be based on factors that can represent certain condition and/or applicability of the concept itself [232]. Furthermore, it also can deal with the meta-concepts which can produce semantic meaning of the legal knowledge [235, 236]. It is consisted with following seven elements – (a) the description of the concept, (b) type of the concept, (c) the priority status of the concept, (d) the source of the concept, (e) the scope of the concept, (f) the applicability condition of the concept, and (g) the instances of the concept.

### 10.6 Functional ontology of law

The functional perspective of legal system considers legal system as an instrument of modifying the society towards achieving a set of specific socio-political or economic goals. This perspective motivated Valente to develop his ontology for law, known as Functional Ontology of Law (FOL), shown in Figure 1 [237], addressing the reacting factors of legal system towards the social behaviors. However, the foundation of FOL is constituted by following six branches of legal knowledge –

- Normative knowledge outlines the basis of social behaviors through a standard code of behavior of the people who lives in a society. Valente's this branch of legal knowledge is influenced by the Hart's notion of primary norm, which describes the normative conditions of a contextual situation which approves or rejects any particular behavior of individual and/or society as a whole.
- World knowledge as a legal abstract model (LAM)[143] that regulates the behavior of the individual as well as the society. It prescribes acceptable behaviors and establishes a legal framework of collective behavior for all natural and legal personalities as well as for the society at large. The LAM bridges normative and common sense based knowledge and is consisted with following two types of knowledge –

  - Definitional knowledge[144] represents static part of the knowledge appearing from legal definition, legislative content, authoritative orders and commands, legal relations, court cases, and legally permitted condition for performing certain tasks. These all categories of definitional knowledge constitute a large legal vocabulary in order to describe certain perspective of the legally acceptable world and used by legislator to regulate the collective as well as individual behavior.
  - Causal knowledge is founded by the definitional knowledge.

[143] See Valente, A., and J. Breuker. 1995. On-line: An architecture for modelling legal information. In Proceedings of the Fifth International Conference on Artificial Intelligence and Law (ICAIL'95), ed. T. Bench-Capon, 307–315. New York: ACM Press.
[144] Valente, A., and J. Breuker. 1994c. Ontologies: The missing link between legal theory and ai/&law. In Legal knowledge based systems (JURIX'94) the foundation for legal knowledge systems: The relation with legal theory, ed. H. Prakken, A. Muntjewerff, and A. Soeteman, 138–150. Lelystad: Koninklijke Vermande. ISBN 90 5458 190 5.

- Responsibility knowledge is a type of legal knowledge that either limits or delimits the responsibility of an agent in order to perform certain set of behavior. It also provides legal consequences of violating that knowledge.
- Reactive knowledge is such legal knowledge that describes a certain code of performance which can be executed when primacy norm is violated by an agent.

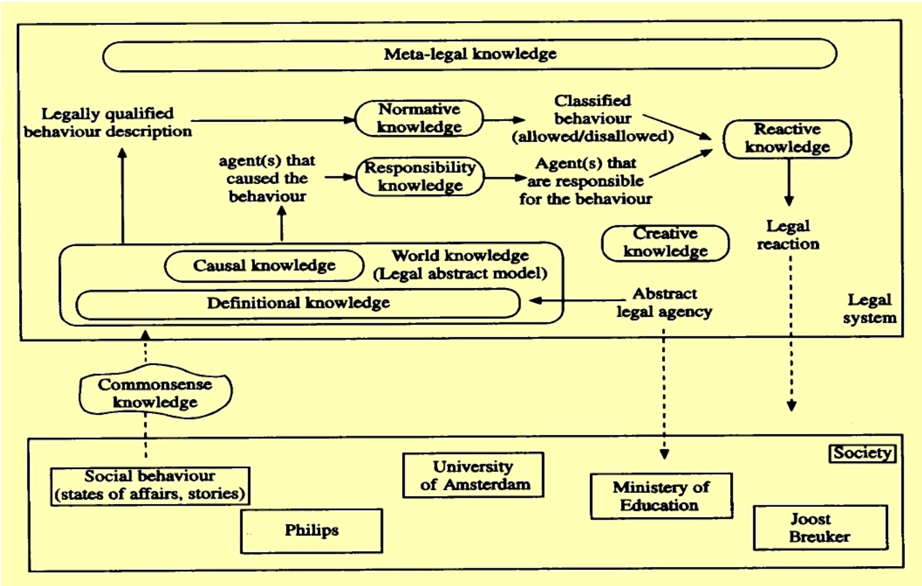



**Fig.1.** Legal ontological structure of FLO [237]

- Meta-legal knowledge[145] is a certain type of legal knowledge which indicates relations and bondages with other types of legal knowledge. This is similar concept to Hart's secondary rules, which bridges primary and secondary norms together. There are following two fundamental functions of this type of legal knowledge –
  - It provides regulatory framework in order to manage dynamics of legal system, for example through amendments.
  - It delivers legal mechanisms to resolve conflicting rules that exists within different branches of legal knowledge.

  These functions together constitute four sub-category of meta-knowledge. They are
  - Norm data, deals with different types of information relating with norms such as scope and sources of the norm and how and where to apply etc.
  - Ordering norms that aims to solve the conflicts exist in different legal knowledge.

[145] See Spinosa, P., G. Giardiello, M. Cherubini, S. Marchi, G. Venturi, and S. Montemagni. 2009. Nlpbased metadata extraction for legal text consolidation. In ICAIL '09: Proceedings of the 12th International Conference on Artificial Intelligence and Law, 40–49. New York: ACM.

- Normative default provides standard code of behavior where primacy norm is absent.
- Validity knowledge helps to decide which legal knowledge is valid under which legal contexts.

- Creative knowledge allows creating new laws where there is no existence of formal law.

### 10.7 Dynamic interconnected system for developing ontology of law

A legal top ontology, the law as dynamic interconnected system, is proposed by Jaap Hage and Bart Verheij, based on three abstract characters of laws [238]. They are – the law is a system derived from states of affairs, the law is dynamic due to its nature of adaptability by changing its own states, and the law is interconnected between legal rules and state of affairs. In addition, the model has three components –

- State of affairs which is constituted by possible explanation of the physical and abstract world,
- Events which can affect and reinforces the state of affairs, and
- Rules which establish two types relationship between states of affairs – causation and constitution[146].

In the temporal context, constitution is timeless while causation follows the order of time [239]. However, on one hand, causation may changes the event and that affect the states of affairs. On the other, constitution creates new state of affairs in order to add to the existing networks of two types of states of affairs – temporary and durable states of affairs. As law is considered dynamic system, these states of affairs by the influence of law get changes over time to time, and vice versa. The temporary state of affairs is very fragile towards the legal system and so it is very flexible towards extinction of its own existence and transform as a new state of affairs that might add other existing state of affairs. Besides, supervenience of one state of affairs over the other has significant role in the application of legal rules. It can be formulated by the definition of legal terms and concepts. In addition, there are following three types of modalities of the state of affairs –

- Anankastic state of affairs deals with three conditional parameters – necessary, possible and impossible. In law, it also concerns with the competence. The lack of competency in legal system may invalidate the enforceability of any judicial decision.
- Deontic state of affairs deals with permission, obligation and forbidden. There are two basic categories of deontic state of affairs – the ought-to-do and the ought-to-

[146] See Winkels, R., A. W. Boer, J. A. Breuker, and D. J. Bosscher. 1998. Assessment based legal information serving and cooperative dialogue in CLIME. In Proceedings of the Eleventh Conference of Legal Knowledge-based Systems (JURIX'98), ed. J. Hage, T. Bench-Capon, A. Koers, C. de Vey Mestdagh, and C. Gr¨utters, 131–146. Gerard Noodt Instituut (GNI),Nijmegen.

be. Nevertheless deontic state of affairs is not equivalent to non-model states of affairs which supervene.
- Probabilistic sates of affairs deals with certainty, uncertainty and possibility.

Rule connects states of affairs as well as events. The construction of rule is not as same as the construction of either state of affairs or event. The presence of rule in the state of affairs is easily detectable. An event can create a state of affairs and the rules can direct the events and its effects. The resultant new state of affairs may produce casual rules. However, the rule that only exist can connect the states of affairs, otherwise not. A rule has following two parts –

- Condition part – is based on one or more states of affairs that contain variable and it is instantiated in the course of state of affairs.
- Conclusion part – is based on one single state of affair and it is harmoniously instantiated to the state of affairs.

Event causes alterations in the overall setting of states of affairs and occurrence of event itself is a state of affairs. The act is also an event constituted by the active performance such as juristic acts. The effects of event over the state of affairs are unavoidable and it also includes legal consequences. An event may also effect simultaneously over more than one state of affairs as well as over the contractual bonding of multiple states of affairs. In the latter case, it causes more relatively legal consequences than other types of effects. Events also can supersede other events as well as multiple states of affairs.

## 10.8 CLIME ontology

The central focus of the CLIME ontology [240,241,242] was to develop legal ontology with conceptual retrieval and normative valuation of those legal concepts mainly for web-based legal advice system. It dealt with international laws relating with maritime pollution and ship-classification. Broadly it had two purposes – (a) to enable user to use natural language interfaces in order to analysis their own cases by using those legal terms and concepts already available in the CLIME ontology, and (b) to enable the system to manage legal knowledge coming related international rules and regulations. In addition, it can automatically check the internal consistency among the rules it contains. It is based on following two separate components –

- Domain ontology aims to formalize the terms and concepts related with ship design, construction, maintenance and other related areas of ship-classification. In CLIME there is no such core ontology in order to formulate any particular and/or overall context of the ship-classification. One of the main purposes of this domain ontology is to produce abstract top ontology in order make clear distinction between concepts like agent, functions, and/or artifacts etc.

  In order to build relationships between legal terms and concepts, it used labeled and graph data techniques using an inexpressive language. It does not permit the relations as term-nodes, rather the terms are connected with the legal documents by using text element. That also helps the knowledge base in order to define the relations from legal point of view. There are two key knowledge presentation primitives have used. They are – subsumption, when a term applies to any instance to which the other terms also apply, and disjointness, when two terms cannot be applied to the same instance.

- A knowledge base of norms is to map from legal rules to deontic constraints and it also qualifies a case. Consequently, these legal rule based norms used in CLIME are limitedly expressed and do not qualify descriptions of rules. However, in addition, the knowledge base contains other necessary meta-information about particular rules in order to formulate clear internal ontological architecture for any case description.

In CLIME, knowledge acquisition technique has two stages. The first is the conceptual retrieval stage where legal concepts and their relations are defined. It does not allow external knowledge representation. The second is the normative assessment stage where the content of the first stage is evaluated. In addition, Legal Encoding Tools (LET) was used in order to formulate CLIME ontology. LET is also capable to show the sources of the legal terms and concepts mentioned in the domain ontology. However, due to its limited expressivity, CLIME does not cover all knowledge of their concerned legislative documents.

### 10.9 Mommers's knowledge based ontology for law

Laurens Mommers, in his paper 'A knowledge based ontology of the legal domain' [243] articulated his two perspectives for developing such type of ontology for law. First, the epistemological perspective helps us to understand how knowledge is formed and justified. Second, the ontological perspective examines what entity exists and in which way. Together of these perspectives helps to have integrated understanding of legal domain as well as how to represent the legal knowledge. In addition, a general overview of legal domains and theories is also necessary for understanding how law is evolved by time and legal history. Therefore a legal ontology must allow multi-layered ontological status and their epistemic contributions, so that legal knowledge can be captured in well-formulated way. There are six basic categories in his proposed model – entities, ontological status layers, epistemic roles, relations, acts and facts.

There are two types of entities – legally relevant entities and legal entities. Legally relevant entities are further constituted by seven types of entities. They are - sentences, statements, propositions, beliefs, artifacts, rules and concepts. There are eight types of legal entities such as legal principles, legal norms, legal decisions, legal systematization, judicial interpretation, judicial classifications, legal rules and legal concepts. The entities are characterized by the ontological status layer. Existence, constitution and recognition – are the ontological status for legally relevant entities. Legal efficacy, legal validity, legal constitution and legal recognition – are the ontological status of legal entities.

Epistemic role uses count-as relation in order to apply it on any object. For example, reason can be count as a statement. Epistemic roles for legally relevant entities are – reasons, defeaters, factual knowledge as well as practical knowledge. Legal reasons, legal defeaters, factual legal knowledge and practical legal knowledge – are the epistemic roles for legal entities. Interdependencies are expressed by relations. It might involve with consequences and imposition of new roles and phenomena. It may appear in three forms – causation, counting as, and recognition.

Acts represent important activities of the entities. It also helps entities to be identical by its own course of action. Legally relevant acts are – applying rules, making decisions, making systematization, making interpretations, and making classification. Legal acts are – applying legal rules, making legal decisions, making legal systematization, making judicial interpretation, and making judicial classifications. The legally relevant facts are – brute facts, conventional facts and institutional fact. While brute facts are not attitude-driven, recognized and institutional facts are driven by community and systemic institutional rules respectively. The legal facts are – recognized legal facts, recognized by legal authority, conventional legal facts, established by community, and institutional legal facts, appears from the application of legal rules.

### 10.10 LRI-Core legal ontology

Whereas FOL is influenced by the works of Kelsen, Hohfeld and Hart, LRI core legal ontology is to structure the meaning of legal concepts to enable the system for acquisition of legal knowledge [244,245]. It has three layers – foundational or upper ontology, legal core ontology and legal domain ontology. The upper ontology in LRI-Core does not contain all foundational legal concepts, rather it contain around 300 concepts that have legal significance over the legal core ontology. It is developed in OWL-DL and it has been actively increasing its conceptual contents. It is consisted with five major categories of the world – physical concept, mental concept, abstract concept, roles, and terms for occurrences. These categories are discussed below in brief –

- Occurrence: The entities and their relations can detect when they occur or happens in the reality. The idea of LRI-Core behind the category occurrence is that entity is temporal in any situation, it means perdurants, but concept is eternal, it manes endurants. When mental concept is applied in any situation, concept and occurrence can be distinguished and identified. In addition, divergence appears when mental concept is compared with the actual behavior or its memory. In particular, episodic memory clarifies the memories related with events as well as occurrence. In LRI-Core, it deals with temporal dimensions of execution, which includes objects and processes. Therefore, process is not occurrence, but event is.
- Physical entity: it involves and evolves through physical objects and processes, shown in *Figure 2*. On one hand, the visible and recognizable world is appeared through the existence of object which has mass, extension and made out of matter and substance. On the other, process uses energy to manipulate objects. What process brings is changes, even though change itself is temporal concept depending on

the occurrence in order to make change happens. Process can cause a number of events altogether. In LRI-Core considers action as process, which is instigated by agent.

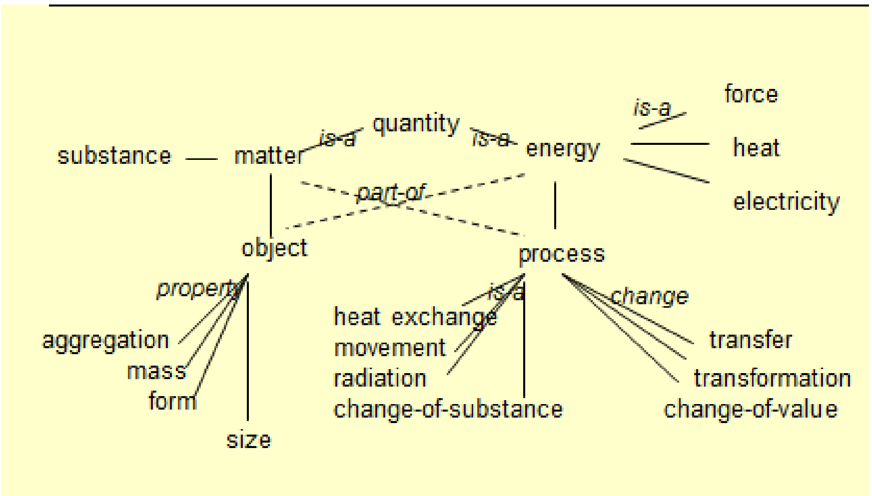



**Fig.2.** Process and object in LRI-Core ontology for Law [244]

- Mental entity: In LRI-Core mind is consisted with mental object such as concept and memory. When mind execute its process, it transforms its expression through these objects. While concept is designed by experience, memory is repossessed. One of the most important distinctions between mental and physical entity is that causation helps to occur physical process but mental process is directed by intention. However, action affects and reinforces both entity of physical as well as mental world.
- Abstract entity: The domain ontology of LRI-core is populated by abstract concepts. The fundamental roles of this type of entity are formalized by creating domain ontology of Dutch criminal law. The aim was to manage criminal trial in semi-automated way, specifically by analyzing records of criminal court hearing.
- Role: In LRI-Core, it deals with the functions of mental and physical object and process as well as agent's behavior. The role also expresses the collective behavior of society and organization. While mental role is epistemological, function is considered as the physical object's role. In particularly legal domain, evidence as well as assumption also can be addressed as role in the process of legal reasoning governed and enforceable by laws. The actors who play the role are described in legislation too.

### 10.11 Jur-IWN

The Jur-Wordnet, also known as Jur-IWN, is extended version of legal ontology provided by EuroWordNet [246]. It has two goals – (a) to develop content description model for facilitating legal knowledge modeling, and (b) enable the system as a resource in order to manage multilingual and varied legal information coming from different sources. In Jur-IWN, terms are inter-connected with each other as lexical relation and concepts are formalized based on the ontological perspective of the concept and legal domain[147]. However, it is based on DOLCE foundational ontology[148] and it considered legal domain as a representation of systems of rules that express the standard version of social behavior. All of concept of domain ontology of Jur-IWN is categorized as agents, roles and mental objects.  These are described below in brief –

- Legal agent: In Jur-IWN, legal subject considers physical existence as a sufficient condition, but not necessary one. Consequently, the role produced by constitutive and regulative rules is a legal agent performed by natural and legal personalities.
- Role: There are two types of roles in Jur-IWN – functional and legal roles. generally these roles represents the explanations of physical and non-physical object followed by DOLCE.
- Mental object: The consequences of mental process are based on the internal structure of mental objects. Therefore cognitive states are perdurants and subsumed by consciousness.

In addition, Jur-IWN proposes that legal concept is constituted by legal roles, events, parameters and their inter-relationships with a setting of legal concept determined by a legal case. This perspective enables the system to build and process a functional demonstration of law. In this regard, Jur-IWN imputed few relationships from DOLCE. Some of them are given below –

- Legal norm descriptions[149] and judicial situation relations, where normative text from the legislative document are considered as legal norm, which may involves with institutional function, power, behavior and acts. It may also be approved by judicial process and situation.
- Legal constitution and dependency relations indicate that legal person, subject, act are depended on physical entities, norms and situation respectively and human facts do not depend on will, but on consciousness.
- Participation relations establish connection between legal subjects, legal facts and human activities.
- Inherence relations express the implicitness of legal acts into the legislative documents.

---

[147] See Roventini A., Alonge A., Bertagna F., Calzolari N., Girardi C., Magnini B., Marinelli R., Speranza M., Zampolli A. (in press), ItalWordNet: Building a Large Semantic Database for the Automatic Treatment of Italian, in "Linguistica Computazionale", Istituti Editoriali e Poligrafici Internazionali, Pisa-Roma, ISSN.

[148] See Gangemi A., Guarino N., Masolo C., Oltramari, A., Schneider L. 2002. Sweetening Ontologies with DOLCE. In Proceedings of EKAW 2002, Siguenza, Spain, pp 166-178.

[149] See Gangemi A., Pisanelli DM., Steve G., 2001, A formal Ontology Framework to represent Norm Dynamics. Proceedings of Second International Workshop on Legal Ontologies, Amsterdam, NL.

### 10.12 Lame's ontology of French law

Guiraude Lame, in his paper '*Knowledge acquisition from texts towards an ontology of France law*' [247] articulated his legal ontological approach based on two steps – (a) explicit knowledge acquisition directly from the legislative texts where legal terms and concepts are explicitly given, and (b) implicit knowledge acquisition that is not given in the legislative texts but it is required in order to support explicit knowledge. This approach is entirely based on normative legislative texts and useful for legal documentation purposes [248,249]. These two steps are described below in brief –

- Explicit knowledge acquisition: aims to develop the terminological knowledge base. It first extracts legal terms and concepts from the legislative documents and then establishes lexical relationships between those concepts and terms. To make the process easily accomplishable, he divided the tasks into following two steps –
  - Extraction of explicit terms and adequate suggestion relevant with those terms: Generally here terms are identified as noun or noun phrases. He used natural language processing techniques in order to detect those terms easily from the large legislative document.
  - Identification lexical relation between selected legal concepts and terms[150]: He used following techniques in order to do that -
    - Prefix of the noun phrases in order to make lexical relation between the terms. This technique is known as semantic hyperonymy.
    - Contextual analysis is also performed as another useful technique for making explicit lexical relation between terms.
    - Identification of lexical syntactic schemas in the sentence helped to find out potential lexical relations.
- Implicit knowledge acquisition: aims to figure out the supporting knowledge, those are not explicit in the legislative documents, for the explicit legal terms and concept. In order to do that following three models has been proposed –
  - The hierarchical model: Generally normative texts are based on hierarchical relationships between the texts as well as documents, known as normative pyramid[151]. By following this hierarchical relation, it is easy to detect the explicit knowledge required for making full meaning of implicit concepts and terms.
  - The structural model: Ontological formalism always carries its own structure. Sometime it is easy to follow the structure in order to export the knowledge. In

[150] See Lame, G. 2005. Using nlp techniques to identify legal ontology components: Concepts and relations. In Law and the semantic web. Legal ontologies, methodologies, legal information retrieval, and applications, ed. V. R. Benjamins, P. Casanovas, J. Breuker, and A. Gangemi. Lecture notes in computer science, Vol. 3369, 169–184. Berlin/Heidelberg: Springer.

[151] See Lame, G., and S. Despr`es. 2005. Updating ontologies in the legal domain. In Proceedings of the Tenth International Conference on Artificial Intelligence and Law (ICAIL 2005), June 6–11, University of Bologna, Vol. 155-162. New York: Association for Computing Machinery.

the case of ontology modeling of the France law, they followed following structural model in order to collect explicit knowledge. This model supports XML standard.

- The functional model: This permits collecting knowledge from the ontological research community, especially from functional ontology research. Because functional ontology of law clearly distinguish different categories of legal concepts and their roles. Therefore, reusing those functional ontology of laws might help to collect explicit knowledge required for supporting implicit knowledge.

### 10.13 LKIF

Legal Knowledge Interchange Format (LKIF) started with two objectives [250,251] – (a) to provide translation service between different legal knowledge bases formalized in different ontological format and architectural framework, and (b) to represent legal knowledge formalism in a unique and standardized format so that it can be used as a base of various legal knowledge systems for proving a number of legal services. LKIF has been developed based on following three frameworks[152] –

- Situational framework: It provides structural plans in order to accomplish specific goals in a certain context. Each plan includes one or more transactions where actor participates and plays role. In the legal domain, procedural law generally represents situational framework. Additionally, action and situational framework are seen together in the body of legal norms.
- Mereological framework: It deals with the compositions of object and process of entities. Definition of legal concepts and terms often includes mereological aspects into it. Generally it is expressed as part-of. In particular, it permits to differentiate parts and wholes, containment and functional composition and decompositions. It also formulates the foundational basis of many important concepts like place or location, moments and intervals in time.
- Epistemological framework: It guides the notion and role of inference in the legal reasoning process. Such type of examples can be found in problem solving methods, which is subdivided into three stages – hypotheses formation, identification of constraints, and explain the empirical data in order to solve. Each of these stages transfers their inherent attributes and characteristics to other stages through inference processes. In the legal domain, functional ontological perspective of law, which claims that control system of the society is the role of the law, is dominated by epistemological framework. It also deals with inter-dependencies between identified steps of any methodological interventions.

The methodology of LKIF is mixed with Hayes's notion of metaphysical top-down construction, Gruber's notion of knowledge acquisition from naive physics and cogni-

[152] See Hoekstra, R., J. Breuker, M. D. Bello, and A. Boer. 2008. LKIF core: Principled ontology development for the legal domain. In Law, ontologies and the Semantic Web. Channelling the legal information flood, ed. J. Breuker, P. Casanovas, M. Klein, and E. Francesconi. Frontiers in Artificial intelligence and applications. Vol. 188. Amsterdam: IOS Press.

tive science, and Schreiber's CommonKADS approach. This combined methodology has been used in the process of identifying scopes and purposes, capturing and coding ontology, integrating existing ontologies and evaluating. In LKIF, there are also a collection of ontology modules, where each module represents a set of independent concepts such as expression, norm, process, action, role, place, time and mereology. These ontologies are compartmentalized into following three levels –

- Top level: It provides fundamental concepts require representing legally relevant facts and events. Few examples of such concepts are time, location, time, parthood, change, event etc. Many common concepts are borrowed from LRI-Core ontology. This level also provides clear distinctions between physical, abstract and mental concepts as well as the concept 'occurrence'.
- Intentional level: The construction of this level is motivated by the idea that legal reasoning is led by common sense based intelligence behavior that is influenced by the law. Therefore, this level is consisted of those concepts and their relations that represent human's intelligence behavior. In addition, it also contains concepts for describing mental state of agent like intention, belief etc.
- Legal level: The idea of legal statement motivated to design this level of ontology for LKIF. It defines that legal statement is dependent on two elements – (a) categories of agent who makes the statement, and (b) the rights and authoritative powers of the agent influenced by delegations, assignments and mandates. Therefore, this level represents concepts that express rights, powers, action of legal agents. It also includes the concepts related with legal roles related with legal statement.

### 10.14 SAMOD

Simplified Agile Methodology for Ontology Development[153], known as SAMOD, is a step by step methodology for developing ontology following an iterative work-process aiming to create well-developed and documented ontological model with inclusion of exemplar[154]. Three foundational principles of SAMOD are as follow –

- Avoiding inconsistencies: it aims to reduce inconsistencies between the content of TBox and ABox by using interactions between concepts of TBox and ABox. Generally concepts of TBox independently may appear as consistent, but when it interacts with the concepts of ABox's instances, inconsistencies may appear.
- Self-explanatory and easy-understandable model: it targets to compare the ontological model with real world scenarios. In order to do that it describes TBox entity in such way so that it represents the intent and usages of entity itself and has direct links with the examples designed in ABox. It also aims to develop documentation of each single part of ontology development work-process.

[153] Available at speroni.web.cs.unibo.it/publications/samod.pdf
[154] See Beck, K. (2003). Test-driven development: by example. Rivers, The Addison-Wesley Signature Series (p. 220). Addison-Wesley.

- Example of usage: Providing sufficient instances in ABox and linking them with TBox entity is one of the fundamental requirement for developing functional and efficient ontology.

There are two types of experts involved in the formalization process of ontology development – (a) domain experts who supply technical knowledge, clarity and normative validity in language or tools, and (b) there are two groups of ontology engineers. First group develops the ontology in the way domain experts guides them, and second group text the consistency between TBox and ABox entities and instances respectively. In SAMOD, ontology development process is divided into following six phases –

- Motivating scenario: It presents normative description of motivational element behind the ontology development with few concert examples. Generally it is consisted with a name, description of the story that gear motivation, and examples. Everything must be consistent with each other's content.
- Informal competency question: It expresses the informal requirements of the ontology development in a question-answer format. The development process of informal competency question is hierarchical and composed by following elements – a unique identifier, a name, question in natural language, expected answers, example of answers, relationship with other competency question, and dependency between the answer of this competency question with other stages of ontology development.
- Glossary of terms and concepts: It provides a list of terms, concepts and their definitions. The terms may be constructed by noun or noun phases, but definition of it contains the specific meaning of the term. This process helps to understand the cognitive clarity and coherence in the process of defining terms and concepts on which the entire ontology is built up.
- Current model: As the SAMOD is based on the iterative process where each stage has to follow all the steps of ontology development, the current model presents the final ontology of each step. This helps to build the ontology considering its reusability.
- Modelet: It represents stand-alone model of any particular domain. It does not include entity and their relationship that has been used in other modelet. Therefore, each modelet is independent on its own ontological construction which enhances the possibility of reusability.
- Test case: It examines independently every single stages of entire iterative process of ontology development and evaluation. There a Bag of Test Cases, known as BoT, consisted with model, data and query test. Every test has two mandatory components – formal and rhetorical. Formal requirement emphasizes on internal consistency of each unit tests and rhetorical requirement focuses on whether the external elements are well considered in the formation of internal construction of the ontology development. This is how internal and external environments interacts throughout the process of each tests.
  - Model test: It aims to check the clarity and validity of each sub-model as well as the entire model with their motivation scenarios and competency question.

— Data test: It ensures the data consistency between TBox entities and ABox instances.
— Query test: It uses SPARQL to test the functionality of the ontology construction through using query techniques in the RDF library based data sets.

# 11 An evaluative survey on existing perspectives and methodologies

The evaluation of perspectives and methodologies of legal ontology has been done in many different ways. There is no certain standard for assessing such perspectives and methodologies. Generally undertaking such evaluation is also purpose driven. However, this section is dedicated to evaluate above mentioned perspectives and methodologies considering certain sets of criteria discussed in section 8 – explicit and implicit knowledge acquisition, epistemological adequacy, operationality and reusability.

## 11.1 Evaluation of perspectives

### 11.1.1 Explicit and implicit knowledge acquisition

All perspectives discussed in the section 9 do not directly talk about the explicit and implicit knowledge acquisition. However, each of these perspectives in principle investigates its content on the basis of explicit conceptual dependency that exists between different legislative documents. One of the fundamental reasons of not going beyond the explicit legal knowledge acquisition is that law itself is static in nature and hence the formal expression of law is depended on the legislative text but not on the interpretative capability of who attempts to articulate it. *Table 3* shows different positions of legal knowledge acquisition of different perspectives of legal ontology development -

**Table 3.** Knowledge acquisition approach and different perspectives of legal ontology

| *Perspectives* | *Explicit knowledge acquisition* | *Implicit knowledge acquisition* |
|---|---|---|
| Cognitive science | Knowledge acquisition process is based on common sense where explicit and implicit knowledge of the document do not play direct role. | |
| Legal theory | Explicit legislative text represents the implicitness of the reality. | The role of implicit legal knowledge is vital but directly linked with domain or core ontology. |
| Multi-layer legal information | Legislative textual explicitness of different legislation documents establish complete legal under- | Implicitness of legal knowledge helps to link the explicitness of conceptual rela- |

| | | |
|---|---|---|
| | standing. | tionships that exist between different legislative documents. |
| Linguistic | Valid expression of legal text is based on its explicit linguistic nature. | Does not influence the explicit linguistic meaning of the legal text. |
| Legal documentation | Explicit legal textual dependency also lies between different legislative documents and depends on the nature of legal documents. | Implicitness of legal knowledge also helps to establish the connections between different legislative documents as well as within the same content of any single piece of legislation. |
| Computational | As law is static and its expressivity is limited by its textual natures and scope, explicit legal knowledge is flowing bloodline of the computational law. | The implicitness of the legal knowledge is very wide as everything is related with everything. Hence handing computable law based on implicit nature of legal knowledge might increase legal complexity and inconsistency. |
| Legal service science | Legal services are embedded in the explicit nature of legislative text. | It plays a vital role in order to connect different explicit legal services coming from different legislative documents. |
| Legal knowledge management | Explicit legal knowledge governs the domain and core legal ontology. | Interpretative roles of the explicit legal concepts is crucial to understand the entire nature of legal reasoning. It also expresses the foundational ontology for legal reasoning. |

### 11.1.2 Epistemological adequacy

Each of legal ontological perspectives more or less concern about various components of the epistemological adequacy such as clarity, intuitiveness, relevance, completeness and discriminative power. Few perspectives are more focus on clarity and relevance than others. Nevertheless two inherent characteristics of law make the epistemological adequacy of legal knowledge a challenging work during the legal ontological construction stage. Firstly inherently the textual body of law carries a level of cognitive ambiguity and complexity, and secondly the meaning of the static legislative texts always is depended on the way of how and for what legal text has been interpreted. However, *Table 4* shows the position of each of the legal ontological perspectives, discussed in section 9, on different components of epistemological adequacy, discussed in section 8.2.

**Table 4.** Epistemological adequacy and different perspectives of legal ontology

| *perspective* | *Clarity* | *Intuitiveness* | *Relevance* | *Completeness* | *Discriminative power* |
|---|---|---|---|---|---|
| Cognitive science | √ | √ | √ | × | √ |
| Legal theory | √ | √ | √ | √ | √ |
| Multi-layer legal information | √ | √ | √ | √ | √ |
| Linguistic | √ | √ | √ | × | √ |
| Legal documentation | √ | √ | √ | √ | √ |
| Computational | √ | √ | √ | √ | √ |
| Legal service science | √ | √ | √ | √ | √ |
| Legal knowledge management | √ | √ | √ | √ | √ |

In the case of multi-layer legal information and legal documentation perspectives, they emphasis epistemological adequacy on the basis of explicit legislative texture, while legal service science, legal knowledge management and computational perspectives also concern the implicit legal knowledge embedded into the explicit legal texture.

### 11.1.3 Operationality

From the legal ontological perspectives, one of the hardest components of legal ontology is its operationality mainly for two reasons. First it does not solely depend on implementation mechanisms of legal rules embedded with legal terms, concepts and jurisdictions; rather it depends on the technological capabilities of executing the legal tasks and methods that are given to it. Secondly, once there are technological interventions for legal operations, the further challenges rises with the nature and scope of the technology used for such legal operations. Most of the legal ontological perspectives have been discussed in the section 9 do not have any clear positions over the various operationalities of legal ontology, see the summary in *Table 5* -

**Table 5.** Approaches of operationality and different perspectives of legal ontology

| ***Perspectives*** | ***Encoding bias*** | ***Coherence*** | ***Computationality*** |
|---|---|---|---|
| Cognitive science | × | × | × |
| Legal theory | × | × | × |
| Multi-layer legal information | √ | √ | √ |
| Linguistic | × | × | × |
| Legal documentation | √ | √ | √ |
| Computational | √ | √ | √ |
| Legal service science | × | × | × |
| Legal knowledge management | × | √ | √ |

### 11.1.4 Reusability

Reusability of legal ontology is a must criteria to have. Generally different perspectives of legal ontology do not concern about the reusability except the multi-layer legal information and legal documentation perspective. The latter perspective particularly focuses about the reusability of legislative document partially and/or as a whole. However, they do not directly concern about the task, method and domain reusability. Table 6 shows different position of various perspectives on two basic types of reusability.

**Table 6.** Reusability and different perspectives of legal ontology

| ***Perspective*** | ***Task and method reusability*** | ***Domain reusability*** |
|---|---|---|
| Cognitive science | × | × |
| Legal theory | × | × |
| Multi-layer legal information | √ | √ |
| Linguistic | × | × |
| Legal documentation | √ | √ |
| Computational | × | √ |
| Legal service science | × | |
| Legal knowledge management | × | √ |

### 11.2 Evaluation of methodologies

All methodologies of legal ontologies that have been discussed in section 10 have their pros and cons and have their own positions on each of the criteria discussed in section 8, please see *Table 7*. Even though current state of art of legal ontology con

**Table 7.** Different methodologies for legal ontology and their positions on the criteria of ontology construction of legal definitions & their nexus

| ***Methodologies*** | ***Knowledge acquisition*** | ***Epistemological adequacy*** | ***Operationality*** | ***Reusability*** |
|---|---|---|---|---|
| Hafner's semantic network of legal concepts | Based on defining concepts and links with the atomic structure of their corresponding semantic knowledge. | There are six types of semantic links in LRS such as set/member, constituent, super and sub class, attribute, role and event-condition links. Among these links, role and even-condition links express most complex semantic networks of the legal knowledge. This can be used for giving meaning of the words, sentences as well as subject-matters of the legal knowledge. | It does not have any encoding bias and coherence checking methodology. | As collection of nodes and their associated links are used to build complex semantic network of legal knowledge, each individual nodes can be reused. But the reusability criteria was not objective of the LRS. |
| Language for legal discourse | The principle component of the LLD consists with atomic formula, rules and proofs, and usages of different modalities. The atomic formula in LLD is featured by reified relationships, sorts and subsorts and count and mass terms. | There are two sides of the rule represented in the LLD. They are – (a) the left-hand side, which carries the conjunction of atomic formulas based on Horn clause, and (b) the right-hand side, which contains the compound expression in either the form of negation or embedded implication or default expression that includes both default rules and proofs. That proves that LLD is based on intuitionistic semantic, not classical. | It is based on internal and surface syntaxes with different functionalities. Internal syntax is used by the proof mechanism and surface syntax is used to manage communication with external users. In LLD, every atomic relationship is either constant or variable, which is considered as reified relationship. | They do not have maintain any reusability criteria. |
| NORMA | An agent is considered the central focus of the reality which can regulate and changes the world by acquir- | Legal knowledge is characteristic by such some features that are invariant over some time, for example all legislation has its starting and ending time. And most importantly these characters are | They do not use any mechanisms for decreasing encoding bias, increasing coherence and computationability. | Reusability criteria is absent. |

| | | | | |
|---|---|---|---|---|
| | ing knowledge and applying them accordingly. | evident in the behaviors of entity. | | |
| CABAL A semantic network | The semantic network of it contains legal terms and concepts represented as the nodes in the network. | Epistemological adequacy is not considered in this model. Because it is intended to provide following four features – defining search strategy, construction of queries, managing dialogues with external users, and navigating semantic network. | It's operationality is based on three independent functional parts, but they communicate among each other through messages - query generator, data base query manager, and data bases. However, it does not have any functionality to handle coding bias, coherence and advanced computationability. | It does not have any reusability strategy. |
| Frame-based ontology of law | In FBO, legal ontology categorizes legal knowledge into three separate entities. They are norms, acts and concepts. | It has developed seven elements of the concept through which it checks conceptual epistemological adequacy. These seven elements are - (a) the description of the concept, (b) type of the concept, (c) the priority status of the concept, (d) the source of the concept, (e) the scope of the concept, (f) the applicability condition of the concept, and (g) the instances of the concept. | Absence of criteria for encoding biasness, operationability and reusability. | |
| Functional ontology of law | It is consisted with six branches of knowledge – normative, world, responsibility, reactive, meta-legal and creative knowledge. | It does not maintain any criteria for epistemological adequacy, operationability as well as reusability. | | |
| Dynamic interconnected system for developing ontology | The model has three components – state of affairs which is constituted by possible explanation of the physical and abstract world, events which can affect and reinforces the state of affairs, | In order to have epistemological adequacy, it compartmentalizes its three components into subcomponents. For example, there are three types of modalities of state of affairs. They are – anankastic, deontic and probabilistic. Each of these deals with different parameters. This is how it ensures the lack of inconsistencies within the system. | It does not propose any criteria for its operationability and reusability. | |

| | | | |
|---|---|---|---|
| of law | and rules which establish two types relationship between states of affairs – causation and constitution. | | |
| CLIME ontology | In CLIME, knowledge acquisition technique has two stages. The first is the conceptual retrieval stage where legal concepts and their relations are defined. It does not allow external knowledge representation. The second is the normative assessment stage where the content of the first stage is evaluated. | In order to build relationships between legal terms and concepts, it used labeled and graph data techniques using an inexpressive language. It does not permit the relations as term-nodes, rather the terms are connected with the legal documents by using text element. That also helps the knowledge base in order to define the relations from legal point of view. There are two key knowledge presentation primitives have used. They are – subsumption, when a term applies to any instance to which the other terms also apply, and disjointness, when two terms cannot be applied to the same instance. However, it does not ensure the epistemological adequacy within the system. | Absence of operationability and reusability criteria. |
| Mommers's knowledge based ontology for law | There are two types of entities – legally relevant entities and legal entities. Legally relevant entities are further constituted by seven types of entities. They are - sentences, statements, propositions, beliefs, artifacts, | Epistemic role uses count-as relation in order to apply it on any object. For example, reason can be count as a statement. Epistemic roles for legally relevant entities are – reasons, defeaters, factual knowledge as well as practical knowledge. Legal reasons, legal defeaters, factual legal knowledge and practical legal knowledge – are the epistemic roles for legal entities. Interdependencies are ex- | No operationability and reusability criteria. |

| | | | | |
|---|---|---|---|---|
| | rules and concepts. There are eight types of legal entities such as legal principles, legal norms, legal decisions, legal systematization, judicial interpretation, judicial classifications, legal rules and legal concepts. The entities are characterized by the ontological status layer. Existence, constitution and recognition – are the ontological status for legally relevant entities. Legal efficacy, legal validity, legal constitution and legal recognition – are the ontological status of legal entities. | pressed by relations. It might involve with consequences and imposition of new roles and phenomena. It may appear in three forms – causation, counting as, and recognition. | | |
| LRI-Core legal ontology | It is consisted with five major categories of the world – physical concept, mental concept, abstract concept, roles, and terms for occurrences. | In order to maintain epistemological adequacy it has three ontological layers - foundational or upper ontology, legal core ontology and legal domain ontology. The upper ontology in LRI-Core does not contain all foundational legal concepts, rather it contain around 300 concepts that have legal significance over the legal core ontology. | It is developed in OWL-DL and it has been actively increasing its conceptual contents in order to reduce the inconsistencies and encoding biasness. | It reused many concepts from DOLCE. And as it has separate layers of ontology, it is easy to reuse. |
| Jur-IWN | All of concept of domain ontology of Jur-IWN is categorized as agents, roles and | Jur-IWN proposes that legal concept is constituted by legal roles, events, parameters and their interrelationships with a setting of legal concept deter- | Less encoding biasness as it imputed many concepts and relationships from DOLCE. | It is based on DOLCE foundational ontology and it considered legal domain |

| | | | | |
|---|---|---|---|---|
| | mental objects. | mined by a legal case. This perspective enables the system to build and process a functional demonstration of law. This is the way it attempts to checks its epistemological adequacy. | | as a representation of systems of rules that express the standard version of social behavior. |
| Lame's ontology of French law | It is based on two steps – (a) explicit knowledge acquisition directly from the legislative texts where legal terms and concepts are explicitly given, and (b) implicit knowledge acquisition that is not given in the legislative texts but it is required in order to support explicit knowledge. This approach is entirely based on normative legislative texts and useful for legal documentation purposes. | Explicit knowledge acquisition aims to develop the terminological knowledge base. It first extracts legal terms and concepts from the legislative documents and then establishes lexical relationships between those concepts and terms. Implicit knowledge acquisition aims to figure out the supporting knowledge, those are not explicit in the legislative documents, for the explicit legal terms and concept. | No operationability and reusability criteria. | |
| LKIF | It is based on three frameworks – situational, mereological and epistemological. In LKIF, there are also a collection of ontology modules, where each module represents a set of independent concepts such as expression, norm, process, action, | The methodology of LKIF is mixed with Hayes's notion of metaphysical top-down construction, Gruber's notion of knowledge acquisition from naive physics and cognitive science, and Schreiber's CommonKADS approach. This combined methodology has been used in the process of identifying scopes and purposes, capturing and coding ontology, integrating existing ontologies and evaluating. It guides the notion and role of infer- | Less encoding biasness, consistency is checked through building relationships among different ontological layers. | Even though it is founded on common sense based legal terms, it will be easy to reuse it. |

| | | | | |
|---|---|---|---|---|
| | role, place, time and mereology. | ence in the legal reasoning process. Such type of examples can be found in problem solving methods, which is subdivided into three stages – hypotheses formation, identification of constraints, and explain the empirical data in order to solve. Each of these stages transfers their inherent attributes and characteristics to other stages through inference processes. | | |
| SAMOD | There are two types of experts involved in the formalization process of ontology development – (a) domain experts who supply technical knowledge, clarity and normative validity in language or tools, and (b) there are two groups of ontology engineers. First group develops the ontology in the way domain experts guides them, and second group text the consistency between TBox and ABox entities and instances respectively. | It has six methodological stages – motivating scenario, informal competency question, glossary of terms and concepts, current model, modelet and test cases. Each of these stages is hieratical and followed by an iterative process. This is the way it provides its framework for epistemological adequacy. However, SAMOD is designed for constructing legal ontology and therefore, it lacks approaches for legal epistemology. | It examines independently every single stages of entire iterative process of ontology development and evaluation. There a Bag of Test Cases, known as BoT, consisted with model, data and query test. Every test has two mandatory components – formal and rhetorical. Formal requirement emphasizes on internal consistency of each unit tests and rhetorical requirement focuses on whether the external elements are well considered in the formation of internal construction of the ontology development. This is how internal and external environments interacts throughout the process of each tests. Model test aims to check the clarity and validity of each sub-model as well as the entire model with their motivation scenarios and competency question. Data test ensures the data consistency between TBox entities and ABox instances. Query test uses SPARQL to test the functionality of the ontology construction through using query techniques in the RDF library based data sets. | As it is based on an iterative process and engineered in step-by-step. It is easy for reusability. |

-siderers them as methodology, they can be suitably addressed as perspectives for engineering legal ontology. For example, Functional Ontology of Law (FOL) can be considered as perspective rather an methodology for an ontology.

## 12 Analytical Findings

None of these perspectives and methodologies fully supports all the criteria developed for engineering ontology for legal definitions and their nexus, discussed in section 8, see *Table 8 and 9*. Therefore, a mixed perspective as well as methodology is required with further amendments.

**Table 8.** Which perspective fits for legal ontology for nexus as discussed in section 8.

| *Perspectives* | *Knowledge acquisition* | *Epistemological adequacy* | *Operationability* | *Reusability* |
|---|---|---|---|---|
| Cognitive science | × | × | × | × |
| Legal theory | × | × | × | × |
| Multi-layer legal information | √ | √ | √ | √ |
| Linguistic | × | × | × | × |
| Legal documentation | √ | √ | √ | √ |
| Computational | × | × | × | × |
| Legal service science | × | × | × | × |
| Legal knowledge management | × | × | × | × |

In the case of legal ontology perspective, on the one hand, multi-layer legal information and legal documentation perspective support all criteria – knowledge acquisition, epistemological adequacy, operationality and reusability. On the other, as this doctoral project is intended for engineering ontology of legal definitions and their nexus, these two perspectives is the most convenient.

**Table 9.** Which methodology of legal ontology fulfills criteria discussed in section 8.

| *Methodologies* | *Knowledge acquisition* | *Epistemological adequacy* | *Operationality* | *Reusability* |
|---|---|---|---|---|
| Hafner's semantic network of legal concepts | × | × | × | × |
| Language for legal discourse | × | × | × | × |
| NORMA | × | × | × | × |
| CABALA semantic network | × | × | × | × |
| Frame-based ontology of | × | × | × | × |

| | | | | |
|---|---|---|---|---|
| law | | | | |
| Functional ontology of law | × | × | × | × |
| Dynamic interconnected system for developing ontology of law | × | × | × | × |
| CLIME ontology | × | × | × | × |
| Mommers's knowledge based ontology for law | × | × | × | × |
| LRI-Core legal ontology | × | × | × | × |
| Jur-IWN | × | × | × | × |
| European VAT regulatory ontology | × | × | × | × |
| Lame's ontology of French law | √ | × | × | × |
| LKIF | × | × | × | × |
| SAMOD | × | × | √ | √ |

In the case of methodology, considering Table 9, none of existing methodologies is appropriate for legal ontology for nexus. Therefore chapter 3 proposes a new methodology for knowledge acquisitions and construction of legal ontology for nexus.

# Chapter 3

## Methodology for Legal Ontology for Nexus: Water, Energy and Food in EU Regulations

*Addressing the interconnected systems involving food, water and energy is critical to achieving solutions to one of the most pressing issues facing our planet.*

- The Water, Energy and Food Security Resource Platform, Federal Government of Germany, 2015.

……*Megatrend 4: Growing Food, Water, and Energy Nexus*

*Demand for food, water, and energy will grow by approximately 35, 40, and 50 percent respectively owing to an increase in the global population and the consumption patterns of an expanding middle class. Climate change will worsen the outlook for the availability of these critical resources. Climate change analysis suggests that the severity of existing weather patterns will intensify, with wet areas getting wetter and dry and arid areas becoming more so. Much of the decline in precipitation will occur in the Middle East and northern Africa as well as western Central Asia, southern Europe, southern Africa, and the US Southwest.……*

- National Intelligence Council, US. Global trends 2030: alternative worlds, pp 5, 2012.

## 13 Overview of the Methodologies for Legal Ontology for Nexus

Concerning domain based ontology for water, energy and food sectors; there are a lot of computational ontologies mainly with following characteristics –

- Isolated concepts and their definitions based on non-legal expert's categorizations that do not have any relation with legal sources.
- Not in collaboration with standard based legal documentation, e.g. Akoma Ntoso.
- No association of concepts' designs, classifications, and enrichments mechanisms with legislative texts and/or legal definitions, rather based on non-legal expert's opinions and research oriented, but non-legal, parameters and indicators.

However, each of these ontologies has their own conceptual strengths and semantic capabilities. For example, they have industrial or engineering scope (e.g. Infrastructure Product Based Ontology - SESAME-S[155]), or geospatial objectives (Surface-

[155] See Schwanzer M, Kojic Veljovic M, Stefanovic M (2011) Semantics for Energy Efficiency in Smart Home Environments - Tomic, Fensel

Water-Model-Ontology), or water based ontology (e.g. CUAHSI, SWEET, SSN, WaterMLL, HY-FEATURES), they are not integrated with the correspondent legal concepts (e.g. AGROVOC) etc. The Table 1 shows a brief summary of existing major ontologies and their relationships with legal contents and standard based legal documentations. Therefore, the methodologies have been used by these ontology engineers are not appropriate for modeling legal ontology for nexus. As a result, from the legal nexus perspective, it requires designing a methodology in such a way that can allow legal ontology engineers to extract all concepts, sub-concepts and their corresponding properties and restrictions from relevant EU water, energy and food regulations. So that the legal ontology will ensure its' association with relevant legal definitions and its' collaboration with standard based legal documentations for facilitating legal reasoning for nexus.

**Table 1.** Relations between existing ontologies and legal contents (e.g. legal definition and/or documentation)

| ***Name of ontology*** | ***Main subject-matters*** | ***Association with legal definition*** | ***Collaboration with standard based legal documentation*** |
|---|---|---|---|
| AGROVOC [252] | 40000 concepts[156] | No | No |
| SESAME-S[157] [253] | Energy efficiency | No | No |
| CUAHSI[158][254] | 6500 concepts | No | No |
| SSN[159] [255] | 41 concepts and 39 properties. | No | No |
| SWEET[160] [256] | 6000 concepts divided into 200 ontologies. | No | No |
| Towntology and hydrology [257] | 150 concepts, 34 relations, 66 attributes, and 256 | No | No |

[156] On food, nutrition, agriculture, fishery, forestry and environment

[157] (Semantic SmArt MEtering – Services for energy efficient) on on energy concepts related with energy efficiency variables.

[158] Hydrologic Ontology for Discovery developed in CUAHSI framework on hydrological variables.

[159] Semantic Sensor Net on marine concepts.

[160] Semantic Web for Earth and Environmental Terminology on Earth science and their various components.

| | | | |
|---|---|---|---|
| | axioms relating with city planning. | | |
| WatERP[161] | 600 terms | No | No |

Under these above mentioned considerations, this chapter, first, evaluates existing major water, energy, food related ontologies and their methodologies from legal nexus perspective. Then it presents the methodology that has been used for modeling legal ontology for nexus using three phases of ontology development tasks – (a) pre-ontology development tasks – consists with three major responsibilities – i) taxonomy development from the respective legislative texts, ii) designing concepts' definition from legal sources, and iii) concept enrichments using various mechanisms, (b) throughout-ontology development tasks – mainly concerns with modeling ontology using protégé 5 ontology editor, and (c) post-ontology development tasks – evaluating ontology using five reasoners - FaCT++, HermiT 1.3.8.3, Pellet, Snorocket, Jcel.

## 14 Existing major ontology and methodology in water, energy and food domains

First of all, even though there is a lack of legal ontology for nexus, there are many domain oriented ontologies designed for performing particular semantic tasks. Therefore, in this section, seven existing major ontologies and methodologies related with water, energy and food domains are discussed. They are AGROVOC ontology from food domain, SESAME-S ontology from energy domain, and CUAHSI, WatERP, Twontology and Hydrology ontology from water domain, SSN and SWEET ontologies from environment domains. Some of these ontologies are designed and created by leading institutions like the OGC, National Aeronautics and Space Administration (NASA) or World Wide Web Consortium (W3C) or European Union funded project. Even though these ontologies are not designed for modeling nexus, they are widely used and mapped or imported in other ontologies by a good number of knowledge engineers and scientists in order to standardize the definitions of all used concepts. Water ontologies developed by Consortium of Universities for the Advancement of Hydrologic Science (CUAHSI)[162] and Towntology & hydrOntology designed by renowned figures like Vilches-Blázquez, Bernabé Poveda, Suárez-Figueroa, & Rodríquez Pascual also have been examined in this section. It is noteworthy to mention that core scientific ontological models of water, energy and food domains are avoided to be evaluated as the objective for modeling legal ontology for nexus is to develop ontology for representing legal definitions of water, energy and food extracted from respective legislative texts. Four following aspects are considered in order to evaluate these ontologies -

[161] "WatERP presents a new concept to exchange supply and consumption knowledge across the entire water supply distribution chain. See http://www.waterp-fp7.eu/

[162] Open Geospatial Consortium Inc., 2010

- *Organizational aspect* – that describes the organization/s that were involved for developing such ontology and their purposes.
- *Conceptual foundational aspect* - that evaluates non-legal or legal sources of concepts' definitions and their categorizations used in these ontologies.
- *Technical and methodological aspect* – that describes ontology implementation languages, used description logics and their sizes of total number of used terms, properties logical and axioms etc.
- *Legal nexus aspect* - In addition, the evaluation also includes major benefits and weaknesses of each ontology from legal nexus point of view.

Furthermore, a strong emphasis has been drawn over the conceptual foundation of all above mentioned ontologies. Because one of the primary sources of terms, properties and their legal restrictions or axioms in the legal ontology for nexus is legislative texts. However, the summary of evaluation is shown in Table 1.

## 14.1 CUAHSI Ontology

**Organizational aspect.** A university consortium, with more than 100 U.S. universities and water-related international organizations, supported by the National Science foundation developed the Hydrologic Ontology for Discovery. CUAHSI's mission to enable the water science community for formulating advanced understanding of the central role of water in not only energy and food domains rather with the respect of society, life and earth. The main purpose of this ontology is based on idea of time-series data discovery[163] at any fixed point and scales using physical, chemical and biological measurements.

**Conceptual foundation aspect.** As the ontology was designed for time-series data discovery, it used and adopted a keyword structure that helps organizing parameter based data variables along with thematic categorizations from general concepts to greater concepts. These keywords are hierarchically arranged and linked in a 'leaf concept' as the ODM controlled taxonomy[164]. These linkages help data publishers in order to avoid complexity of tagging variables. All the concepts are stored in a database that has four primary tables named as – Tabular Ontology[165], Ontology, Hierarchy, and synonyms. Furthermore, CUAHSI has developed this ontology as to compile a national catalogue for water formation by incorporating information from heterogeneous and disparate water databases. Therefore, CUAHSI used this ontology in order to standardize concepts and keywords that can be used in these diverse databases.

[163] See Weigend A. S., Gershenfeld N. A. (Eds.) (1994), Time Series Prediction: Forecasting the Future and Understanding the Past. Proceedings of the NATO Advanced Research Workshop on Comparative Time Series Analysis (Santa Fe, May 1992), Addison-Wesley.
[164] See for detail at http://his.cuahsi.org/mastercvreg.html
[165] A detail description is given in A. Pivk. (2005) Automatic Generation of Ontologies from Web Tabular Structures. PhD Thesis (in Slovene), University of Maribor, Slovenia.

**Technical and methodological aspect.** This ontology is consisted with 6500 concepts implemented in multi-files of Ontology Web Language followed by description logic family designed for OWL full by World Wide Web Consortium (W3C). The ontology is sub-divided into following three layers –

- Navigation – the most general or top layer provides 'HydroSphere' concepts that includes different conceptual elements of location of the resources such as land, ground water etc. It also provides all related concepts with water and soil quality.
- Compound – layer focuses on nature of the resources consisted with physical and biological parameters of water.
- Core/Leaf – layer consists with end concepts of any branch in this ontology.

The higher level of the ontology is not searchable as the result would be too large due to their huge number of chemical and biological properties. In contrast, lover level of ontology is searchable as the lower concepts will show only related child concepts. The most central technical problem in water information sharing is interoperability. From this point of view, this ontology is intended to solve interoperability problems in the national water networks. More precisely, in order to solve water information interoperability problem, the time-series is served on WaterML (Water Markup Language)[166] which provides necessary water information exchange schemas. Furthermore, WaterML2, used in the WatERP ontology, is current standard for water information interoperability.

**Legal nexus aspect.** Even though CUAHSI ontology used hydrological aspects of water information cycle, it does not relate water concepts with food and/or energy concepts. This ontology does not define any properties and based on parent-child relationships. Therefore it has low expressiveness with no concepts enrichment mechanisms. As a result, no knowledge of water information can be inferred. In addition, in the ontology, there are no disjoint-classes which can be a source of inconsistency while an instance will be used in association with two different classes. In the case of conceptual foundation, it does not use any legislative texts.

### 14.2 AGROVOC ontology

**Organizational aspect.** AGROVOC, also known as a portmanteau of agriculture and vocabulary, is a collection of over 40000 terms in 23 languages concerning the interested areas of Food and Agriculture Organization of the United Nation (FAO). It was first published in 1980s as a controlled vocabulary in the field of agricultural science and technology. Then in 1990s all vocabulary transferred into a digital data store by a relational database and since 2003 it become available in OWL format in order to provide semantic and lexical relationships among the terms in more refined and pre-

[166] All versions of WaterML is available at http://his.cuahsi.org/wofws.html

cise way. The objective behind it is to create a multilingual repository of concepts[167] in order to be considered as Concept Server (CS) in the agricultural domain for facilitating three important features – (a) to construct domain specific ontologies, (b) export contemporary and traditional thesauri, and (c) to form knowledge organization systems (KOS). More progressively, it became an SKOS[168] resource in 2009.

**Conceptual foundation aspect.** In order to convert AGROVOC vocabulary into ontology, FAO took following conceptual foundation measures –

- Minimized biasness of a concept, which generally originates from a particular language, by giving an independent meaning of a concept regardless its origin and inherent influences that coming from its origin language.
- Captured lexical relationships of a concept like lexical equivalence such as translations and/or synonyms etc in a domain model with accurate measure.
- Consisted with following three levels of representation – (a) concepts that express the abstract meaning, e.g. the immaterial meaning of 'rice' in a particular perspective, (b) terms that expresses language-specific lexical forms, e.g. 'Rice', 'Paddy', 'Arroz' etc, and (c) term variants that expresses categorizations of each term under its unique identity principles. However, construction of the actual hierarchy and semantic structure is based on the abstract concepts where term and term variants is encapsulated. Therefore, even though terms alone are not present in the hierarchy, they express separate entity linked with the concepts or other terms and term variants.

**Technical and methodological aspect.** The Web Ontology Language (OWL) is used as the main technological platform for building the Concept Server ontology for following reasons – (a) OWL as a standardized ontology language provides maximal interoperability with other ontological systems, (b) the OWL file is already interoperable with any RDF triple-store, which provides easy integration structure with other sources of RDF/XML based data and allows optimizations in the data-processing and visualization, (c) OWL is enable to draw equivalences between classes and individuals from heterogeneous terminologies, (d) OWL can easily performs inference consistency checks on linked ontologies, which might help in order to identify and resolve conflicts among ontologies, (e) automated logic based reasoning can be used in order to arrive to conclusions beyond the prescribed and/or asserted relationships and restrictions hold in the ontology. There are three concepts at the top level in CS – 'category', 'classification scheme' and 'lexicalization'. The concepts in the 'category' level subsume the domain concept as every domain concept also potentially represent

[167] See P. Vossen, editor. EuroWordNet: A Multilingual Database with Lexical Semantic Networks . Kluwer Academic Publishers, 1998.

[168] SKOS is an area of work developing specifications and standards to support the use of knowledge organization systems (KOS) such as thesauri, classification schemes, subject heading lists and taxonomies within the framework of the Semantic Web, see http://www.w3.org/2004/02/skos/

as a category. However, the domain concepts are the root of all domain concepts in the Concept Server as they construct the core hierarchical structure of the server. The concept lexicalization subsumes all lexical information.

**Legal nexus aspect.** Even though AGROVOC ontology carries a number of concepts, terms and term variants those are related with water, energy, food domains, but it lacks, Like CUAHSI ontology, following capabilities in order to be used in the purposes of legal ontology for nexus – (a), the sources of all concepts and terms are mainly non-legal sources e.g. lexical relationship or language etc, (b) lack of defining property and their role of restrictions over the concepts and terms, that makes impossible to apply legal restriction over the terms that exist in the law.

### 14.3 Semantic Sensor Net (SSN) ontology

**Organizational aspect.** The Network Incubator Group[169], a group of W3C, has developed SSN ontology. The main task of this group is to explore emerging activities in the web-related concepts and activities. The main purpose of this ontology is three-fold – (a) conceptual descriptions of properties and capabilities of sensors, (b) linking of those descriptions with the act of sensing, and (c) to initiate results from this observational processes as outcomes.

**Conceptual foundational aspect.** The SSN ontology follows the descriptions of a family of concepts regardless their expressivity as it is a pattern based ontology for describing sensor's behaviors and information. All the conceptual expressions of this family concept are integrated into following modules –

- 'Device' and 'System' module – represent concepts and properties related with process of sensing and their physical properties.
- 'Process' and 'Operating Restriction' module – are consisted with the concepts and properties that express more detail of sensor processing. It also represents restrictions over each concepts play a role with in the sensor processing tasks.
- 'Data' module – are built with those concepts and properties that describes observations values.
- 'Measuring Capability' and 'Constraint Block' – these module is based on those concepts and properties that have the relationship with measurement capabilities.

Each family-concept of these modules is inter-connected in order to express the conditions needed to be considered for all observation and processes. SSN ontology indirectly aims to minimize the gaps in semantic sensor web by data provenance through directing definitions of metrological definitions, methods and measures.

[169] The aim of this group is to begin the formal process of producing ontologies that define the capabilities of sensors and sensor networks, and to develop semantic annotations of a key language used by services based sensor networks, see http://www.w3.org/2005/Incubator/ssn/

**Technical and methodological aspect.** This ontology is also developed in OWL2 language and divided in 10 modules with 41 concepts and 39 properties. It has been constructed over a central node system known as 'Stimulus-Sensor-Observation (SSO)' pattern. It also provides semantic linkages with Linked Open Data Cloud (LODC)[170], Marine Metadata Interoperability (MMI)[171] and other standard ontology such as DUL[172], SKOS thesaurus etc. The purpose of these semantic and ontological linkages is to model data discovery mechanism and improve mutual abstraction and perception. These all semantic links are used in Sensor Markup Language (SensorML)[173] in order to define exchange information format with Observation and Measurement Service (OGC)[174]. This ontology, additionally, provides automated related concepts and axioms capture mechanisms. This indicates that when it performs ontology specifications, it also simultaneously performs executing restrictions over the observations values, properties etc.

**Legal nexus aspect.** On one hand, even though SSN ontology has been developed in order to work with Open Geospatial Consortium[175], it did not customize the metrological aspects of water, energy and food nexus. On the other hand, measurement entities are based on standard sensors' measurement system and values but not linked with the organization, such as the term 'Authority'. Therefore, measurement performed over water quality might show a certain type of parameter based result but will not show who performs it. However each definition of these measurements concepts are not linked with connected legal definition. Therefore, entire ontology is isolated from the legal analyses and legal semantic linkages with appropriate legislative texts, rules and norms.

### 14.4 SESAME-S ontology

**Organizational aspect.** SESAME-S stands for Services for Semantic Smart Metering implemented by a group of European institutes – Telecommunication Research Cen-

---

[170] An interesting diagram is given as a part of LODC's work at http://lod-cloud.net/

[171] Is to support collaborative research in the marine science domain, by simplifying the incredibly complex world of metadata into specific, straightforward guidance. See https://marinemetadata.org/

[172] Is to provide a set of upper level concepts that can be the basis for easier interoperability among many middle and lower level ontologies.see http://ontologydesignpatterns.org/ont/dul/DUL.owl

[173] Is to provide a robust and semantically-tied means of defining processes and processing components associated with the measurement and post-measurement transformation of observations, see http://www.opengeospatial.org/standards/sensorml

[174] See S J D Cox (2015). "Ontology for observations and sampling features, with alignments to existing models". Semantic Web Journal. in review. pp. 1–18. Retrieved 2015-07-20.

[175] The OGC (Open Geospatial Consortium) is an international not for profit organization committed to making quality open standards for the global geospatial community. These standards are made through a consensus process and are freely available for anyone to use to improve sharing of the world's geospatial data, see http://www.opengeospatial.org/

ter Vienna, Austria; E-Smart Systems d.o.o, Serbia; eSYS informationssysteme GmbH, Austria; Experimental Factory of Scientific Engineering, Russia; Semantic Web Company GmbH, Austria; and Upper Austria University of Applied Sciences, Campus Hagenberg, Austria. The core aim of this ontology was to make end-consumers enable to make well-informed decisions about their energy consumption.

**Conceptual foundation aspect.** This ontological solution covers concepts and their relationships of entire energy value chain domain. The source of initial concepts and their demonstrations are twofold – customer's expectations towards the commercial energy services and technological specifications of energy equipment. The extended version of this solution additionally provides concept definitions of consumer's privacy in the energy domain so that it can be used as semantic link data for analyzing B2C scenarios in the B2B[176] setting.

**Technical and methodological aspect.** SESAME-S solution came with three technological outcomes – (a) it designed a sensor and smart metering can be installed in the house where inhabitant lives, (b) that metering system is based on semantic software based on OWL standard through ontology in order to perform reasoning as well as controlling of energy consumption by defined restrictive ontology used inside the metering system, and (c) to establish interoperability between sensor's inputs and prescribed guidelines of the energy consumption pre-defined in the ontology.

**Legal nexus aspect.** This solution additionally contains sensor-enabled energy efficiency concepts in societal and ecological terms but not in the terms of nexus. All concepts and terms used in this solution taken from non-legal technical sources such as interviews with customers as well as technical specification of the energy equipment. There is even no ontological performance with legal compliance of energy consumption.

### 14.5 SWEET ontology

**Organizational aspect.** The SWEET ontology stands for the Semantic Web for Earth and Environmental Terminology developed by NASA's Jet Propulsion lab for Earth System Science[177]. The main objective of this ontology is to reducing prevailing gap in the semantic understanding of the Earth Science.

**Conceptual foundation aspect.** It provides a vast ranges of concepts from following eight top-level ontological categorizes in order to integrate semantic relationships among majority fields of Earth Science – (a) representation, (b) process, (c) phenom-

[176] See Shelly, Gary (2011). Systems analysis and design. Boston, MA: Course Technology, Cengage Learning. p. 10. ISBN 0-538-47443-2.
[177] See http://www.jpl.nasa.gov/earth/

ena, (d) realm, (e) state, (f) matter, (g) human activities, and (h) quantity. In contrast with other ontologies like CUAHSI or AGROVOC, the conceptual content structuring was based on inherent discipline based knowledge, not based on how domain knowledge is used. Therefore, this ontology is not based on the project's objective or goals rather it is general in nature and hence can be used for any other semantic integrations. It is also noteworthy to mention that hydrographic cycle is also defined as categorization of cycles in its top ontologies based on scientific knowledge.

**Technical and methodological aspect.** Like other ontologies discussed in the chapter, this ontology is implemented in OWL languages followed by family description logic. It is comprised with 6000 concepts in 200 insolated ontologies. Orthogonal design mechanism is used for modeling all ontologies that SWEET belongs, which gives benefits of quick retrieval of knowledge efficiently and ensures re-usability features of ontology. Due to its generality, technically SWEET ontology is more reusable. As all concepts and terms used in this ontology are populated with instances, which made this ontology heavy due to its high memory consumption. This ontology is not for handling sensor observations. Integration of marine data in this ontology enabled it to be used by other projects and association. For example, GEON6 (GEO Sciences Network)[178] used this ontology in order to enhance cyber infrastructure for incorporating 3 and 4 dimensional Earth Science Data.

**Legal nexus aspect.** The top level ontologies are ambiguous with their content and they are not related with terms and concepts of nexus. It also does not express any legal terms, extracted from the legislative texts such as environmental and climate change legislations, of Earth Science. Therefore, interoperability it ensures are very specific from the legal nexus point of view but general from knowledge accusation point of view as NASA focused on inherent nature of knowledge in order to develop this ontology. Even though International Research Institute for Climate and Society (IRICS)[179] used this ontology in order to understand, manage and anticipate rapid climate change impacts through analyzing real time data coming from satellite and other environmental technologies[180], what the important thing is missing in this ontology is to not have legal integration in the formation process of concepts, terms and instantiation.

### 14.6 WatERP ontology

**Organizational aspect.** WatERP ontology is an outcome of WatERP project developed by a group of European institutes – BDigital, INCLAM SA, Disy Infor-

[178] See http://www.geongrid.org/index.php/about/
[179] See http://iri.columbia.edu/
[180] Recent studies on environmental technologies are found in OECD Studies on Environmental Innovation Invention and Transfer of Environmental Technologies. OECD. September 2011. ISBN 978-92-64-11561-3.

mationssysteme GmbH, Catalan Water Agency, Staffodshire University, Institute of Communication and Computer Systems, Hydrometeorological Innovative Solution, Technologiezentrum Wasser, and Stadtwerke Karlsruhe GmbH, funded by 7th Framework program of the European Union. The aim of this project was to develop a web based Open Management Platform (OMP)[181] grounded with real time knowledge of water demand and supply in order to enable water distribution system in such a way so that it can be integrated and customized. The ontology is also intended to provide all inferred information about water supplies, flows and managements within the framework of OMP.

**Conceptual foundation aspect.** WatERP ontology is based on the idea of continuously expanding scenario and iterative ontology development process. All concepts, terms, expressions in the form of properties, restrictions and axioms are very generic from the water supply management field but incrementally tested in the pilot cases initiated by the WatERP project in following categories – (a) languages and variables used in water supply field, (b) time interval regarding decision making and data collection, (c) interconnected vocabularies over data schemes and systems, (d) defining concepts and terms used in the decision making process. Concepts enrichment techniques such as generating disjoint classes have been used in to order to construct clear inferences, separated and limited instantiation of some conflicting and/or similar entities. These disjoint classes also provide necessary knowledge division and categorization, which also indirectly help to remove inconsistencies.

**Technical and methodological aspect.** WatERP is implemented by using OWL 2 based protégé ontology editor containing 6oo terms from water field. In the first iteration phase of this ontology, it imported all water and environmental related concepts from CUAHSI ontolgy, discussed at section 14.1. Additionally, many concepts and terms have been incorporated from the WaterML2 schema. Furthermore, SSN ontology has been integrated in WatERP ontology in order to ensure reusability or mapping of existing relevant ontology as well as to integrate it more adequately with WaterML2.

**Legal nexus aspect.** Like SSN, CUAHSI and/or SWEET ontologies, WatERP ontology did not extract concepts from legislative texts and legal definitions. Even though there already exist legal framework for different types of water management such as ground water, waste water, bathing water, water for fish and/or mineral water[182] etc, none of them are used lightly in WatERP ontolgy. However, it also did not use any restriction over terms in order to make water and food nexus and/or water and energy nexus.

[181] One of such examples of OMP is IPMI (Intelligent platform management interface), see http://www.intel.com/content/www/us/en/servers/ipmi/ipmi-home.html

[182] One of such example is the Directive 2009/54/EC of the European Parliament and of the Council of 18 June 2009 on the exploitation and marketing of natural mineral waters.

## 14.7 Towntology and HydrOntology

**Organizational aspect.** Two linked ontologies – Towntology and HydrOntology developed by a semantic group of the Universidad Politecnica de Madrid. This group also developed other most used ontology development methodologies such as Methondology and NeoN etc. Even though this group is expert on ontology engineering on chemistry, science, e-commerce etc, they initiated and implemented this linked ontologies. Furthermore, particularly Towntology project is funded by COST9 (European Co-operation in the field of Scientific and Technical Research) under the category of urban civil engineering.

**Conceptual foundation aspect.** Concepts and terms of these ontologies are mainly focused on city planning and water infrastructures in urban regions. Primarily these ontologies were used by Civil Engineers for designing urban physical infrastructure. However as HydrOntology covers relatively more wider ranges of concepts, properties and their relationships over hydrographic domain than Towntology, it became an ontology for global uses. The entire series of concepts in HydrOntology is divided into three following categories –

- *Entity River basin* related concepts such as drainage area and/or feeding bed of a river etc.
- *Entity hydrographic phenomena* is consisted with the concepts and properties of how water structure is configured into a region, and
- *Entity morphology* contains those concepts help to describe the consequences when water undergoes.

In the case of Towntology, all concepts are related with water supply, treatment and distribution. The rich expressivity is performed by defining properties characteristics such as functional, transitive, asymmetric etc. It also used axioms such as concept definition as well as restrictions over the properties as well as concepts.

**Technical and methodological aspect.** OWL language has been used in order to develop these ontologies followed by description logic family. However, hydrOntology is written in Spanish language and build upon 3 entities, which contain about 150 concepts from hydrological field. It also contains 34 properties, 66 attributes and 256 axioms. Both ontologies used a vast number of ontological resources such as properties, rules and axioms, which are essential in order to enrich the concepts with its associated metadata.

**Legal nexus aspect.** There exist links between water related environmental concepts such as rivers, mineral water etc and artificial material based concepts such as distribution system of water etc. These links are mostly established in law. However, even though these two types of concepts are present in the hydrOntology, it does not have any restrictive expression related with water and energy nexus. For example, to detect metrological relationships between distribution of water and energy required for that.

## 15 OntoClean: domain-independent meta-properties of concepts

OntoClean is a methodology designed to analyze taxonomies used for ontology development based on domain-independent meta-properties of concepts, which is proposed by Nicola Guarino and Chris Welty[183] in 2000. It proposes a different perspective of the meaning of property which is in contrast with the way the meaning of property has been used in logic and semantic web domains. In logic, for instance, a unary predicate in intention is known as property which is a member of a class or concept[184], whereas a property is treated as a binary relationship in the semantic web[185]. In contrast, OntoClean uses property and class or concept as synonymous and hence a meta-property is the property of any concept. These meta-properties are – identity, unity, rigidity and dependence.

Identity is very well known in metaphysics as well as in database modeling for allocating primary key for rows in a table. In the OntoClean, it is associated with two fundament conditions – it must informative and at the same time it cannot be trivial. The concept 'sortal'[186] is associated with the identity criteria of any entities. In OntoClean, if any concept carries its identity criteria is called sortal, which is further used to analyze sortal individuation and expandability[187], which can be indicated with the +I superscript, -I for non-sortals. In addition, a concept is marked with +O, -O otherwise, if only if satisfy following conditions – the concept is rigid, it has its own identi-

[183] The core four papers on OntoClean are – (a) Guarino, Nicola and Chris Welty. 2004. An Overview of OntoClean. In Steffen Staab and Rudi Studer, eds., The Handbook on Ontologies. Pp. 151-172. Berlin:Springer-Verlag, (b) Guarino, Nicola and Chris Welty. 2002. Identity and Subsumption. In Rebecca Green, Carol A. Bean, & Sung Hyon Myaeng (Eds.), The Semant.css of Relationships: An Interdisciplinary Perspective. Pp. 111-125. Dordrecht: Kluwer, (c) Guarino, Nicola and Chris Welty. 2002. Evaluating Ontological Decisions with OntoClean. Communications of the ACM. 45(2):61-65. New York:ACM Press, and (d) Welty, Chris and Nicola Guarino. 2001. Support for Ontological Analysis of Taxonomic Relationships. J. Data and Knowledge Engineering. 39(1):51-74. October, 2001.

[184] W.V. Quine was the first to recognize the importance of the introduction of variables as indicating the acceptance of entities. "The ontology to which one's use of language commits him comprises simply the objects that he treats as falling . . . within the range of values of his variables." "Notes on Existence and Necessity," Journal of Philosophy, Vol. 40 (1943), pp. 113-127; compare also his "Designation and Existence," Journal of Philosophy, Vol. 36 (1939), pp. 702-709, and "On Universals," The Journal of Symbolic Logic, Vol. 12 (1947), pp. 74-84. For more philosophical aspects of logic, see Goble, L., 2001. Philosophical Logic, Oxford: Blackwell Publishers.

[185] See http://www.w3.org/standards/semanticweb/

[186] The detail philosophical understanding of sortal is explained in http://plato.stanford.edu/entries/sortals/

[187] Guarino, Nicola. 1999. The role of Identity Conditions in Ontology Design. Proceedings of the IJCAI-99 Workshop on Ontology and Problem Solving Methods (KRRS), Stockholm, Sweden, August 2, 1999. Republished in C. Freksa and D. M. Frank (eds.), Spatial Information Theory: Cognitive and Computational Foundations of Geographic Information Science, Springer Verlag 1999.

ty criteria and the same identity criteria is not carried by all the concepts subsuming[188] it.

The concept ‘mereology[189]’ mainly deals with parthood relations, which has dominating role for explaining the meaning of unity under OntoClean context[190]. Identification of whole with its corresponding parts and underlying boundaries helps to analyze whether the conceptual relations between concepts are compatible with their associated unity criteria. More precisely, a concept carries unity criteria if, only if, there exists a single relation under which each instance of the concept is necessarily whole independent from any particular time in consideration. +U is used to express if a concept carries unity criteria where all instances are wholes under the same relation, otherwise –U or ~U. The concept carries non-unity, denoted as –U, if some instances of a concept are not wholes by the same relation. Furthermore, the concept is anti-unity, indicated by ~U if all instances of a concept are not wholes by the same relation[191].

Philosopher Leibniz proposed necessity of ‘identity of indiscernible’[192] which has relationship with the OntoClean’s meta-property ‘Rigidity[193]’ due to the problems caused by temporal consideration during the life cycle of any concept[194], especially in the semantic web. The concept ‘essential property’ is used in OntoClean where Leibiz’s law holds. If a concept holds some essential property that cannot change, the concept is rigid and therefore designated by +R, otherwise non-rigid –R or anti-rigid ~R which means their properties must be changeable.

---

[188] More about the role of subsumption in the logic can be found here - http://plato.stanford.edu/entries/consciousness-unity/ and Esquisabel, Oscar M., 2012, “Representing and Abstracting. An Analysis of Leibniz's Concept of Symbolic Knowledge”, in Abel Lassalle Casanave (ed.), Symbolic Knowledge from Leibniz to Husserl, London: College Publications, pp. 1–49, and Bayne, T. and Chalmers, D., 2003. What is the unity of consciousness? In Cleeremans 2003.

[189] Burkhardt, H. and Dufour, C. A., 1991, ‘Part/Whole I: History’, in H. Burkhardt and B. Smith (eds.), Handbook of Metaphysics and Ontology, Munich: Philosophia, pp. 663–673.

[190] For detail see Guarino, Nicola, and Chris Welty. 2000. Towards a methodology for ontology-based model engineering. In, Bezivin, J. and Ernst, J., eds, Proceedings of the ECOOP-2000 Workshop on Model Engineering. June, 2000.

[191] Guarino, Nicola, and Chris Welty. 2000. A Formal Ontology of Properties (Preliminary Version). In Benjamins, R., Gomez-Perez, A., Guarino, N., and Uschold, M., eds, Proceedings of the ECAI-2000 Workshop on Applications of Ontologies and Problem-Solving Methods. August, 2000.

[192] For detail look at Leibniz, G. W., Philosophical Papers and Letters, in Loemker 1969, and http://plato.stanford.edu/entries/identity-indiscernible/ and Rodriguez-Pereyra, G., 1999, "Leibniz's Argument for the Identity of Indiscernibles in His Correspondence with Clarke", Australasian Journal of Philosophy, 77: 429-38.

[193] Welty, Chris and William Andersen. 2005. Towards OntoClean 2.0: a framework for rigidity. Journal of Applied Ontology 1(1):107-116. Amsterdam:IOS Press.

[194] Anastasia Analyti and Ioannis Pachoulakis. A survey on models and query languages for temporally annotated RDF. International Journal of Advanced Computer Science and Applications, 3(9):28–35, 2012.

The OntoClean's meta-property 'dependence' is not similar with the concept constitution under mereology[195]. Therefore, the property 'unity' does not represent the external dependency of a concept over the existence of another entity. In OntoClean, a concept is externally dependent over another concept if each instance of former concept is necessarily some instances of latter concept which is neither a part nor constitute of such instance. Being dependent is expressed with +D, independent with -D.

On the top of using these above mentioned meta-properties of a concept, OntoClean uses following constraints and assumptions in order to analyze conceptual hierarchies in the taxonomy[196], given two properties A and B, when A subsumes B –

- B must be anti-rigid if A is anti-rigid.
- B must carry same identity criterion as A carries.
- B must carry same unity criterion as A carries.
- B must have anti-unity if A carries anti-unity.
- B must be externally depended if A is externally depended.
- No entity without identity means every element of a domain must instantiate some identity criteria – which is addressed as sotral individuation.
- If an instance related to different times, it must be an instance of a general property carrying the same type of criterion for its identity – which is known as sotral expandability.

The OntoClean methodology is intended to be used for establishing as well as evaluating hierarchical relationships that exist in the taxonomy for legal ontology for nexus, which is further discussed in following section.

## 16 Methodology for legal ontology for nexus

Chapter 2 of this thesis shows different perspectives and construction methodologies of legal ontology and summarized following pints – (a) legal documentation perspective well suits with the purpose of developing legal ontology for nexus, (b) there is a need to develop a new methodology in order to construct legal ontology for nexus. In addition, section 14 of this chapter shows that all available and influential ontologies

[195] For detail, see following papers - Baker, L. R., 1997, 'Why Constitution Is Not Identity', Journal of Philosophy, 94: 599–621, and Evnine, S., 2011, 'Constitution and Composition: Three Approaches to Their Relation', ProtoSociology, 27: 212–235, and Pickel, B., 2010, 'There Is No 'Is' of Constitution', Philosophical Studies, 147: 193–211, and Stump, E., 2006, 'Resurrection, Reassembly, and Reconstitution: Aquinas on the Soul', in B. Niederbacher and E. Runggaldier (eds.), Die Menschliche Seele: Brauchen wir den Dualismus?, Frankfurt: Ontos, pp. 151–171.

[196] Völker, Johanna, Denny Vrandecic, and York Sure. 2005. Automatic Evaluation of Ontologies (AEON). In Y. Gil, E. Motta, V. R. Benjamins, M. A. Musen, eds. Proceedings of the 4th International Semantic Web Conference (ISWC2005), volume 3729 of LNCS, pp. 716-731. Springer Verlag:Berlin-Heidelberg, November 2005, and Guarino, Nicola and Chris Welty. 2004. An Overview of OntoClean. In Steffen Staab and Rudi Studer, eds., The Handbook on Ontologies. Pp. 151-172. Berlin:Springer-Verlag.

in water, energy and food domains, beside their ontological, semantic and interoperability strength are not extracted from the legislative texts nor developed with the idea of incorporating the ontology in the digitalized legal documentation. Hence all these available ontologies are not by nature legal ontology for their respective domain. As a result, from the methodological point of view, it is required to fulfill two following requirements in order to develop legal ontology for nexus –

- To construct legal ontology separately for each of water, energy and food domains, where all concepts, terms, properties, restrictions and annotations will be extracted from the respective legislative texts and legal definitions. This simply will maintain two following features –
  - Reusability of each of these legal ontologies in their respective domain.
  - Incorporation into the digital legal documentation.
- To construct these legal ontologies in such a way that will not create any conflict or inconsistency while all legal ontologies will be merged in order to get the legal ontology for nexus.

Under considering these insights, the methodology for legal ontology for nexus is designed. In addition, it is noteworthy to mention that this legal ontology is an integral component of the legal knowledge framework for Nexus, which is theoretically proposed and presented as a by-product of this doctoral thesis and discussed in the chapter 1. However, from the methodological point of view, broadly ontological tasks for legal ontology for nexus are divided into three phases – (a) pre-ontology development tasks, (b) throughout-ontology development tasks and (c) post-ontology development tasks as it is shown in Figure 1.

### 16.1 Pre-Ontology Development Tasks

After setting up goal and objectives for building legal ontology for nexus, the next most crucial phase is pre-ontology development tasks. This phase generally takes longer time and relatively higher cognitive analytical works. Building an effective and efficient ontology is entirely depended on this phase, which may involve with a lot of tasks such as preparing questions and answers that one wants to get from the ontology etc, for detail see chapter 2. However, particularly for the purposes of building this legal ontology for nexus, this phase is mainly consisted with following three major tasks –

- *Taxonomy development*[197] – this mandatory sub-task deals with extracting legal concepts and terms from the most relevant legislative texts in order to develop legal taxonomy for each of the selected legal definitions.

- *Initial concept definition* – Once extracting taxonomy from legislative texts is done, the next step is to design and/or collect definition/s for each of these legal

[197] How taxonomy plays role in ontology construction is explained in Carbonell, J. G. and J. Siekmann, eds. (2005). Computational Logic in Multi-Agent Systems, Vol. 3487. Berlin: Springer-Verlag. ISBN 978-3-540-28060-6

concepts, terms, restrictions from again legislative texts mentioned in the taxonomy.

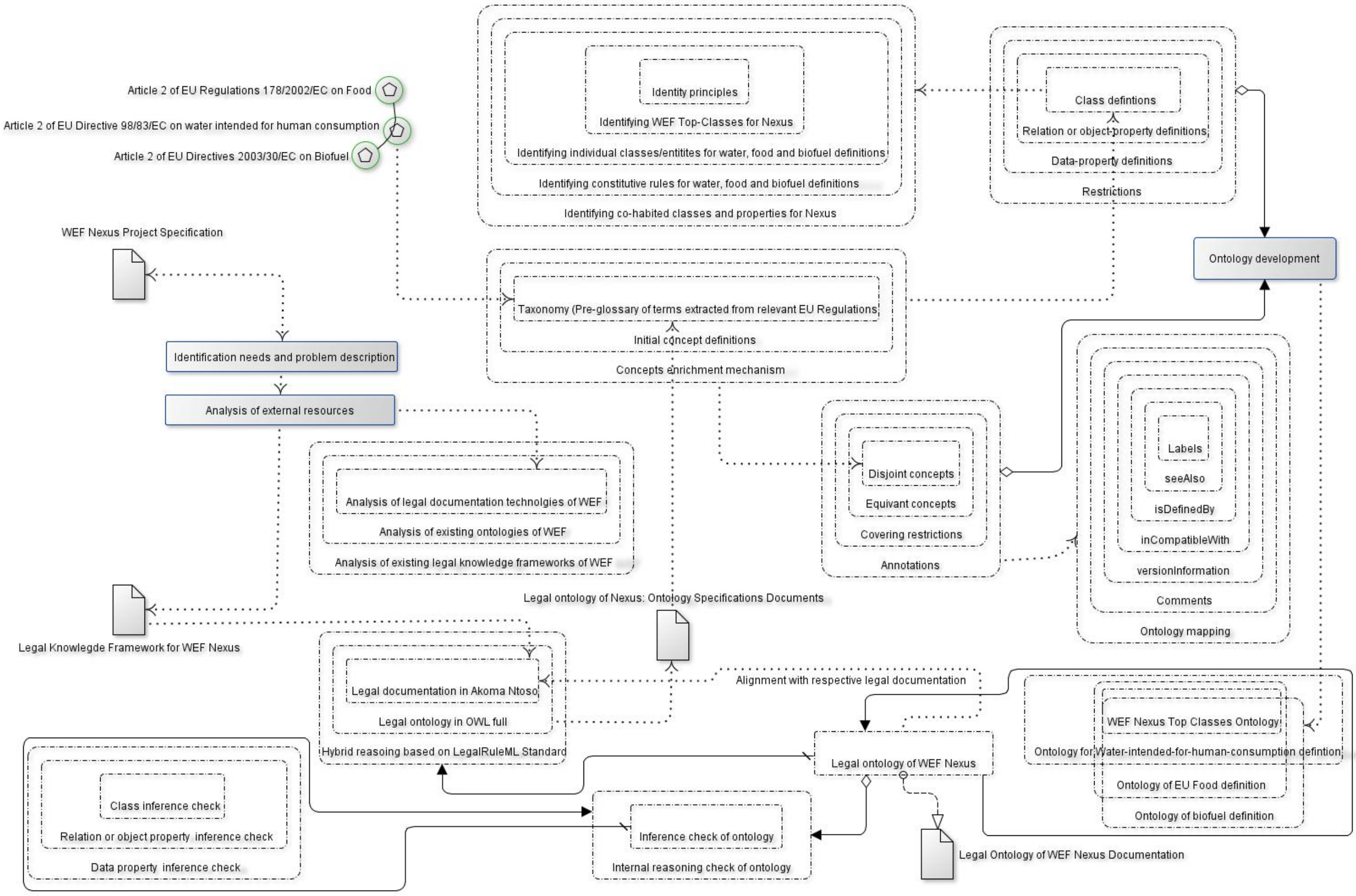



**Fig.1.** Methodology for legal ontology for nexus

- *Concept enrichment mechanism*[198] - Once designing concept's definition is done, the next step is to make links between and among the concepts in order to enrich the concept. There are several ways that can be performed such as identifying equivalent and/or disjoint concepts, proving relation axioms over the concept etc.

---

198 Detail of concept enrichment in the context of knowledge acquisition is explained in Carey, S. (1999). knowledge acquisition: enrichment or conceptual change? In E. Margolis, & S. Lawrence, concepts: core readings (pp. 459–489). Massachusetts: MIT press.

Each of these sub-tasks is performed in chronological order in order to complete all tasks efficiently. They all are discussed below -

### 16.1.1 Taxonomy Development

Following three Articles concerning respective legal definitions of WEF from EU regulations have been selected for extracting pre-glossary of terms[199] for legal ontology of nexus –

- Article 2 of EU Directive 98/83/EC defines the water intended for human consumption.
- Article 2 of EU Directive 2003/30/EC defines bio-fuels.
- Article 2 of EU Regulation 178/2002/EC defines food.

All of these Articles are chosen because of their dominance in EU legal domains. For instance, (a) EU Directive 98/83/EC is the first EU Directive that defines water for human consumption as well as specifies the legal parameters of the quality of the water, which is considered as the most leading EU Regulation in the water industry as well as water compliance checks, (b) EU Directive 2003/30/EC is the first in EU Regulations that defines biofuels and provides legal structure of promoting biofuels in European Single Market, and (c) EU Regulation 178/2002/EC is also the first legally binding EU Regulation in food domain that not only define food, rather it also define what shall not be considered legally food in the EU single market. Furthermore, it establishes the Food Safety Authority for EU region. Entire legislative texts of these three Articles have been provided in Chapter 1, 2 and Chapter 4 with comprehensive analyses from different stand-points, for detail see respective chapters.

However, following definitions are used for representing concepts, terms and entities in this ontology – (a) entity is any name of class and/or sub-classes used in this legal ontology and carry URI (Uniform Resource Identifier). It can be either a concept or term; (b) concept also represents class and/sub-class in this legal ontology. Therefore, entity and concept are used interchangeably. For example, 'Material' is an entity in this ontology with its own URI as well as it is represented as a concept with its own abstract meaning in this ontology, and (c) term is used in order to express concept, vice versa. Hence, the term itself can be used as concept and entity too. For example, 'Water' is, on the one hand, an 'entity' in this ontology as it possess URI. On the other hand, it is a concept as it represents an abstract meaning and it is also a term in order to express its sub class relationship with its parent class 'Substance' as the term 'Water' is a sub class of the concept and/or entity 'Substance'. Nevertheless, in order

[199] See Ajani, G., G. Boella, L. Lesmo, M. Martin, A. Mazzei, D. P. Radicioni, and P. Rossi. 2009. Legal taxonomy syllabus version 2.0. In 3rd workshop on legal ontologies and artificial intelligence techniques joint with 2nd workshop on semantic processing of legal text (LOAIT 2009), Colocated with the 12th International Conference on Artificial Intelligence and Law (ICAIL 2009), ed. N. Casellas, E. Francesconi, R. Hoekstra, and S. Montemagni. IDT series, Vol. 2, 9–17. Barcelona: IDT/Huygens Editorial.

to identify the concepts and terms besides using Lame's approach, following techniques have been used –

- By identifying 'noun' in the legislative texts, the concept is recognized such as 'Water', 'Food' and 'Biofuel'.
- By identifying 'legal phrase' in the legislative texts, the concept is recognized too such as 'Water intended for human consumption'.
- By identifying 'object' in the legislative texts, the concept is recognized too, e.g. 'human consumption'.

### 16.1.2 Initial Concepts' Definitions

Fundamentally structuring knowledge in several parts is represented in the ontology, which starts with separating concept from the knowledge with its unique abstract meaning. Therefore this is cognitively very challenging and primarily based on taxonomy developed for this ontology. However, in order to do it efficiently, the tasks of this phase are sub-divided into following sections -

- *Concepts definition* – primarily deals with the extraction of legal definition from relevant EU legislations for each concept and term defined in the taxonomy of this ontology by applying identity principles. In addition, it categories concepts and their sub-concepts or terms.
- *Object property*[200] *identifications and definitions* – in order to structure the concept providing its semantic qualitative relationship with relevant predicates and/or copula in the ontology, object property is identified as well as defined in the context of the legal definition of water, biofuels and food.
- *Data property*[201] *identification and definitions* – there also exists data property in the legislative texts and carries quantitative value based restriction over the legal concepts and terms. Without considering those data properties, automatic metrological calculation cannot be performed over any concept.
- *Legal Restriction*[202] – once identification and defining of concept, object and data property are completed, the next level is to create restriction over the concept using appropriate object and/or data property in order to make a meaning full representational ontology.

Each of these sub-tasks are discussed below in the light of legal ontology for nexus -

[200] ObjectProperty := IRI, see http://www.w3.org/TR/owl2-syntax/#Object_Properties
[201] DataProperty := IRI, see http://www.w3.org/TR/owl2-syntax/#Data_Properties
[202] Class expressions in OWL 2 can be formed by placing restrictions on object property expressions, see http://www.w3.org/TR/owl2-syntax/#Object_Property_Restrictions

#### 16.1.2.1 Class/Concept's definition

Even though all concepts are extracted from the legislative texts, particularly from three legal definitions mentioned in the section 16.1.1., for the legal ontology for nexus; the definitions of all concepts are not given there. Therefore, in the case of not getting appropriate definition of any of the defined concepts in the respective legal definition of water, biofuel and food, other relevant EU legislations have been consulted. In the case failing these two options, following texts have been consulted - legal dictionary, authoritative statements and popular literatures.

Starting from the EU regulations and directives in the domain, however, the definition of the concept has been isolated manually from the inside of legislative texts through a comprehensive linguistic analysis of each sentence. For example, article 2 of EU Directive 98/83/EC specifies that –

*'……**water intended for human consumption**' shall mean:*

*(a) all **water** either in its original state or after treatment, intended for drinking, **cooking**, food preparation or other domestic purposes, regardless of its origin and whether it is supplied from a distribution network, from a tanker, or in bottles or containers;…..”*

From this legislative text, the legal phrase '*water intended for human consumption*' is identified as a legal concept and the definition of it also has been taken from this same legislative text. However, '*water*' is also identified as a term in order to express the meaning of the legal phrase '*water intended for human consumption*', but this Article does not define the meaning of water. Therefore, Article 2 of EU Regulation 178/2002/EC is consulted as it declares that '*Water*' is a type of '*Substance*'. Therefore, the term '*Water*' is extracted from EU Directive 98/83/EC, but the definition of it taken from EU Regulation 178/2002/EC. However, unlike the term '*Water*', the legal definition of term '*Cooking*' is not found in any of EU legislations. Therefore, the meaning of it has taken from Oxford dictionary due to another reason is that no available legal dictionary defines it yet from the legal point of view. In order to do this task effectively, following table-structure has been used, shown in Table 2 –

**Table 2.** Methodology of structuring concept for legal ontology for nexus

| ***Concept's name*** | ***Source of the concept*** | ***Definition*** | ***Source of the definition*** | ***Name of the sub-class/es*** | ***Equivalent class/es*** | ***Disjoint class/es*** |
|---|---|---|---|---|---|---|
| | | | | | | |

However, the tasks of this phase are further sub categorized into following steps –

**Identity principles[203].** In the book of Aristotle's Metaphysics[204], the identity principle is symbolically represented as

*'A is A'*

Where there are three elements – thing, essence and identity. In this symbolic example, first 'A' is the proposition represents subject or thing and the second 'A' is predicate or its essence with the copula 'is', which is particularly expresses the relation of identity. This theory is further elaborated and celebrated by many scholars, even in the computational ontology field. One of such Italian scholars is Nicola Guarino who suggested that theory of identity principles is fundamental requisite in order to formulate clearer, rigorous, better understandable ontology. This theory is used as a very important exercise in order to avoid inconsistency and conflicts in the formation of and structuring concepts in this pre-ontology development task. In order to make it clearly understandable how this theory is applied in this ontology, following example is drawn. Article 2 (1)(a) of EU Directive 2003/30/EC specifies that

*"…'biofuels'* ***means*** *liquid or gaseous fuel* ***for*** *transport* ***produced from*** *biomass…''.*

In this legislative text, the concept 'biofuel' is defined by using following three copulas, the bold and underlined in the above text, those express three types of identity relations with other terms, e.g. '*transport*', '*Biomass*'.

- Copula '*means*' – it shows the form-identity relations of biofuel that can be in two different forms such as '*liquid*' or '*gaseous*'.
- Copula '*for*' – it shows how biofuels shall be used or permitted to be used by law. It particularly articulates the legally permitted activity-identity '*Transport*' that shall be performed by '*biofuels*'.
- Copula '*produced from*' – it establishes the source-identity of '*biofuels*' mentioning that it shall be produced from '*biomass'*.

Under considering this analysis of identify principles of the legal definition 'biofuels', it is clear to conclude that if biofuels does not comply with its form-identity, activity-identity and source-identity, it will not be considered as a biofuels under the jurisdiction of EU Directive 2003/30/EC. However, it does not mean that in real word, there will not exist any biofuel without complying with these three identity relations of

[203] Unlike identity principles, the identity of indiscernibles is an ontological principle that states that there cannot be separate objects or entities that have all their properties in common. That is, entities x and y are identical if every predicate possessed by x is also possessed by y and vice versa; to suppose two things indiscernible is to suppose the same thing under two names, see Carriero, John Peter (2008). Between Two Worlds: A Reading of Descartes's Meditations. Princeton University Press.

[204] Book VII, part 6 – translated by W.D. Ross

biofuels. Of course, from metaphysical point of view, biofuel[205] is a type fuel and therefore it can exist with being used for transport and without being sourced from biomass. However, from the EU legal perspective, it may not be legally valid.

**Applying OntoClean's meta-properties.** The application of different meta-properties of a concept, as discussed in section 15, in legislative text or legal domain will not be as same as it supposes to be in any other domains. One of main reasons behind it is that the concept carries legal meaning within the context of legislative text is not rigid due to the fact that legal rules evolve over time by proper legal adjustments imposed by legitimate authority. That may affect and reinforce the temporal as well as jurisdiction related validity of a concept embed in the legislative text.

**Table 3.** Usages of OntoClean in Legal Ontology for Nexus

| *Concept* | *Source of the concept* | *Identity* | *Unity* | *Rigidity* | *Dependent* | *OntoClean in notation* |
|---|---|---|---|---|---|---|
| | | | | | | |

Another important reason is that the legislative text has its own legally valid hierarchical taxonomy within and/or outside of the legislation, which must be maintained while implementing such concepts. However, Table 3 has been used in order to apply meta-properties of OntoClean for developing as well as evaluating he taxonomy designed for legal ontology for nexus.

**Identifying and defining WEF Top-Classes/concepts[206].** After completing the tasks of taxonomy development and concepts' definition, now there are about 156 concepts and terms extracted from the selective legislative texts, see section 16.1.1. However, now the new problem is that the fields or areas of these concepts are so diverse and heterogeneous by their nature. For example - (a) 'Transport' is a term that is used to express activity-identity of the concept 'biofuels' and there is no other such term that can be related with this term exists in all of these selective legal definitions, (b) 'Cooking' is another term exists in Article 2 of EU Directive 98/83/EC that also express activity-identity of the concept 'water intended for human consumption' and there is no other such related term exists in the same or other selected legal definition. Now considering examples (a) and (b), it may seem that they are completed isolated terms by their legal source. However, from the identify principles point of view, they are inter-connected as both of them express activity-identity relations with two differ-

[205] See Li, H.; Cann, A. F.; Liao, J. C. (2010). "Biofuels: Biomolecular Engineering Fundamentals and Advances". Annual Review of Chemical and Biomolecular Engineering 1: 19–36. doi:10.1146/annurev-chembioeng-073009-100938

[206] See, Sowa, J. F. (1995). "Top-level ontological categories". International Journal of Human-Computer Studies 43 (5-6 (November/December)): 669–85. doi:10.1006/ijhc.1995.1068.

ent concepts. Therefore in order to cover all of these types of isolated terms but inter-related with their identity principles based relations, idea of creating top-classes for legal ontology for nexus appeared. Hence 16 Nexus Top Classes have been identified and transformed those concepts with their related object-properties as a complete ontology, see section 19 of the chapter 4. In order to does it efficiently, following table structure have been followed, shown in Table 4.

**Table 4.** Methodology of identifying Nexus Top-Classes using identity principle relations

| ***Concept's name*** | ***Related terms or concepts with IP*** | ***Type of Identity-principle (IP) relation*** | ***Top-Class that covers related terms or concepts with IP*** |
|---|---|---|---|
| | | | |

**Defining common and uncommon concepts/classes that exist in the respective legal definitions of WEF.** Once identifying of WEF top classes is done, the next challenge is to categories the common and uncommon entities that exist in all three selected legal definitions of water, biofuels and food. This task is performed in order to avoid inconsistency and over-lapping status of same concepts that exist in different legal definitions simultaneously. For example - (a) the term 'Water' exists in following both legislation - Article 2 of EU Directive 98/83/EC and EU Regulation 178/2002/EC, (b) the term 'residue' exists in following both legislations - Article 2 of EU Regulation 178/2002/EC and EU Directive 2003/30/EC, (c) the term 'Tobacco substance' is only found in Article 2 of EU Regulation 178/2002/EC. However, this task has been done by using following table structure, shown in Table 5.

**Table 5.** Methodology of identifying common and uncommon classes

| ***Concept's name*** | ***Source of the concepts*** | ***Does it belong to multiple legislations? If yes, mention sources*** | ***Parent class/es of it*** | ***Child class/es of it*** |
|---|---|---|---|---|
| | | | | |

This task became very useful while merging of all separated ontologies of all selected legal definitions took in place, for more explanation see section 23 of chapter 4. Two most important of such usefulness are mentioned below –

- It helps to construct categorizations of concepts and sub-concepts in such way that does not allow having multiple entities of all common concepts.
- It also helps to place the uncommon concepts under the right categorizations, so that it reduces possibility of misplacement while merging takes in place.

**Identifying constitutive rules from each WEF legal definitions.** Now the biggest challenge is to identify the constitutive rule that exist in the identity principles of the term or concept and of course with proper reasons. However the constitutive rule, under the context of the legal ontology for nexus, means any legal concept or term that fulfills both of following conditions –

- *Role to create activity/ies* - for example, the legal phrase 'WaterIntendedForHumanConsumption' is addressed as a sub-class of the top-class 'ConstitutiveRule' extracted from Article 2 of EU Directive 98/83/EC as this term has activity-identity relation, on the one hand, with a number of terms such as 'Cooking', 'Drinking', 'Domestic Activity' etc.
- *Logical dependency of those activities is based on legal rule/s* – on the other hard in order to make any water qualified as the 'WaterIntendedForHumanConsumption' and then to use it to order to perform such activities, it depends on the checks of water compliance mentioned in the EU Directive 98/83/EC.

Fundamentally using legal concept and/or term as constitutive rule helps to identify legal nexuses that exist among/between water, energy and food domains. In the section 19.1, 20.1, 21.1, 22.1 and 23.1 of the chapter 4 describes total 9 constitutive rules in detail under the context of legal ontology for nexus.

#### 16.1.2.2 Object-property identification and definition

Object property plays important role in order to create qualitative restriction over the concepts or terms. From the ontological technical point of view, the object property is also considered as an entity with its URI. Following measures have been taken for identifying object property from the legislative texts –

- Generally verb and/or predicate of the legislative sentence direct to identify object property.
- There are some cases where verb in the legislative sentence is used in order to identify sub-class of the terms, e.g. the verb '*includes*'. In such cases, identifying object property from the verbs of the legislative texts is avoided.

In order to make a better explanation of it, following example is drawn from Article 2 of EU Regulation 178/2002/EC –

"*....'Food'* ***includes*** *drink, chewing gum and any substance, including water,* ***intentionally incorporated into*** *the food ....*"

Considering this legislative sentence, there are two verbs or verb phrase such as '*includes*' and '*intentionally incorporated into*'. In the case of first verb '*includes*', it indicates the sub-classes of the term '*Food*' such as '*Drink*', '*Chewing Gum*' and '*Water Substance*' etc. Therefore, the verb 'includes' is not addressed as an object property. However, the other verb phrase '*intentionally incorporated into*' used as an object property in order to establish semantic relationship between the following terms – '*Water Substance*' and '*Food*'.

**Table 6.** Construction of object and data proeprty for the legal ontology for nexus

| ***Property name*** | ***Source of Property*** | ***Domain and Range*** | ***Equivalent and disjoint*** | ***Characteristics*** | ***Super-property*** |
|---|---|---|---|---|---|
| | | | | | |

There are total 35 object-properties have been identified as well as defined for the legal ontology for nexus using Table 6. All of these object properties are discussed in chapter 4.

#### 16.1.2.3 Data property identification and definition

Unlike object property, the data property helps to establish quantitative value based semantic relation between terms. Three measures have been taken for identifying data property from the inside of legislative texts – (a) number, (b) percentage, and (c) value based information. There is only one data property has been extracted from Article 2 (2) (f) of EU Directive 2003/30/EC -

"*...The percentage by volume of bio-ETBE that* ***is calculated as*** *biofuel is 47 %...*"

In this legislative sentence, 'is calculated as' is detected as data property. Because it expresses a specific percentage value in order to measure the volume of Bio-ETBE for qualifying it as a biofuel. The data-property is further structured by using Table 6.

#### 16.1.2.4 Legal restrictions

From the technical point of view, application of restriction over the concept or term plays following important roles – (a) it limits the expression over the concepts or terms, (b) it guides the semantic relations between/among concepts, terms and properties. From the legal point of view, it helps to construct some legal rules, in a very limited way, over the concepts using different forms of relations with their relevant properties. Three following mechanisms have been used in order to construct restrictions –

- *Mechanism 1* – constructing restriction through creating sub-class relationship between term and legal concept, for more detail see section 20.3 of the chapter 4.
- *Mechanism 2* – applying restriction over the concept and/or term using domain and range of the object-property. By OWL 2, it is also possible to characterize this type of relation such as functional, symmetric, asymmetric etc. For detail with examples see section 21.2 of the chapter 4.

- *Mechanism 3* – creating restriction using universal and/or existential and/or cardinal relationships implemented in Manchester syntax. For detail with examples see section 19.3, 21.3 and 22.3 of the chapter 4.

Total 31 asserted legal restrictions, except dis-joint restrictions, have been constructed in the legal ontology for nexus. All of these restrictions are explained in chapter 4. It is noteworthy to mention that there are many inferred restrictions too obtained from these 31 asserted legal restrictions using Table 7, explained with more detail in section 23 of the chapter 4.

**Table 7.** Construction of object and data proeprty for the legal ontology for nexus

| ***Concept name*** | ***Restricted property*** | ***Restriction Filler*** | ***Source of the Restriction*** | ***Restriction type [Some( Existential), only (universal), min (cardinality), Exact cardinality, and max cardinality.]*** | ***Formulas*** |
|---|---|---|---|---|---|
| | | | | | |

### 16.1.3 Concept enrichment mechanism

A number of mechanisms are used in order to enrich meta-data of concepts and their inherent characteristics. They are – (a) defining dis-joint concepts and/or terms, (b) outlining legally equivalent classes, (c) covering legal restrictions with their innate characteristics, and (d) providing sufficient annotations for each concept, term, property and restriction, so that the ontology will be equipped with its own self-explanation. All of these mechanisms are described below with examples taken from the selected legal definitions -

#### 16.1.3.1 Disjoint class

From technical point of view, defining disjoint classes help to avoid inconsistency and improve instantiations in the ontology. From the legal perspective, law sometime clearly defines the disjoint classes inside the legislative texts. Therefore, defining disjoint classes is also legally obliged as well as restricted. For example, third paragraph of Article 2 of EU Regulation 178/2002/EC specifies that

> "*......'Food'* ***<u>shall not include</u>****: (a) feed; (b) live animals unless they are prepared for placing on the market for human consumption.....*"

From this legislative text, it is explicit that the term '*Feed*' is disjointed with the legal concept '*Food*'. Here the bold underlined obligatory verb '*shall not include*' helps us to detect the legal dis-joint constraints over the concept '*Food*'. There are total 8 disjoint classes identified and extracted from the selected legislative texts for the legal ontology for nexus. It is noteworthy to mention that disjoint class that exists outside of the selected legislative texts is not considered in this ontology. For example, the terms 'WaterAfterCompliance' and 'WasteWater' are surely dis-jointed terms but they are not defined as such in the legal ontology for nexus. Because the selective legislative texts do not support explicitly this disjoint constrains.

#### 16.1.3.2 Equivalent class

Defining equivalent classes, from the technical point of view, transfer and share directly all the attributes that equivalent classes hold inside the ontology. From the legal point of view, equivalent legal concepts are obliged to be directed under the same legal rules. For example, the first paragraph of Article 2 of EU Regulation 178/2002/EC demonstrates that

"*.......Definition of 'food' For the purposes of this Regulation, **'food' (or 'foodstuff')** means any substance or product, whether......*"

Considering this legislative text, the terms 'Food' and 'Foodstuff' are legally equivalent. Therefore, all legal rules that shall apply to the term 'Food' shall also be applied to the term 'Foodstuff'. That makes understanding of legal nexus between/among water, biofuels and food nexus easy. Let's consider another example – Article 2 (1) (b) of EU Directive 2003/30/EC specifies that

"*.....**biomass** means the **biodegradable fraction of** products, waste and **residues**....*"

This legislative text explicitly establishes that the term '*Biomass*' is equivalent to the term '*BiodegradableFractionOfResidues*'. This Article also mentions that biofuels shall be produced from biomass. As '*Biomass*' is equivalent to the term '*BiodegradableFractionOfResidues*', the legal rules that apply to the term 'Biomass' are also equally and legally applicable to the term '*BiodegradableFractionOfResidues*'. Therefore it means that biofuel shall also be produced from '*BiodegradableFractionOfResidues*'. Now let's consider again the third paragraph of Article 2 of EU Regulation 178/2002/EC which specifies that

"*.............'Food' shall not include:.............(h) **residues** and contaminants.......*"

Considering this legislative text, the term 'Residues' is disjointed with the term 'Food' as described in the previous section. That establishes an explicit legal nexus between biofuel and food. However, there are total 15 equivalent classes are identified and defined for the legal ontology for nexus. All of these equivalent classes are described in the chapter 4.

#### 16.1.3.3 Covering restrictions

Once the legal restriction is identified and extracted from the legislative texts, the next required step is to characterize the restriction. This enriches legal restriction that is applied over the terms and/or concepts using object and data properties. There are two ways to do that in OWL 2 – (a) declaring universal or existential relationship between the concept/terms using object property, and/or (b) asserting type of character that the restriction is attributed with. Such characters can be – functional, inverse functional, transitive, symmetric, asymmetric, reflexive and irreflexive.

However, in the selected legislative texts, mostly two types of characters of legal restrictions are identified. They are functional and asymmetrical. From the technical point of view, functional property is a single valued property and asymmetric property is one directional property. From the legal point of view, functional property exemplifies a certain causal role. For example, Article 2 (1) (c) of EU Directive 2003/30/EC specifics that -

"*.....**renewable fuels**, other than biofuels, which **originate from** **renewable energy sources**....*"

In this legislative text, '*originate from*' is, on the one hand, a functional object-property, because it shows the source-identity relation of the term 'RenewableFuels' to the term 'RenewableEnergySources'. That particularly exemplifies the causal role of the first term towards the second term. On the other hand, it is asymmetric because this source-identity relation between these two terms is one-directional in this specific legislative text. It means 'renewable energy source' cannot be the 'renewable fuels'.

#### 16.1.3.4 Annotation axioms

Annotation [207] makes ontology self-explanatory, even though annotation does not involved with inference processes of ontology. This provides a clear explanation of each concept, term, property and restriction that are used in the ontology. In the legal ontology for nexus, following annotation axioms are intended to be used in order to make it self-explanatory. Such used annotations are –

- definition – that generally contains the legal meaning of each entity.
- isDefinedBy – that expresses the authority, institute and/or person who defines the meaning.
- comments – that adds any particular observational description over any entity in order to make the definition more explicit.
- seeAlso – that shows the relevant content helpful to understand the context.
- inCompatibleWith – that carries the other necessary definition or explanation with which the core definition is compatible with.

[207] OWL 2 applications often need ways to associate additional information with ontologies, entities, and axioms. To this end, OWL 2 provides for annotations on ontologies, axioms, and entities, see http://www.w3.org/TR/owl2-syntax/#Annotations

## 16.2 Throughout Ontology Development Tasks

On the basis of the outcomes produced from pre-ontology development tasks, following set of ontologies have been developed –

- *Moduel 1* – WEFNexusTopClasses ontology
- *Moduel 2* – EUDefWater ontology
- *Moduel 3* – EUDefBiofuels ontology
- *Moduel 4* – EUDefFood ontology
- *Moduel 5* – EUWEFNexus ontology

Module 1 '*WEFNexusTopClasses*' ontology is modeled in order to import and reuse it in the construction of other moduels 2 to 4 as their basis ontology by default. It means if any change happens in Module 1, by default the change will be automatically replaced in Module 2 to 4. In order to get the final and targeted legal ontology for nexus, Module 1 to 4 merged together without any single change.

**Implemented language and logic.** Web Ontology Language full (OWL Full), family of description logic and protégé 5 editor are used in order to implement these ontologies.

## 16.3 Post-Ontology Development Tasks

There are following six major tasks conducted in the post-ontology development phrase –

(a) Evaluation of taxonomy of legal ontology for nexus by using OntoClean's domain-independent meta-properties, discussed in section 15 of this chapter.

(b) Checking inferences and ontological consistencies of legal ontology of nexus using automated reasoner**.** Following reasoners build-in protégé 5 are primarily used for inference reasoning as well as consistency checking –

   a. FaCT++[208] - this is a FaCT OWL-DL reasoner based on FaCT algorithms implemented in C++.
   b. HermiT 1.3.8.3[209] - is based on hypertableau calculus which provides efficient reasoning for specially those ontologies written in OWL.

---

[208] FaCT++ is the new generation of the well-known FaCT OWL-DL reasoner. FaCT++ uses the established FaCT algorithms, see http://owl.man.ac.uk/factplusplus/ and Tsarkov, D. and Horrocks, I.: FaCT++ Description Logic Reasoner. In: IJCAR pp.292-297 (2006) http://dx.doi.org/10.1007/11814771_26

[209] HermiT is the first publicly-available OWL reasoner based on a novel "hypertableau" calculus which provides much more efficient reasoning than any previously-known algorithm, see http://hermit-reasoner.com/ and Motik, B., Shearer, R., Horrocks, I.: HermiT: Hypertableau

c. Pellet[210] – is written in Java for OWL 2.
d. Snorocket[211] – is also implemented in Java using polynomial classification algorithm.
e. jcel[212] - is based on rule-based completion algorithm specifically designed for the description logic EL+.

As ontology reasoner[213] is an artificial intelligence approach, it also helps to obtain inferred[214] new legal nexuses using the asserted model of ontologies developed from these three selected legal definitions, as described in section 15.1.1. It also permits to query the ontological knowledge of legal nexuses across navigating all classes, properties and restrictions in relation with their instances.

(c) Evaluating entire legal ontology for nexus using evaluative criteria set in Chapter 2.
(d) Description of each concept model of legal ontology for nexus, one of such examples is shown in Figure 2, is scrutinized using human reasoning approach. A good outcome is produced when artificial intelligence based reasoners is used for ontology checking in specifically Protégé editor platform. This is that after each use and/or synchronization of built-in reasoner, it shows all '*Sub-classes Of*' relations of the term inherited from anonymous ancestors, which is basically inferred knowledge that ontology holds about that term. This gives an opportunity to check manually such '*Sub-class of*' relation of the term. For example, in the case of the term 'QualityOfWater', shown also in the Figure 2, the asserted '*Sub-class of*' relation is -

$$QualityOfWater \sqsubseteq \exists\ shallNotAffect\ .\ (\ WholesomenessOfFoodstuff\ )$$

But the inferred '*Sub-class of*' relation from its anonymous ancestor is as follow –

---

Reasoning for Description Logics. Journal of Artificial Intelligence Research 36, pp. 165-228 (2009)

[210] Pellet is an OWL 2 reasoner in Java; open source (AGPL) and commercially licensed, commercial support, see http://www.w3.org/2001/sw/wiki/Pellet

[211] See Lawley, M. J., Bousquet, C.: Fast classi cation in Protégé: Snorocket as an OWL 2 EL reasoner. In: Proc. 6th Australasian Ontology Workshop (IAOA10). Conferences in Research and Practice in Information Technology, pp. 45{49. (2010)

[212] See ceur-ws.org/Vol-858/ore2012_paper12.pdf ·

[213] See F. Baader, C. Lutz, and B. Suntisrivaraporn. CEL – A Polynomial-time Reasoner for Life Science Ontologies. In Proceedings of the 3rd International Joint Conference on Automated Reasoning, volume 4130, pages 287–291. Springer, 2006.

[214] See T. Gardiner, D. Tsarkov, and I. Horrocks. Framework for an Automated Comparison of Description Logic Reasoners. In The Semantic Web - ISWC 2006, volume 4273, pages 654–667. Springer, 2006.

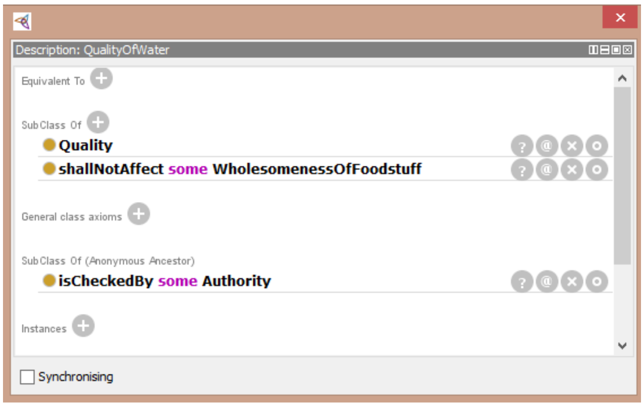


**Fig.2.** Description of the term 'QualityOfWater'

$$Quality \sqsubseteq \exists\ isCheckedBy\ .\ (Authority)$$

Now, applying human reasoning, it is ensured that these asserted and inferred '*Sub-class of*' relations of the term 'QualityOfWater' are consistent with Article 2 of EU Directive 98/83/EC.

(e) Testing A-Box and T-Box consistency in the legal ontology for nexus using DL query[215]
(f) Validation and documentation using LODE[216]

All above mentioned tasks of post ontology development phrase are in detail explained in Chapter 5.

## 17 Essential remarks

This chapter is followed by chapter 2 which provides fundamental basis for developing new methodology for legal ontology for nexus. However, chapter 2 and 3 collectively concludes following points –

- Methodologies used for modeling legal ontology in different projects, discussed in chapter 2, such as LKIF, are not applicable for constructing the legal ontology for nexus due to the reason that these methodologies are mostly common-sense based and these ontologies are not purely constructed on legislative texts.
- Methodologies used for modeling domain ontology for water, energy and food domains, discussed in section 14 of this chapter, are not applicable too due to the reason that primarily these methodologies are not used for modeling legal ontology from related legislative texts.
- In addition, as available ontologies in water, energy and food domains do not represent legal concepts that require for establishing nexus, it justifies the rationality for developing a methodology for modeling legal ontology for nexus.
- This modular based methodology can be applied to model legal ontology for other domains as well as jurisdictions.

[215] See http://protegewiki.stanford.edu/wiki/DLQueryTab
[216] See http://www.essepuntato.it/lode

# Chapter 4

## Legal Ontology for Nexus: Water, Energy and Food in EU Regulations

"*It is amusing to discover, in the twentieth century, that the quarrels between two lovers, two mathematicians, two nations, two economic systems, usually assumed insoluble in a finite period should exhibit one mechanism, the semantic mechanism of identification - the discovery of which makes universal agreement possible, in mathematics and in life*."

- Alfred Habdank Skarbek Korzybski,

[A Polish-American independent scholar who developed a field called general semantics]

## 18 Overview of Legal Ontology for Nexus

Three EU legislations have been selected for extracting taxonomies of concepts and their definitions that are required for engineering legal ontology for water, energy and food nexus:

- Article 2 of EU Directive 98/83/EC that defines water intended for human consumption.
- Article 2 0f EU Directive 2003/30/EC that defines bio-fuels, and
- Article 2 of EU Regulation 178/2002/EC that defines food.

For building this ontology, maximum number of object and data properties is also taken from the above mentioned legislative texts. In the case of concepts definitions, beside these three selected legislative texts, a range of related EU legislations[217] have been used. However, popular, scholarly and professional literatures[218] also have been

[217] For example, there is no specific EU regulation that defines the term 'Activity'. However, Article 3 of REGULATION (EC) No 716/2007 mentions – "Member States shall submit to the Commission (Eurostat) data on foreign affiliates in respect of the characteristics, the economic activities and the geographical breakdown as referred to in Annexes I, II and III." And we found that Annexe III of this Regulation provides a list of activities that Member States must follow in order to produce their corresponding reporting in a prescribed manner. Hence, we linked this Article, in the annotation of the entity 'Activity', in order to show legal compatibility and generic importance, as a legal taxonomy, of entity 'Activity' with EU Regulations.

[218] Differences among popular, scholarly and professional literatures are – popular literature mainly covers news and current events of people, places and political concerns, whereas scholarly literatures are generated by researchers and published through peer-review process, and professional literatures are produced by professionals maintaining standard of scholarly literature such as dictionary and newsletter etc. See more http://newarkwww.rutgers.edu/ecollege/popular.htm

used in order to extract the most suitable concept's definition, when we particularly failed to get a legal definition of those required concepts. Nevertheless, we engineered five following ontologies, with separated OWL files, considering reusability features of these ontologies[219] –

- WEF nexus top classes ontology, which is based on umbrella terms those are commonly used in other ontologies listed below.
- EDDefWater ontology which is based on EU definition of water intended for human consumption
- EUDefBiofuels ontology which is based on EU definition of biofuels
- EUDefFood ontology which is based on EU definition of food
- EUWEFNexus ontology which is merged with all ontologies listed above.

WEFTopclasses is reused by importing in the building of other ontologies - ontologies of EU legal definitions of water, biofuels and food. Then all above ontologies are merged in order to produce the legal ontology for nexus and constructed it as a separate OWL ontology. In the merged ontology, it is found that common entities that exist in different ontologies without changing their concept definition and restriction/s. However, it is noteworthy to emphasize the fact that merging ontology rather enhanced, beside reusability, the scalability[220] of legal ontology for Nexus.

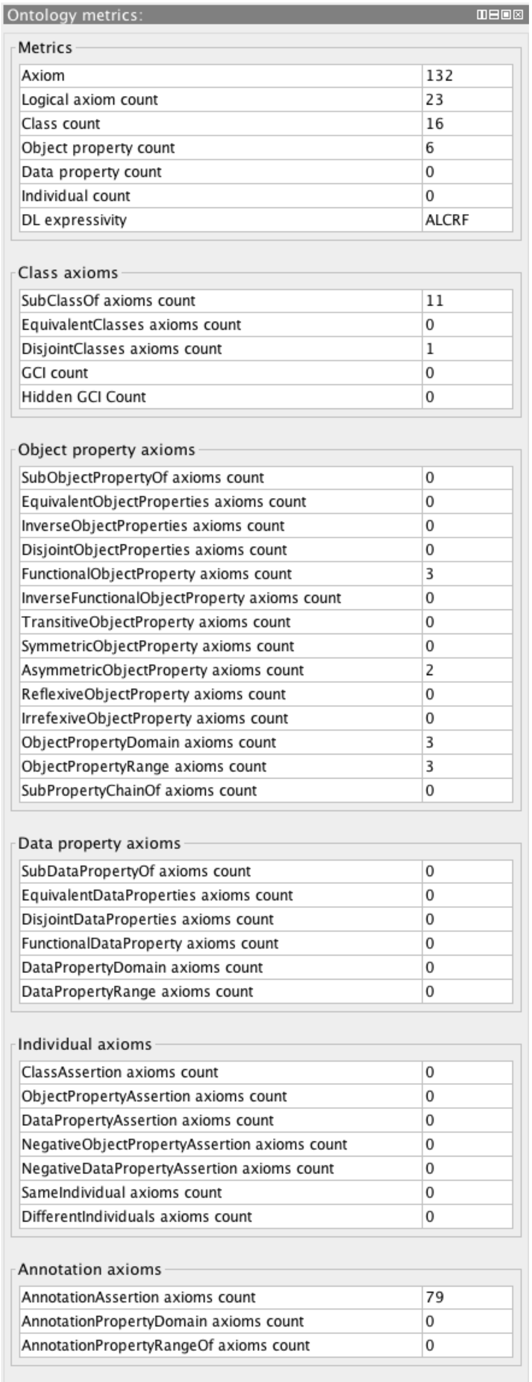
This chapter demonstrates five legal ontologies for nexus that includes WEF TopClasses ontology. It first starts enunciating Topclasses ontology for water, energy and food nexus. Then it subsequently presents legal ontologies of water, energy and food describing concept definitions, extracted from various EU regulations, and different concept enrichment mechanisms such as constructing restrictions over concepts and their corresponding properties. At the end, it deploys legal ontology for nexus. In addition, it also explains the reasoners'[221] results at the end of descripting each ontology. All ontologies are described by maintaining following structure –

- Describing taxonomies and their related concept definitions
- Presenting constitutive rule, in case of ontology of EU definitions
- Object and data property descriptions
- Restrictions over entities
- Reasoners' result

[219] See Motta, E., Fensel, D., Gaspari, M. and Benjamins, R.: Specifications of Knowledge Components for Reuse, In Proceedings of the 11th International Conference on Software Engineering and Knowledge Engineering, Kaiserslautern, Germany, KSI Press, pp. 36-43 (1999).

[220] See Zhao, G., Meersman, R.: Architecting ontology for scalability and versatility. In On the Move to Meaningful Internet Systems 2005: CoopIS, DOA, and ODBASE Lecture Notes in Computer Science Volume 3761, 2005, pp 1605-1614.

[221] See Kontopoulos, E., Bassiliades, N., Governatori, G., Antoniou, G.: A Modal defeasible Reasoner of Deontic Logic for the Semantic Web. In: International Journal on Semantc Web and Information Systems, 2011, 18-43.



Ontology metrics:

| Metrics | |
|---|---|
| Axiom | 132 |
| Logical axiom count | 23 |
| Class count | 16 |
| Object property count | 6 |
| Data property count | 0 |
| Individual count | 0 |
| DL expressivity | ALCRF |

| Class axioms | |
|---|---|
| SubClassOf axioms count | 11 |
| EquivalentClasses axioms count | 0 |
| DisjointClasses axioms count | 1 |
| GCI count | 0 |
| Hidden GCI Count | 0 |

| Object property axioms | |
|---|---|
| SubObjectPropertyOf axioms count | 0 |
| EquivalentObjectProperties axioms count | 0 |
| InverseObjectProperties axioms count | 0 |
| DisjointObjectProperties axioms count | 0 |
| FunctionalObjectProperty axioms count | 3 |
| InverseFunctionalObjectProperty axioms count | 0 |
| TransitiveObjectProperty axioms count | 0 |
| SymmetricObjectProperty axioms count | 0 |
| AsymmetricObjectProperty axioms count | 2 |
| ReflexiveObjectProperty axioms count | 0 |
| IrrefexiveObjectProperty axioms count | 0 |
| ObjectPropertyDomain axioms count | 3 |
| ObjectPropertyRange axioms count | 3 |
| SubPropertyChainOf axioms count | 0 |

| Data property axioms | |
|---|---|
| SubDataPropertyOf axioms count | 0 |
| EquivalentDataProperties axioms count | 0 |
| DisjointDataProperties axioms count | 0 |
| FunctionalDataProperty axioms count | 0 |
| DataPropertyDomain axioms count | 0 |
| DataPropertyRange axioms count | 0 |

| Individual axioms | |
|---|---|
| ClassAssertion axioms count | 0 |
| ObjectPropertyAssertion axioms count | 0 |
| DataPropertyAssertion axioms count | 0 |
| NegativeObjectPropertyAssertion axioms count | 0 |
| NegativeDataPropertyAssertion axioms count | 0 |
| SameIndividual axioms count | 0 |
| DifferentIndividuals axioms count | 0 |

| Annotation axioms | |
|---|---|
| AnnotationAssertion axioms count | 79 |
| AnnotationPropertyDomain axioms count | 0 |
| AnnotationPropertyRangeOf axioms count | 0 |

**Fig.1.** WEFNexusTopClasses Ontology metrics

In the case of modeling ontologies, Protégé 5 has been used as ontology editor and three plug-in reasoners have been used for checking overall consistency performance of the ontology. These reasoners are - Fact++, HermiT 1.3.8.3., and Pellet. In order to make easier explanation, many graphs have been used, generated directly from the Protégé editor's platform.

# 19 WEFNexusTopClasses Ontology

The objective of building WEFNexusTopClasses ontology is to create first order umbrella entities and their properties enabling to shield the taxonomies those are extracted from diverse bodies of legislative texts for building ontology under consideration. For example, Article 2 of EU Directive 98/83/EC did not explicitly mention about the entity 'Activity', (see the taxonomies of WEFNexusTopClasses given in Figure 2). Nevertheless, it mentioned some activities those are related with the usages of 'water intended for human consumption' such as cooking, drinking and other domestic usages of water. Therefore, the entity 'Activity' is used as a top class in the WEFNexusTopClasses ontology in order to cover all sub-classes of the entity 'Activity' mentioned in different legislations engineered, for example, in the EUDefWater ontology. However, that is further reused in developing other ontologies of legal definitions through directly importing WEFNexusTopClasses ontology into others.

There are total sixteen entities – eleven classes and five sub-classes, and six object properties operating with total 132 axioms and 23 logical axioms with ALCRF expressivity, shown in Figure 1. Among the class axioms, there are 11 axioms related with sub-classes and 1 disjoint axiom. In the case of object property axioms, there are 3 functional, 2 asymmetric, 3 domains and 3 ranges object property axioms. In addition, there are 79 annotation axioms have been used in order to express entities' metadata such as concept's definitions in comment annotation and further reference in seeAlso annotation etc.

The following sub-sections are dedicated to describe all entities, including classes, sub-classes and properties, and their relationships through unfolding different restrictions that play important roles over these entities. At the end, it also shows the reasoners' result of the ontology.

## 19.1 Taxonomy of WEFNexusTopClasses ontology

There are 16 entities in the taxonomy of WEFNexusTopClasses ontology - Activity', 'Product', 'Market', 'Material', 'LivingOrganism', 'Substance', 'Authority', 'Sources', 'Quality', 'ConstitutiveRule', 'Resource'. The entity 'Activity' has two sub-classes – 'ProductionActivity' and 'ConsumptionActivity', and the entitty 'LivingOrganism' has three sub-classes – 'Plant', 'Human', and 'Animal', shown in Figure 2.

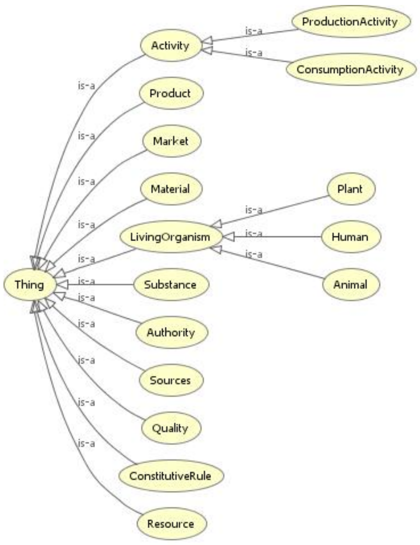



**Fig.2.** Taxonomy of WEFNexusTopClasses ontology

Most of all concept definitions of classes and sub-classes are taken from legislative texts. If not found any appropriate legal definition or legal content based description for making meaning of the concepts, dictionary and other popular, scholar and professional literature has been used. The descriptions of each entity are given below.

**Entity 'Activity'.** Oxford dictionary defines the term 'Activity' as "a thing that a person or group does or has done". In biology, the term 'Activity' is used to express a process, such as digestion, that any living organism performs in order to be alive. However in the case of legal definition of 'Activity', there is no such EU regulation directly defines it. The 'Activity' as a legal term with a particular meaning has been used in the Regulation (EC) No 716/2007[222], where a list of 'Activity' is given for foreign administrative works and formal reporting purposes. Furthermore, a lot of terms[223] have been using in EU water, energy and food domains which can be a type of activity, but no EU legislation from these domains gave a proper legal definition of it. Therefore, the meaning of oxford dictionary of it used[224] and it is selected as a Top Class for the legal ontology for WEF Nexus in order to categorize all types activities mentioned in the EU water, biofuels and Food definitions. The term 'Activity' has two subclasses – ProductionActivity and ConsumptionActivity.

*Entity 'ProductionActivity'* . Oxford dictionary defines 'ProductionActivity' as an activity of making something from raw materials. It also referred as a series of activities, mainly considered as process, of being something assembled or manufactured. However, there are many terms exist in EU food definition which can be addressed as a type of ProductionActivity. For example, Article 2 of EU Regulation 178/2002/EC mentions about preparation, preservation, processing and marketing of the food production. All of these terms can be directed under the term 'ProductionActivity'.

*Entity 'ConsumptionActivity'* . Angus Deaton (1992) in his book "understanding consumption"[225] mentioned that 'ConsumptionActivity' is a kind of activity that helps us to consume goods and services. It also refers activity involved with final usages of goods and services in order to satisfy human wants and needs. Even though, like 'ProductionActivity', there is no legal definition of it, there are many terms exist in Article 2 of EU Directive 98/83/EC and Regulation 178/2002/EC that can be directed under the TopClass term 'ConsumptionActivity'. Few examples of such terms are – 'Feed', 'Cooking', 'FoodPreparation', 'Drinking' etc.

[222] Of the European Parliament and of the Council of 20 June 2007 on Community statistics on the structure and activity of foreign affiliates.

[223] Article 2 of EU Directive 98/83/EC mentions about cooking, drinking, and domestic usages of water and Article 2 of EU Regulation 178/2002/EC mentions about food production.

[224] Which is in compatible with the Regulation (EC) No 716/2007, even though this Regulation particularly contextualized the term 'Activity' for foreign administrative and reporting works. Because the Annex 3 of this Regulation provided a list of 'Activity' those are implied with the definition given by the oxford dictionary.

[225] Published by Oxford University Press. ISBN 0-19-828824-7.

**Entity 'Authority'.** There is no generic legal definition of the term 'Authority'. However, there are many EU Regulations of specific domains by which the institutions are formed; each of such EU Regulations provides a legal definition of the term 'Authority' in order to cover that particular context and domains[226]. However, the Business dictionary[227] defines authority as "institutionalized and legal power inherent in a particular job, function, or position that is meant to enable its holder to successfully carry out his or her responsibilities". This definition of the authority is also in compatible with following two other definitions –

*Definition 1 - Power that is legally and formally institutionalized in order to perform certain legal activities, generally domain based.*

*Definition 2 – A legal personality or agency formed by government in order to perform and achieve some policy goal.*

Now if above definitions are considered, it means that there is a multiple authority that exists in order to maintain each of EU WEF domains. Hence, the term 'Authority' must be a Top Class entity for WEF ontology, which may further contains name of domain specific authorities those are installed by various legislations. For example, Article 2 of EU Directive 98/83/EC does not define generic meaning of the term 'Authority', but mentioned the quality and wholesomeness of foodstuffs are checked by competent national authorities in the water domain.

**Entity 'ConstitutiveRule'.** Prof. John Searle in his works[228] mentioned that an activity is generated by constitutive rules the origin of which is logically dependent on the rules. These rules can be generally two types – imperative as well as non-imperative or count-as. The most famous example of such rules is chess rules or rules of football. However, there is no such EU legislation that defines specifically the term 'constitutive rules'. But Article 9(6) of Directive 2014/65/EU[229] clearly indicated the important of application of constitutive rules in business administration without defining the constitutive rules. It provides the legal reasoning ground for legalizing the activities inherited from the legal rules.

---

[226] For example, Article 2(1) of Regulation (EC) No 1925/2006 defines 'Authority' means – "the European Food Safety Authority established by Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety".

[227] The businessdictionary.com

[228] (a) John Searle, Speech Acts, Cambridge University Press 1969, ISBN 0-521-09626-X. (b) John Searle, "Indirect speech acts." In Syntax and Semantics, 3: Speech Acts, ed. P. Cole & J. L. Morgan, pp. 59–82. New York: Academic Press. (1975). Reprinted in Pragmatics: A Reader, ed. S. Davis, pp. 265–277. Oxford: Oxford University Press. (1991)

[229] Of the European Parliament and of the Council of 15 May 2014 on markets in financial instruments and amending Directive 2002/92/EC and Directive 2011/61/EU.

In the case of EU definitions of water, bio-fuels and food, there exist a number of constitutive rules that generate activities the origin of which are entirely dependent on the rules mentioned in the definition. For example, Article 2 of EU Directive 98/83/EC carries a constitutive rule is that water used in the food preparation must maintain the quality of the water intended for human consumption without compromising the wholesomeness of the foodstuffs. Because this rule simply generates a number of activities such as – (a) cleaning the water if it is waste water, (b) implication of water quality mentioned in the Annexes of EU Directive 98/83/EC, (c) investigating the wholesomeness of the foodstuffs when water is applied to it in according to the laws of the competent authority, and (d) etc. In order to perform these activities, it is also required to comply with other legal rules coming from EU energy and food Regulations. Therefore, in order to create a common ontological path for all constitutive rules coming from different EU Regulations, it has been selected as one of TopClasses.

**Entity 'LivingOrganism'.** Even though there is no specific EU legislation that defines the term 'living organism', Article 2(1) of Directive 2001/18/EC[230] defines organism as "any biological entity capable of replication or of transferring genetic material". However, the Biology dictionary[231] defines living organism as "any organism or a living form that possesses or shows the characteristics of life or being alive. They provided 9 characteristics of living organism that includes 7 abilities – such as having organized structure, requires energy to survive, ability to reproduce/ grow/ metabolize/ respond to stimuli/ adapt to the environment/ move/ and respire. In the case of EU definitions of water, biofules and food, there mentions different types of living organisms without even defining the meaning of the term 'living organism'. For example, the term 'human', 'plant', 'animal' is used in EU water, food and bio-fuel definitions respectively. As a result, it has been used as another top class with following three sub-classes.

*Entity 'Animal'* . Biology dictionary defines animal as a living organism possess minimum following characteristics – being eukaryotic and multicellular, being heterotrophic and digesting food in internal chamber, lacking cell wall, being generally motile, embryos passes through a blastula stage and possessing specialized sensory organs. In addition, Article 3(5) of Regulation (EC) No 1069/2009[232] defines animal as any invertebrate or vertebrate animal. Furthermore, Article 2 of EU Directive 2003/30/EC mentions that one of the sources of biomass is animal substance by which biofuel are produced. This is why the term 'Animal' is used as one of the Top-classes.

[230] Of the European Parliament and of the Council of 12 March 2001 on the deliberate release into the environment of genetically modified organisms and repealing Council Directive 90/220/EEC.

[231] See biology-online.org/dictionary

[232] Of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002.

*Entity 'Human'*. Mcllinioff's dictionary[233] defines – "a Human being, living organism, is without regard to sex, legitimacy, or competence and also addresses as 'Natural person' in law. This person is the central figure of law, as elsewhere, characterized by personal attributes of mind, intention, feelings, weaknesses, morality common to human beings, with rights and duties under the law". In addition, Biology dictionary mentioned that human being also can be addressed as social animal that has capability of living life with inherent values and ethics. Inappropriately, there is no EU legislation carries the legal definition of the term 'human being'. However, on one hand, Article 2 of EU Directive 98/83/EC defines the water that is particularly intended for human consumption, but the Directive did not define the meaning of 'human being'. On the other hand, like EU water definition, Article 2 of EU Regulation 178/2002/EC defines food designed for human consumption but does not define the term 'human'. As the term 'human being' is common at EU water and food definitions, it is used as a top class.

*Entity 'Plant'* . Free dictionary[234] defines plant as a living organism that typically synthesizes its food from inorganic substances, without sense organs, nervous system and power of locomotion, but possesses cellulose cell walls. In line with this definition, Article 3(5) of Regulation (EC) No 1107/2009[235] also defines plants as "live plants and live parts of plants, including fresh fruit, vegetables and seeds". The term 'Plant' has been commonly used in EU biofuel and food definitions, hence it is used as a top-class.

**Entity 'Market'.** Even though there is no legal definition of the term 'market' exists in the EU Regulations, there are many EU legislations related with the term 'internal market', 'single market', and/or 'relevant market'. EU Regulations related with single market[236] defines market in which free movement of goods, services, capital and persons is ensured and in which EU citizens can do business legally and are free to work, study and live. In the case of EU food and biofuels definition, there are many terms exist those have property relationship with the term 'Market'. For example, Article 2 of EU Regulation 178/2002/EC mentions that if the meat is produced for the market, then it is considered as food, otherwise not. That also has direct and indirect property relationship with other terms exist in EU water and biofuel definitions. Hence, the term 'Market' is used as a top class.

---

[233] Mcllinioff's Dictionary of American Legal Usage, 1992.
[234] See thefreedictionary.com
[235] Of the European Parliament and of the Council of 21 October 2009 concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC
[236] Regulation (EU) No 596/2014 of the European Parliament and of the Council of 16 April 2014 on market abuse (market abuse regulation) and repealing Directive 2003/6/EC of the European Parliament and of the Council and Commission Directives 2003/124/EC, 2003/125/EC and 2004/72/EC.

**Entity 'Material'.** Free dictionary defines the material as "a substance of which a thing is made or composed". In EU Regulation[237], it also says that material is the matter from which something is made out of. There are many terms in the EU water, biofuels and food definitions can be considered as a type of Material. For example, Article 2 of EU Regulation 178/2002/EC mentions the term 'WaterSubstance' which is used to produce 'FoodProduct'. Another example is Article 2 of EU Directive 2003/30/EC mentions the terms such as 'Biomass', 'BiodegradableFractionOfProduct', 'IndustrialWaste', by which biofuel is produced. Therefore, these terms are subclasses of the top-class 'Material'.

**Entity 'Product'.** Business dictionary[238] defines product as commercially distributed goods that is an output of production processes and/or manufacturing and passes through a distribution channel in order to make it consumed and/or used. In EU Regulation[239], a product is when it is made using traditional materials and characterized by a traditional composition or method. However, in the case of EU water, food and biofuels definitions, there are many terms can be headed under the top class ''Product'. For example, Article 2 of EU Regulation 178/2002/EC has following terms 'Cosmetic', 'MedicinalProduct', 'TabaccoProducts', 'ChewingGum', 'Drink', 'FoodSubstance' etc and Article 2 of EU Directive 2003/30/EC has following terms 'SyntheticBiofuel'. These all terms can be types of top-class 'Product'.

**Entity 'Quality'.** Even though there is no such EU legislation provide a generic definition of quality, EU Regulation 2023/2006[240] defines the term 'good manufacturing practice (GMP)' as "those aspects of quality assurance which ensure that materials and articles are consistently produced and controlled to ensure conformity with the rules applicable to them and with the quality standards appropriate to their intended use by not endangering human health or causing an unacceptable change in the composition of the food or causing a deterioration in the organoleptic characteristics thereof". In addition, EU Directive 98/83/EC also provides quality standard of water intended for human consumption, without giving a definition of what is quality, and EU Regulation 178/2002/EC also indicates the quality of food as wholesomeness of the foodstuff, but does not clarify the meaning of wholesomeness. In the case of EU biofuels definition, EU Directive 2003/30/EC says that biofuels must be made out of biomass, not from other materials and/or substance, which indicates 'biomass' as a quality material sources for producing biofuels. It means there are many terms in EU water, biofuels and food definitions those concern with the top-class 'quality'.

---

[237] Regulation (EC) No 1935/2004 of the European Parliament and of the Council of 27 October 2004 on materials and articles intended to come into contact with food and repealing Directives 80/590/EEC and 89/109/EEC.

[238] See businessdictionary.com

[239] Council Regulation (EC) No 509/2006 of 20 March 2006 on agricultural products and foodstuffs as traditional specialities guaranteed

[240] Commission Regulation (EC) No 2023/2006 of 22 December 2006 on good manufacturing practice for materials and articles intended to come into contact with food.

**Entity 'Resource'.** Miller and Spoolman (2011)[241] defined resources[242] as materials, services, knowledge or other assets that are converted to produce some benefits and/or satisfy some needs. Even though there is no specific legal definition of it in EU legislations, many EU regulations indirectly used this term in order to produce some important constitutive rules. For example, Article 2 of EU Directive 2003/30/EC mentions that the source of biofuels is biomass as a renewable energy source, but does not indicate that biofuel itself is a renewable energy resource. Another example, Article 2 of EU Regulation 178/2002/EC says that water-substance itself is a food as well as the source of food. However these legislations indirectly expresses that biofuel and water itself are resources. Hence the term 'Resource' is used as a top-class.

**Entity 'Source'.** Oxford dictionary defines source as "a place, person, or thing from which something comes or can be obtained". In addition, even though EU Directive 2003/30/EC does not define what is source, it mentions the term 'source' in its Article 2(1)(c) saying that "other renewable fuels' means renewable fuels, other than biofuels, which originate from renewable energy sources as defined in Directive 2001/77/EC (2) and used for transport purposes". Also Article 2 of EU Directive 98/83/EC implicitly mentions that original water also can be a source of water intended for human consumption. Furthermore, Article 2 of EU Regulation 178/2002/EC likewise mentions that 'water' can be a source of food. As all of EU water, biofuels and food definitions have some terms and property relationships with the term 'source', it has been used as a top-class.

**Entity 'Substance'.** In US cases[243], the term 'substance' has been defined as essential part of a thing as distinguished from form. In EU, Article 3(2) of Regulation (EU) No 649/2012[244] says that substance' means any chemical element and its compounds as defined in point 1 of Article 3 of Regulation (EC) No 1907/2006[245]. In the case of EU water, biofuels and food definitions, there are a lot of terms can be categorized as type of substance such as 'AnimalSubstance', 'Carbon', 'Contaminant', 'PsychotropicSub-

[241] Miller, G.T., and S. Spoolman (2011). Living in the Environment: Principles, Connections, and Solutions (17th ed.). Belmont, CA: Brooks-Cole. ISBN 0-538-73534-1.

[242] See also Jump up to: a b Ricklefs, R.E. (2005). The Economy of Nature (6th ed.). New York, NY: WH Freeman. ISBN 0-7167-8697-4.

[243] See (a) State v. Iiurgdoerfer, 107 Mo. 1, 17 S. W. 040, 14 L, It. A. 846: and (b) Hugo v. Miller, 50 Minn. 105. 52 N. W. 3S1 ; Pierson v. Insurance Co., 7 Iloust. (Del.) 307, 31 Atl. 900.

[244] Regulation (EU) No 649/2012 of the European Parliament and of the Council of 4 July 2012 concerning the export and import of hazardous chemicals Text with EEA relevance.

[245] Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC.

stance', 'TobaccoSubstance', 'Water', 'VegetalSubstance', 'FoodSubstance' etc. Therefore, the term 'Substance' is used as a top-class.

### 19.2 Top-object properties of WEFNexusTopClasses ontology

There are six object-properties have been used in order to establish relationship between and among top-classes. These properties are –

**isCheeckedBy.** This object-property shows the answer of who checks what? More appropriately, it expresses agent-action[246] relationships. For example, competent authority checks wholesomeness of the foodstuff or quality of the water intended for human consumption.

**isMaintainedBy.** This object-property gives the answer of what is maintained by whom? For example, Article 2 of EU Directive 98/83/EC says that the competent national authority maintains that quality check of the water intended for human consumption and also the wholesomeness of the foodstuffs whether affected by the water-substance taking into it.

**isPerformedBy.** This object-property helps to model answer of the question like who performs what? More precisely, the relationships among top-classes such 'Activity', 'ConstitutiveRule', 'Human', and 'Authority' can be established easily with this property. For example, it is easy to ontologically model this statement – both human and authority performs the activity generated by constitutive rules.

**isUsedFor.** This object-property helps to engineer the answer of what is used for what to be done? For example, Article 2 of EU Regulation 178/2002/EC clearly mentions that only biomass is used for making biofuels. From the top-class ontological perspective, here the term 'Biomass' is a material because of it has been used to produce biofuel, and the term 'Biofuel' is itself a type of 'Resource' as well as a type of 'Source' and/or 'Product', because of it depends on the purpose for which biofuel is used.

**maintains.** This object-property models the answer of 'who/what maintains what?' For example EU Regulation 178/2002/EC establishes the Food Security Authority who is responsible for maintaining food market. Hence, this property helps to model the relationship between the top classes – 'Authority' and 'market'.

[246] See E. Lorini, D. Longin, B. Gaudou, and A. Herzig. The Logic of acceptance: grounding institutions on agents attitudes. Journal of Logic and Computation, 19(6), 2009.

**mustMaintain.** This object-property is used as a special one due to its associated verb ‘must’. Because it gives a sense of implication of obligation over the classes as well as sub-classes. For example, EU Directive 98/83/EC says that water intended for human consumption must maintain its quality which is mentioned in the Annexes of the same legislation.

### 19.3 Restrictions over the entities in WEFNexusTopClasses ontology

A number of restrictions are designed over the entities of the WEFNexusTopClasses ontology. These restrictions do not only express the relationships that exist over the class and its associated properties, rather these provide a kind of semantic networks of constitutive rule expressed by the combined form of asserted and inferred model of those restrictions. These are discussed below –

**Restrictions over the classes – ‘Authority’ and ‘ConstitutiveRule’.** The object property ‘isMaintainedBy’ is used to establish the functional relationships between these two top classes. The domain of ‘isMaintainedBy’ is ‘Authority’ and range is ‘ConstitutiveRule’, shown in Figure 3. The statement that these top-classes and object property expresses is that constitutive rule is maintained by authority.

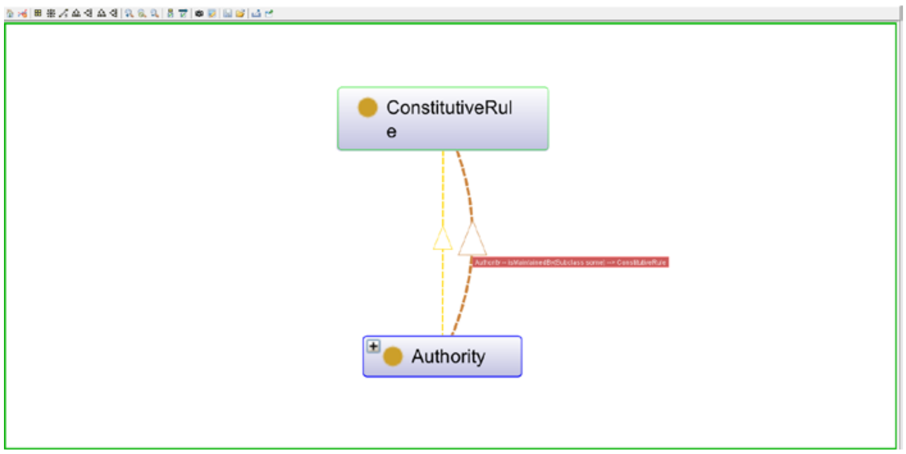



**Fig.3.** Restrictions over the classes – ‘Authority’, ‘Human’ and ‘ConstitutiveRule’

**Restrictions over the class ‘Authority’.** Four object properties – ‘isCheckedBy’, ‘isMaintainedBy’, and ‘maintains’ have been used to established relationships between ‘Authority’ and ‘ConstitutiveRule’, ‘Resource’, ‘Source’, ‘Quality’, ‘Market’, ‘Material’, shown in Figure 4.

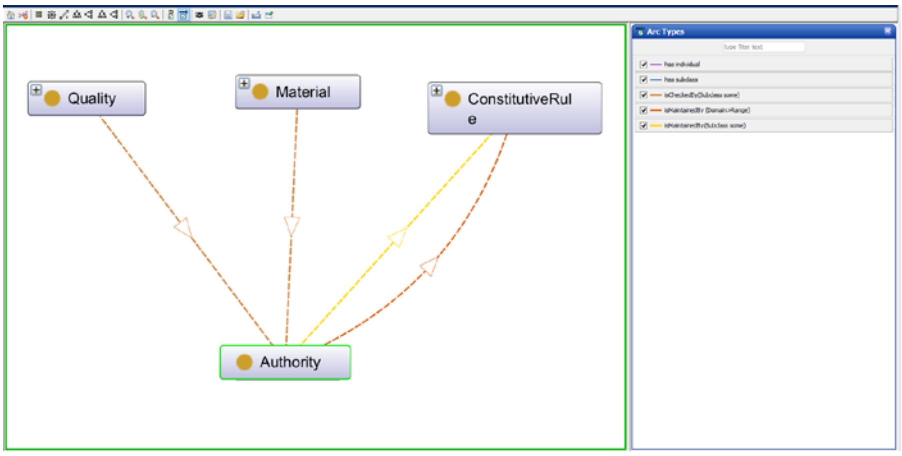



**Fig.4.** Restrictions over the entity 'Authority'

Following restrictions have been modeled with these object properties –

$$Authority \sqsubseteq \exists maintains\ .\ (Market \sqcup Resource \sqcup Sources) \qquad (R1)$$

$$Authority \sqsubseteq \exists\ isMaintainedBy\ .\ (ConstitutiveRule) \qquad (R2)$$

$$Quality \sqsubseteq \exists\ isCheckedBy\ .\ (Authority) \qquad (R3)$$

In the case of R2 and R3, the top class ‘Authority’ is used as a subclass of these restrictions.

**Restriction over the entity ‘Product’ and ‘Quality’.** There are two object properties used for modeling restrictions, see R3 and R4, over these entities – ‘mustMaintain’ and ‘isCheckedBy’, shown in Figure 4 and 5.

$$Product \sqsubseteq \exists mustMaintain\ .\ (\ Quality\ ) \qquad (R4)$$

**Restriction over the entity ‘Activity’.** Object-property ‘isPerformedBy’ is used to make relationship between the entities ‘Activity’ and ‘Human’, show in Figure 5 and R5.

$$Activity \sqsubseteq \exists\ isPerformedBy\ .\ (\ Human\ ) \qquad (R5)$$

**Restriction over the entity “Substance’ .** the relationship between the entities ‘Substance’ and ‘Product’ is modeled by the Object-property ‘isUsedFor’ where the entity ‘Substance’ is used as a subclass of this restriction., shown in Figure 5 and R6.

$$Substance \sqsubseteq \exists isUsedFor\ .\ (\ Product\ ) \qquad (R6)$$

The above mentioned restrictions are asserted manually. However, as a by-product of these asserted restrictions, there exist inferred restrictions too. The R5, for example, is inferred into the sub-classes of the term ‘Activity’ – ‘ConsumptionActivity’ and ‘ProductionActivity’ and produce following inferred restrictions, shown in R7 and R8. In both cases, the terms ‘ConsumptionActivity’ and ‘ProductionActivity’ are used as a subclass of the restriction, shown in Figure 5.

$$ConsumptionActivity \sqsubseteq \exists\ isPerformedBy\ .\ (\ Human\ ) \qquad (R7)$$

$$ProductionActivity \sqsubseteq \exists\ isPerformedBy\ .\ (\ Human\ ) \qquad (R8)$$

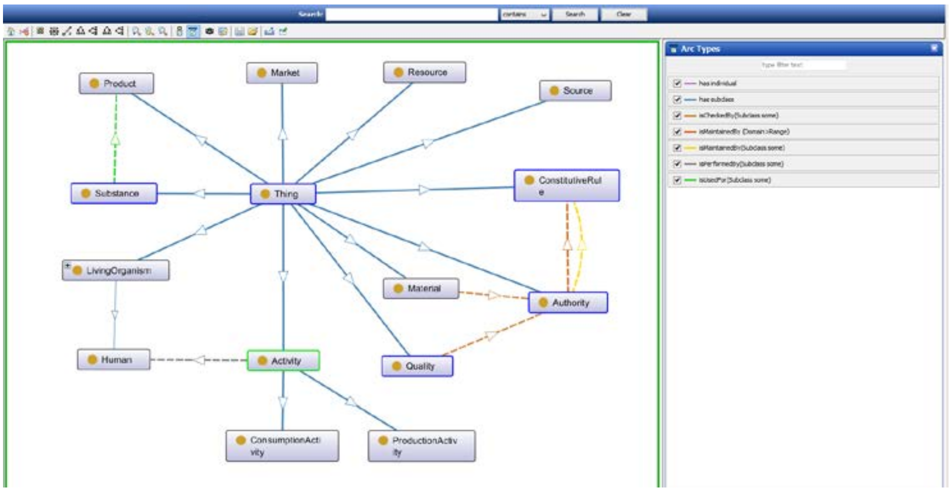



**Fig. 5.** WEFNexusTopClasses ontology

## 19.4 Reasoner’s result of WEFNexusTopClasses ontology

No error and inconsistency is shown by the reasoners. Inferences of class and object property hierarchies are shown sound and completed. Inferences between disjoint class, between the terms ‘Human’ and ‘Animal’ and the terms ‘Resource’ and ‘Sources’ are shown correct and consistence while executing restrictions – shown in R1 to R8. The summary of the reasoner’s result is given in the Table 1.

**Table 1.** Reasoner’s result of WEFNexusTopClasses ontology

| *Reasoners* <br> *Inference types* | *Fact ++* | *HermiT 1.3.8. and 1.3.8.3.* | *Pellet and Pellet (Incremental)* |
|---|---|---|---|
| Error and inconsistency | No | No | No |
| Class inferences | Satisfied | Satisfied | Satisfied |
| Object property inferences | Satisfied | Satisfied | Satisfied |
| Axioms inferences | Sound | Sound | Sound |

# 20 EUDefWater ontology

Article 2(1)[247] of EU Directive 98/83/EC is selected for modeling EU water definition ontology. WEFNexusTopClasses are directly imported, as to reuse, and used as a primary basis of all entities, properties and restrictions in this ontology. There are total 47 classes and sub-classes, including 16 top-classes, and 17 object-properties that include 6 top object-properties imported directly from WEFNexusTopClasses ontology. There are total 401 axioms including 118 logical axioms based on ALCRIF expressivity, shown in Figure 6. In addition, the metrics of it shows following asserted expressions –

- 53 sub-classes and 8 dis-joint classes axioms,
- 2 sub object-property and 1 inverse object-property axioms,
- 14 functional and 12 asymmetric object-property axioms,
- 14 object-property domains and 14 object-property ranges, and
- 211 annotation assertion axioms.

In this section, taxonomy of all entities and object-properties has been discussed. Then all major asserted restrictions and reasoner's result has been explained.

## 20.1 Taxonomy of EUDefWater ontology

[247] 'water intended for human consumption' shall mean:

(a) all water either in its original state or after treatment, intended for drinking, cooking, food preparation or other domestic purposes, regardless of its origin and whether it is supplied from a distribution network, from a tanker, or in bottles or containers;

(b) all water used in any food-production undertaking for the manufacture, processing, preservation or marketing of products or substances intended for human consumption unless the competent national authorities are satisfied that the quality of the water cannot affect the wholesomeness of the foodstuff in its finished form;

Ontology metrics:

Metrics

| | |
|---|---|
| Axiom | 401 |
| Logical axiom count | 118 |
| Class count | 47 |
| Object property count | 17 |
| Data property count | 0 |
| Individual count | 0 |
| DL expressivity | ALCRIF |

Class axioms

| | |
|---|---|
| SubClassOf axioms count | 53 |
| EquivalentClasses axioms count | 0 |
| DisjointClasses axioms count | 8 |
| GCI count | 0 |
| Hidden GCI Count | 0 |

Object property axioms

| | |
|---|---|
| SubObjectPropertyOf axioms count | 2 |
| EquivalentObjectProperties axioms count | 0 |
| InverseObjectProperties axioms count | 1 |
| DisjointObjectProperties axioms count | 0 |
| FunctionalObjectProperty axioms count | 14 |
| InverseFunctionalObjectProperty axioms count | 0 |
| TransitiveObjectProperty axioms count | 0 |
| SymmetricObjectProperty axioms count | 0 |
| AsymmetricObjectProperty axioms count | 12 |
| ReflexiveObjectProperty axioms count | 0 |
| IrrefexiveObjectProperty axioms count | 0 |
| ObjectPropertyDomain axioms count | 14 |
| ObjectPropertyRange axioms count | 14 |
| SubPropertyChainOf axioms count | 0 |

Data property axioms

| | |
|---|---|
| SubDataPropertyOf axioms count | 0 |
| EquivalentDataProperties axioms count | 0 |
| DisjointDataProperties axioms count | 0 |
| FunctionalDataProperty axioms count | 0 |
| DataPropertyDomain axioms count | 0 |
| DataPropertyRange axioms count | 0 |

Individual axioms

| | |
|---|---|
| ClassAssertion axioms count | 0 |
| ObjectPropertyAssertion axioms count | 0 |
| DataPropertyAssertion axioms count | 0 |
| NegativeObjectPropertyAssertion axioms count | 0 |
| NegativeDataPropertyAssertion axioms count | 0 |
| SameIndividual axioms count | 0 |
| DifferentIndividuals axioms count | 0 |

Annotation axioms

| | |
|---|---|
| AnnotationAssertion axioms count | 211 |
| AnnotationPropertyDomain axioms count | 0 |
| AnnotationPropertyRangeOf axioms count | 0 |

**Fig.6.** Metrics of EUDefWater ontology

There are 31 classes and subclasses excluding 16 top-classes imported from the WEFNexusTopClasses ontology. This taxonomy is extracted from the legislative text of Article 2 (1) of EU Directive 98/83/EC. Maximum of them are explicitly mentioned in legislation. However, some of them are taken from the meaning of the legislative text in order to make this ontology clear with less ambiguity. These classes and sub-classes are under the top-class 'Activity' – 'HumanConsumption', 'HumanConsumptionActivity', 'Cooking', 'DomesticActivity', 'Drinking', 'FoodPreparation', 'DistributionOfWater', 'FromDistributionNetwork', 'FromTanker', 'InBottle', 'InContainer', 'FoodProductionActivity', 'MaufatureOfFoodProduction', 'MarkeingOfFoodProduction','PservtionOfFoodProduction', 'PrcessingOfFoodProduction'. 'CompetentNationalAuthoritiesInWaterDomain' and 'WaterIntendedForHumanConsumption' are the sub-classes under the top-class 'Authority' and 'ConstitutiveRule'. 'FoodProduct', 'FooProductWhereWaterIsUsed', 'FoodSubstance' are the sub-classes under the top-class 'Product'. Under the top-class 'Quality', there are two sub-classes – 'QualityOfWater' and 'WholesomenessOfFoodstuff'. Following entities 'FoodSubstance', 'Water', 'WasteWater', 'WaterAfterCompliance', 'WaterAfterTreatment', 'WaterInItsOriginalState', 'WaterBeforeTreatment', 'WaterSubstance', 'WaterSubstanceInFood' are sub-classes under the top-class

‘Substance’. In addition, there is no subclass under the top-classes – ‘LivingOrganism’, ‘Market’, ‘Materials’, ‘Resource’ and ‘Sources’. The concepts’ definitions in this taxonomy are taken in such way that is intended to particularly represent Article 2 (1) of EU Directive 98/83/EC, not to present water-energy-food nexus.


**Fig.7.** Taxonomy of EUDefWater ontology

There are many concepts that can be defined and engineered completely differently for the nexus or other purposes. One of such example is – the entity ‘ManufactureOfFoodProduction’ is shown as a subclass of ‘FoodProductionActivity’, which makes complete sense in the point of Article 2 (1) of EU Directive 98/83/EC. Because this legislation describes ‘ManufactureOfFoodProduction’ is a type of activity where water is likely to be used and the water is sued in the ‘ManufactureOfFoodProduction’ must be the ‘WaterIntendedForHumanConsumption’. However, the taxonomy of this ontology is described below, shown in Figure 7 –

**Entity ‘HumanConsumption’.** EU Directive 98/83/EC defines the water that is intended for human consumption without defining the concept ‘HumanConsumption’. Oxford dictionary, however, defines it as “the activity of eating, drinking, or ingesting of something and performed by human being”. European encyclopedia of law mentions that there are a number of EU legislations[248] describing food product for human consumption where the term ‘Water’ is used as a food.

**Entity ‘HumanConsumptionActivity’.** Article 2 (1) of EU Directive 98/83/EC defines it as any activity performed for and/or in relation with human consumption. Concept types of this activity are also given in same legislation such as cooking, domestic purpose, drinking, and/or food preparation.

**Entity ‘Cooking’.** EU Directive 98/83/EC did not fine the term ‘Cooking’, but just mentioned it as a type of ‘HumanConsumptionActivity’. However, Oxford dictionary defines it as an human consumption activity for preparing food by combing, heating and/or mixing ingredients where water is very likely to be used. In addition, Annex of EU Regulation No 451/2008[249] mentioned that a list of products used for cooking and legally addressed cooking as an activity.

**Entity ‘DomesticActivity’.** Article 2 (1) of EU Directive 98/83/EC mentions that ‘DomesticActivity’, fulfilling domestic purposes where water is directly and indirectly used, is a type of ‘HumanConsumptionActivity’ where water with regulative quality must be used as it is directed in the same legislation. Few examples of such activity can be washing clothes, bathing etc.

**Entity ‘Drinking’.** Oxford dictionary defines it as human consumption activity that deals with taking liquid into the mouth and swallows.

---

[248] See following legislation as an example, Regulation (EU) No 609/2013 of the European Parliament and of the Council of 12 June 2013 on food intended for infants and young children, food for special medical purposes, and total diet replacement for weight control and repealing Council Directive 92/52/EEC, Commission Directives 96/8/EC, 1999/21/EC, 2006/125/EC and 2006/141/EC, Directive 2009/39/EC of the European Parliament and of the Council and Commission Regulations (EC) No 41/2009 and (EC) No 953/2009.

[249] Regulation (EC) No 451/2008 of the European Parliament and of the Council of 23 April 2008 establishing a new statistical classification of products by activity (CPA) and repealing Council Regulation (EEC) No 3696/93.

**Entity 'FoodPreparation'.** Wikipedia[250] mentions it as a type of human consumption activity that prepares food for eating, which is not limited to cooking rather it requires to perform a certain type of activities such as selection, measurements and combinations of various food ingredients in order to acquire desired results.

**Entity 'DistributionOfWater'.** EPA[251] defines that "water distribution system is based on a set of collective activities distributing water to the targeted locations. It consists of an interconnected series of pipes, storage facilities, and components that convey drinking water and meeting fire protection and domestic needs for cities, homes, schools, hospitals, businesses, industries and other facilities". However, Article 2 (2) of EU Directive 98/83/EC[252] defines 'domestic distribution system' as a part of 'DistributionOfWater' that intended for only human consumption. In addition, Article 2(1) of the same legislation defines that 'DistributionOfWater' can be from four different ways – a) from distribution network, b) from tanker, c) in bottle, and d) in container. Therefore, these four entities are used as sub-classes of the entity 'DistributionOfWater'.

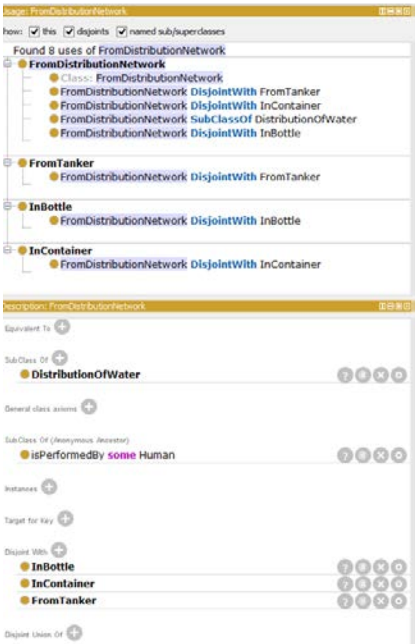


**Fig.8.** Usage of the term 'FromDistributionNetwork'

**Entity 'FromDistributionNetwork'.** EU Directive 2000/60/EC[253] defines that water distributed from the water distribution network is a water service activity. More precisely, the business dictionary defines it as a chain of distribution activities from the suppliers to the consumer using competing water distribution system. However, the term 'FromDistributionNetwork' is disjointed with following terms – 'FromTanker', 'InContainer', and 'InBottle' and is the sub-class of restriction 9, shown in R9 and Figure 8.

[250] See https://en.wikipedia.org/wiki/Outline_of_food_preparation

[251] United State Environmental Protection Agency

[252] 'Domestic distribution system` shall mean the pipework, fittings and appliances which are installed between the taps that are normally used for human consumption and the distribution network but only if they are not the responsibility of the water supplier, in its capacity as a water supplier, according to the relevant national law.

[253] Of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.

**Entity 'FromTanker'.** The dictionary[254] defines it as "a ship, lorry, or aeroplane designed to carry liquid in bulk, such as water, for the purpose of distributing water."

**Entity 'InBottle'.** In according to the Article 2 (1) of EU Directive 98/83/EC, one of the legitimate ways to distribute water is in bottle, which is generic type of the class 'DistributionOfWater'. Nevertheless, legislation did not define the meaning of bottle. The Wikipedia defines the bottled water[255] as – "drinking water (e.g., well water, distilled water, mineral water, or spring water) packaged in plastic or glass water bottles. Bottled water may be carbonated or not. Sizes range from small single serving bottles to large carboys for water coolers". The entity 'InBottle' is disjoint with other type of subclasses of 'DistributionOfWater' such as 'FromDistributionNetwork', 'FromTanker', and 'InContainer'.

**Entity 'InContainer'.** Article 2 (1) of EU Directive 98/83/EC says that water can be distributed in container too. The dictionary defines a container[256] is – "Container is a type of medium for distributing water. Generally is such object used for or capable of holding, esp for transport or storage, such as a carton, box, etc". This entity is also disjoint with 'FromDistribtuionNetwork', 'FromTanker', and 'InBottle'.

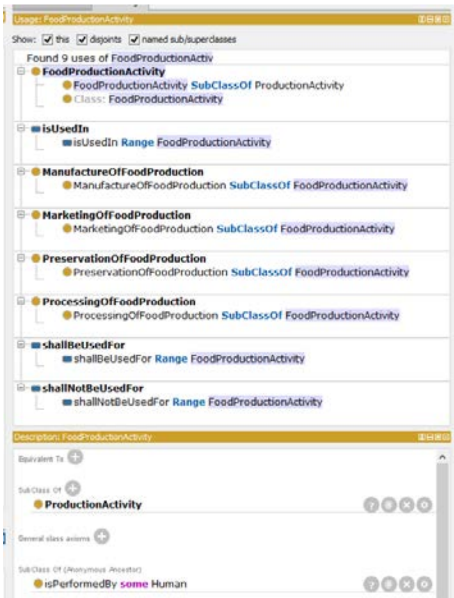


**Fig. 9.** Usages of the entity 'FoodProduction-Activity'

**Entity 'FoodProductionActivity'.** This is a sub-class of the top-class 'ProductionActivity'. In according to the Article 2 (1) of EU Directive 98/83/EC, 'FoodProductionActivity' is a type of 'Activity' where water is used, which must maintain certain level of water quality equivalent to 'water intended for human consumption'. CDC[257] defines 'FoodProductionActivity[258]' that is consisted with a series of activities for transforming raw materials into finished food products. This entity can be categorized into following four sub-classes – 'ManufactureOfFoodProduction', 'MarketingOfFoodProduction', 'PreservationOfFoodProduction', 'ProcessingOfFoodProduction'. There are total 9

[254] See more - http://dictionary.reference.com/browse/tanker
[255] see - https://en.wikipedia.org/wiki/Bottled_water
[256] see - http://dictionary.reference.com/browse/container
[257] Centers for Disease Control and Prevention
[258] See http://www.cdc.gov/foodsafety/outbreaks/investigating-outbreaks/production-chain.html

usages of this entity, shown in Figure 9. These sub-classes are mentioned in EU Directive 98/83/EC and described below –

**Entity 'ManufactureOfFoodProduction'.** Article 2 (1) of EU Directive 98/83/EC implicitly mentions that 'ManufactureOfFoodProduction' is a type of food production activity where water, which is intended for human consumption, is used. In addition, Regulation (EC) No 178/2002 [259] also recognized that manufacturing of the food production is involved with such type of activities that generate food production activity and business.

**Entity 'MarketingOfFoodProduction'.** Regulation (EC) No 1331/2008[260] explicitly mentions about various marketing activities involved with food production. Lars Perner[261] provided a general definition of 'MarketingOfFoodProduction' is that it is a kind of food production activity involved with general marketing approaches and techniques. Furthermore, Article 2 (1) of EU Directive 98/83/EC also says that marketing of food production is consisted with such activities where water might be used, hence water quality must be ensured par law.

**Entity 'PreservationOfFoodProduction'.** Encyclopedia[262] defines it as a food production activity which deals with preserving and/or preparing food in such a way so that food can be stored for the future use. In according to the Article 2 (1) of EU Directive 98/83/EC, preservation of food production is a type of food production activity where water is used.

**Entity 'ProcessingOfFoodProduction'.** Food processing takes clean and harvested components or raw materials and uses them in order to produce marketable food products[263]. EU water definition, as lied down in Article 2 (1) of EU Directive 98/83/EC, implicitly mentions that 'processing of food production' is a such activity where water is likely to be used and therefore, the quality of the water as described in the same legislation, must be followed.

**Entity 'CompetentNationalAuthoritiesInWaterDomain'.** UN defines national competent authorities are empowered to enforce as well as to regulate national con-

[259] Of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety.
[260] Of the European Parliament and of the Council of 16 December 2008 establishing a common authorisation procedure for food additives, food enzymes and food flavourings
[261] Assistant Professor of Clinical Marketing, Department of Marketing, Marshall School of Business, University of Southern California, Los Angeles, CA 90089-0443, USA,(213) 740-7127.
[262] See http://encyclopedia2.thefreedictionary.com/food+preservation
[263] See https://en.wikipedia.org/wiki/Food_processing

trols of certain domains through their procedural laws within their jurisdiction[264]. This is only sub-class of the top-class ‘Authority’. In EU system, Article 2(19) of Regulation (EC) no 1946/2003[265], mentions that "*competent authority" means a competent authority designated by a Party to the Protocol, or the relevant equivalent body of a non-Party, which is responsible for performing the administrative functions required by the Protocol, or equivalent functions in the case of a non-Party, and is authorised to act on its behalf with respect to those functions*”. However, Article 2 (1) of EU Directive 98/83/EC says that competent national authority of water domains will check the quality of water and water’s affect in the wholesomeness of foodstuffs as mentioned in the respective legislations.

**Entity ‘WaterIntendedForHumanConsumption’.** This is only sub-class of the top-class ‘ConstitutiveRule’ in EUDefintionOfWaterIntendedForHumanConsumption ontology. Because in according to Article 2 (1) of EU Directive 98/83/EC the ‘WaterIntendedForHumanConsumption’ has generated a number of activities those are logically dependent on the other legal rules mentioned in the same and/or other legislations or both. For example, shown in Figure 10, in order to ensure implication of the term “WaterIntendedForHumanConsumption”, a number of activities have to be per-

**Fig.10.** Term "WaterIntendedForHumanConsumption" as a "ConstitutiveRule"

Formed such as – (a) its quality must be checked by the competent national authority in according to the parameters set by the respective EU Directives, (b) in order to make “WasteWater”, which is defined in Article 3 of Directive 2008/98/EC , human

[264] For examples, UNODC (United Nations Office on Druges and Crime) provides lists of the competent national authorities empowered to issue certificates and authorizations for the import and export of narcotic drugs and psychotropic substances, and to regulate or enforce national controls over precursors and essential chemicals. The legal bases for designating these authorities are the Single Convention on Narcotic Drugs of 1961 (article 18), the Convention on Psychotropic Substances of 1971 (article 16), and the United Nations Convention against Illicit Traffic in Narcotic Drugs and Psychotropic Substances of 1988 (article 12). See more - http://www.unodc.org/unodc/en/legal-tools/directories-of-competent-national-authorities.html

[265] Of the European Parliament and of the Council of 15 July 2003 on trans boundary movements of genetically modified organisms

consumable, it must be treated and qualified as ‘WaterIntendedForHumanConsumption’ which is defined in another EU Directive, (c) it must be used in any food products that is for human consumption. These all must-do activities are also logically depended on the legal rules such as EU Directives or Regulations.

**Entity ‘FoodProduct’.** USLegal[266] defines when food is ready for sale is considered as food product. ‘FoodProduct’ is a subclass of top-class ‘Product’. Even though, the definition of the term ‘FoodProduct’ does not make clear of its relationship with the terms like ‘Water’, ‘WasteWater’, ‘WaterIntendedForHumanConsumption’ etc. However, in according to the Article 2 (1) of EU Directive 98/83/EC, food product is a type of product where water is likely to be used. There are two sub-classes of it – ‘FoodProductWhereWaterIsUsed’ and ‘FoodSubstance’. These sub-classes are described below –

**Entity ‘FoodProductWhereWaterIsUsed’ and ‘FoodSubstance’.** These two terms themselves can be some types of ‘FoodProduct’. Article 2 (1) of EU Directive 98/83/EC mentions that, on one hand, food product where water is used must not affect the wholesomeness of food. On the other hand, water that is used in food must maintain the quality as prescribed in the EU Directives and equivalent to ‘water intended for human consumption’. In addition, Regulation (EC) no 1925/2006[267] indicated that ‘FoodSubstance’ itself can be considered as ‘FoodProduct’ such as vitamin and/or some raw food materials. The term ‘FoodSubstance’ is also a sub-class of the top-class ‘Substance’.

**Entity ‘QualityOfWater’ and ‘WholesomenessOfFoodstuff’.** EU Directive 98/83/EC defines that the term ‘WaterQuality’ is to explain different level of chemical, physical, biological and radiological characteristics of the water and its affect, in general, to the public health. In addition, Article 4 of EU Directive 98/83/EC describes "wholesomeness of food stuff" as a quality. The general obligation regarding 'wholesomeness of foodstuff' (where water itself considered as food) is given below -

"*Without prejudice to their obligations under other Community provisions, Member States shall take the measures necessary to ensure that water intended for human consumption is wholesome and clean. For the purposes of the minimum requirements of this Directive, water intended for human consumption shall be wholesome and clean if it: (a) is free from any micro-organisms and parasites and from any substances which, in numbers or concentrations, constitute a potential danger to human health, and (b) meets the minimum requirements set out in Annex I, Parts A and B*".

---

[266] See http://definitions.uslegal.com/f/food-product/

[267] Of the European Parliament and of the Council of 20 December 2006 on the addition of vitamins and minerals and of certain other substances to foods.

**Entity 'Water'.** It is a sub-class of the top-class 'Substance'. In according to Article 2 (1) of EU Directive 98/83/EC, 'Water' is a type of 'Substance' and Article 2 of EU Regulation 178/2002/EC, in addition, says that water can also be considered as food. Directive 2000/60/EC[268] also considered 'Water' as 'Substance'. There are four sub-classes of the term 'Water'. They are – 'WasteWater', 'WaterAfterCompliance', 'WaterBeforeTreatment', and 'WaterSubstance'. These sub-clasess are explained below –

**Entity 'WasteWater'.** Article 2 (1) of EU Directive 98/83/EC implicitly mentioned that 'WasteWater[269]' is a type of 'Water' but not the 'WaterIntendedForHumanConsumption'.

**Entity 'WaterAfterCompliance'.** Article 2 of EU Directive 98/83/EC implicitly defines that 'WaterAfterCompliance[270]' is a kind of 'WaterIntendedForHumanConsumption'. It has two sub-classes – 'WaterAfterTreatment' and 'WaterInItsOriginalState'.

**Entity 'WaterAfterTreatment' and 'WaterInItsOriginalState'.** EU Directive 98/83/EC mentions that both 'WaterAfterTreatment' and 'WaterInItsOriginalState' can be a type of 'WaterAfterCompliance', these three terms by their own right represent inherent meaning of 'WaterIntendedForHumanConsumption'. They all are sub-classes of 'WaterIntendedForHumanConsumption' too.

**Entity 'WaterBeforeTreatment'.** In according to the EU Directive 98/83/EC, this term is disjoint with 'WaterAfterTreatment' as this carry an opposite meaning of 'WaterAfterTreatment', which is not 'WaterIntendedForHumanConsumption' but equivalent to the 'WasteWater'.

**Entity 'WaterSubstance' and 'WaterSubstanceInFood'.** EU Directive 98/83/EC prescribes that 'WaterSubstance' is a type of water with many usages. For example, it itself can be used as a food, as well as it can be used as a raw material in the food production. The term 'WaterSubstanceInFood' is a sub-class of 'WaterSubstance' which represents a particular type of 'WaterSubstance' used in food production.

---

[268] Of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy

[269] See also for implicit meaning of the term 'WasteWater' – (a) Directive 2006/44/EC Of the European Parliament and of the Council of 6 September 2006 on the quality of fresh waters needing protection or improvement in order to support fish life, (b) Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives.

[270] See for more about meaning of 'WaterAfterCompliance' in the bath water – Directive 2006/7/EC Of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC.

## 20.2 Object-properties of EUDefWater ontology

There are total 11 object-properties excluding 6 object-properties imported from WEFNexusTopClasses ontology, shown in Figure 11. They are – ‘consumes’, ‘isConsumedBy’, ‘isCoordinatedBy’, ‘isIntendedFor’, ‘shallBeUsedFor’, ‘shallHave’, ‘shallNotAffect’, ‘shallNotBeUsedFor’, ‘shallNotHave’. In addition, ‘isCoordinatedBy’ has two sub-object-properties – ‘isSuppliedFrom’ and ‘isUsedIn’. These all object-properties are taken from the legislative text of Article 2(1) of EU Directive 98/83/EC. They are either mentioned explicitly or implicitly and are explained below –

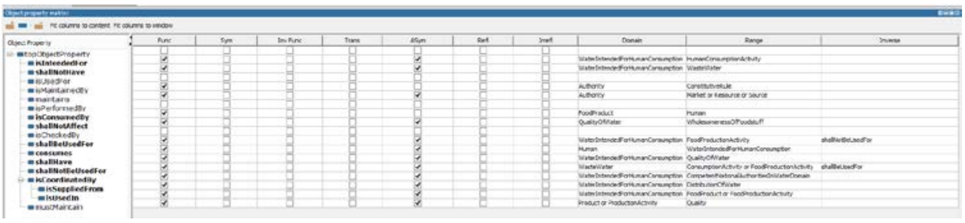


**Fig.11.** Object-properties of EUDefWater ontology

**consumes.** This is an object-property extracted from Article 2(1) of EU Directive 98/83/EC with functional and asymmetric characteristics. By nature it is implicit in the legislative text. Because the Article says about ‘WaterIntendedForHumanConsumption’, which has been used as a sub-class of the term ‘ConstitutiveRule’ and this needs to be linked with the term ‘Human’. That could be done in many different ways. For example, using object property ‘intendedFor’ in order to establish relationship between the terms ‘Water’ and ‘HumanConsumption’. But because of ‘WaterIntendedForHumanConsumption’ is used as a single term in this ontology, object-property ‘consumes’ is used for linking it with the term ‘Human’. That gives an advantage of using term ‘WaterIntendedForHumanConsumption’ simultaneously as also mother-class of the following terms – ‘WaterAfterCompliance’, ‘WaterSubstanceInFood’ and ‘FoodProductWhereWaterIsUsed’. However, the term ‘WaterIntendedForHumanConsumption’ is not a sub-class of the term ‘Water’, because the ‘Water’ is a sub-class of the term ‘Substance’ whereas the term ‘WaterIntendedForHumanConsumption’ is considered as a ‘ConstitutiveRule’.

**isConsumedBy.** This functional object-property is used to connect the domain term ‘FoodProduct’ with its range term ‘Human’, and extracted from the Article 2(1) of EU Directive 98/83/EC. Like object-property ‘consumes’, this is also implicit in the legislative texts. It expresses the statement – ‘FoodProduct’ ‘isConsumedBy’ ‘Human’, which is a very essential and necessary object-property when this ontology will be merged with ‘EUDefFood’ ontology. Because Article 2 of EU Regulation

178/2002/EC defines that the term ‘Feed[271]’ is not equivalent to the term ‘Food’, as food is consumed by human and feed is consumed by animal.

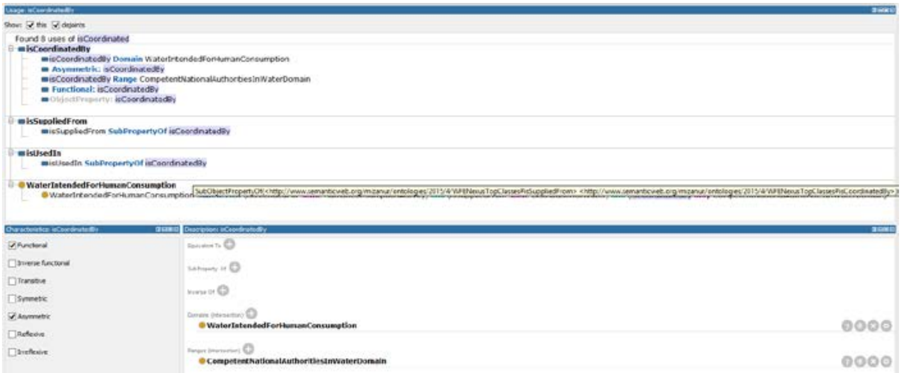



**Fig.12.** Uses of object-property 'isCoordinatedBy'

**isCoodinatedBy.** This is explicitly mentioned in the legislative texts of Article 2(1) of EU Directive 98/83/EC. It has total 7 uses in this ontology, shown in Figure 12. It is functional and asymmetric when it is used between its domain term ‘WaterIntended-ForHumanConsumption’ and its range term ‘CompetentNationalAuthoritiesInWa-terDomains’. It is also used in the formation and execution of some restriction, de-scribed in later section of this chapter. It has two sub object-properties – ‘isSup-pliedFrom’ and ‘isUsedIn’. Because both of these properties also coordinated by competent national authorities in water domains. They are explained below –

**isSuppliedFrom’ and ‘isUsedIn’.** These two sub object-properties also have taken from the Article 2(1) of EU Directive 98/83/EC and their parent object-property is ‘isCoordinatedBy’. The object property ‘isSuppliedFrom’ linked the terms ‘WaterIn-tendedForHumanConsumption’ and ‘DistributionOfWater’, and other object property ‘isUsedIn’ established semantic relationships between the terms ‘WaterIntended-ForHumanConsumption’, ‘FoodProductionActivity’ and ‘FoodProduct’ as their do-mains and ranges respectively with functional and asymmetric characteristics.

**isIntendedFor.** This object property is also extracted from Article 2(1) of EU Di-rective 98/83/EC and established the relationship between its domain term ‘WaterIn-tendedForHumanComsumption’ and its range term ‘HumanConsumptionActivity’. As ‘WaterIntendedForHumanComsumption’ is a ‘ConstitutiveRule’, it requires to gener-

[271] See Article 2 of Directive 2002/32/EC of the European Parliament and of the Council of 7 May 2002 on undesirable substances in animal feed.

ate some activities logically dependent on some legal rules. Under this consideration, the object property ‘isIntendedFor’ shows the connectivity of ‘ConstitutiveRule’ with some activities such as ‘HumanConsumptionActivity’.

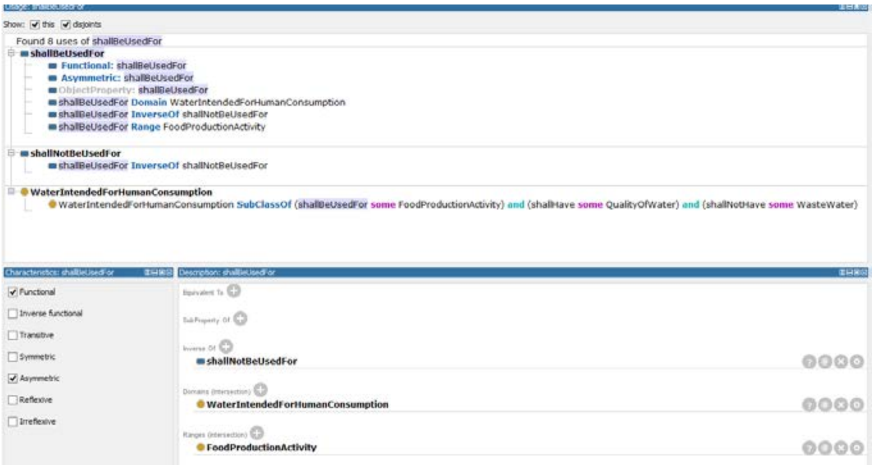



**Fig.13.** Uses of object-property 'shallBeUsedFor'

**shallBeUsedFor and shallNotBeUsedFor.** These object-properties are implicitly mentioned in the Article 2(1) of EU Directive 98/83/EC. The object-property ‘shallBeUsedFor’ connect the domain term ‘WaterIntendedForHumanConsumption’ and range term ‘FoodProductionActivity’ with functional and asymmetric characteristics, which has similar usages like the object property ‘isUsedIn’, shown in Figure 13. However, there is fundamental difference between the usages of ‘shallBeUsedFor’ and ‘isUsedIn’. Because the former one is used as an implication of legal rules as the verb ‘shall’ is used in order to express its legal connectivity and does not have any parent property. But the latter one has a parental relationship with the object-property ‘isCoordinatedBy’. However, the inverse object-property of it is ‘shallNotBeUsedFor’, which has an important implication in this ontology. Because it expresses relationships among the domain term ‘WasteWater’ and two range terms – ‘FoodProductionActivity’ and ‘ComsumptionActivity’ with functional and asymmetric characteristics. Because EU Directive 98/83/EC implicitly expresses that waste water shall not be used in any type of food production and consumption activities such as food preparation, drinking and/or cooking etc.

**‘shallHave’ and ‘shallNotHave’.** Even though they seem inverses of each other, but in this ontology they are used as dissimilar object-properties with their own domains and ranges. Because the object-property ‘shallHave’ links between the domain term ‘WaterIntendedForHumanConsumption’ and its range term ‘QualityOfWater’. Whereas the object-property ‘shallNotHave’ connects the domain term ‘WaterIntendedForHumanConsumption' and its range term 'WasteWater'. It means even though their domain terms are similar with functional and asymmetric characteristics but they both are targeted to different range terms. Therefore, they are not inverses of each other by their characteristics. However, these object-properties are implicit in the legislative texts of Article 2(1) of EU Directive 98/83/EC.

**shallNotAffect.** Even though this object-property seems that it is an inverse object-property of 'shallAffect', but it is not. Because Article 2(1) of EU Directive 98/83/EC says the quality of the water shall not affect the wholesomeness of foodstuffs. Hence, the object property 'shallNotAffect' connects the domain term 'QualityOfWater' and 'WholesomenessOfFoodstuff' with functional and asymmetric characteristics.

### 20.3 Legal Restriction over entities in EUDefWater ontology

All restrictions engineered in this ontology are extracted from Article 2(1) of EU Directive 98/83/EC and by using following three mechanisms –

- *Mechanism 1*: creating sub-class of one term with other terms. For example, 'WaterAfterCompliance' is a sub-class of 'Water', which is primarily a sub-class of top-class 'Substance', with two subclasses on its own right – 'WaterAfterTreatment' and 'WaterInItsOriginalState'. Because all of these classes have physical existence with/without implication of any human and legal rules. From the term 'Substance' point of view, there is no direct connection with the term of 'ConstitutiveRule' such as 'WaterIntendedForHumanConsumption' except legal restriction is applied over these isolated terms. As Article 2(1) of EU Directive 98/83/EC makes the legal meaning of 'WaterIntendedForHumanConsumption' is that it can be in the form of 'WaterAfterCompliance' and/or 'WaterSubstanceInFood' and/or 'FoodProductWhereWaterIsUsed', these terms have been used also as sub-classes of 'WaterIntendedForHumanConsumption' considering the fact that there is no real physical basis of the term 'WaterIntendedForHumanConsumption', shown iin Figure 14. Hence by using the term 'WaterAfterCompliance' as a sub-class of 'WaterIntendedForHumanConsumption', three following points are ensured –

    - implication of legal rule over the constitutive rule 'WaterIntendedForHumanConsumption', and
    - transforming characteristics of physical object such as 'WaterAfterCompliance' into a constitutive rule such as 'WaterIntendForHumanConsumption',
    - implicitly generating activities in order to ensure such transformed characteristics of a legal object (e.g. constitutive rule 'WaterIntendedForHumanConsumption'.

- *Mechanism 2*: creating domain and range restrictions over the object property, described in section 20.2 and shown in Figure 11 to 14.

- *Mechanism 3*: Applying restrictions using universal and/or existential and/or cardinal relationships implemented in Manchester syntax.

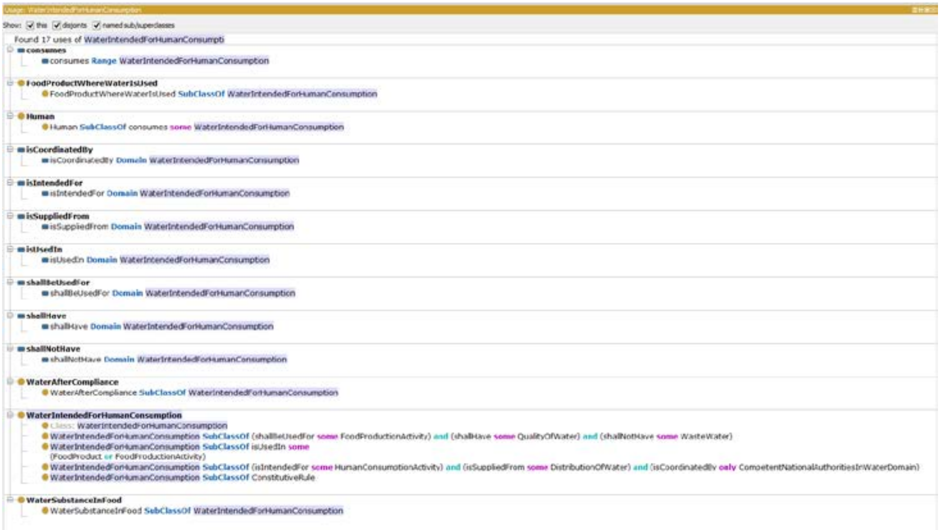



**Fig.14.** Subclass of 'WaterIntendedForHumanConsumption'

However, in this ontology, there are both - asserted and inferred restrictions using Mechanism 1 to 3. All asserted restrictions; explained in R1 to R9, of WEFNexusTopClasses ontology is also present in this ontology with following asserted restrictions –

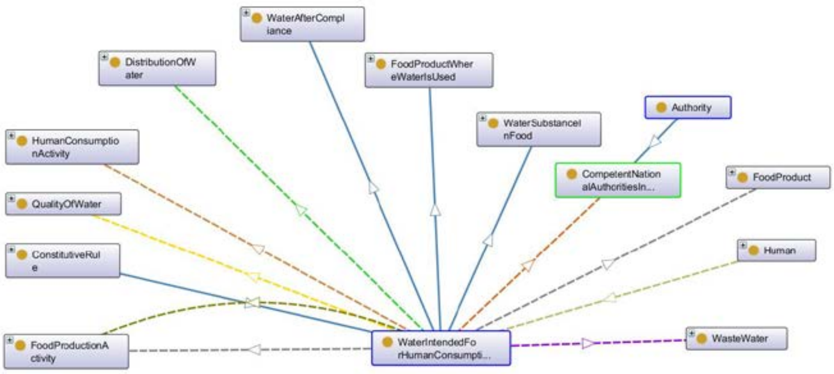



**Fig.15.** Restrictions over the term 'WaterIntendedForHumanConsumption' based on domain and range relationships

**Legal restriction over the entity 'WaterIntendedForHumanConsumption'.** A number of object-properties has been used in order to create following restrictions over this entity, shown in Figure 15 -

*WaterIntendedForHumanConsumption* $\sqsubseteq \exists$ *isIntendedFor . ( HumanConsumptionActivity)* $\sqcap \exists$ *isSuppliedFrom . (DistributionOfWater)* $\sqcap \forall$ *isCoordinatedBy . (CompetentNationalAuthoritiesInWaterDomain)* *(R9)*

The restriction, R9, shows that the constitutive rule 'WaterIntendedForHumanConsumption' implies on 3 different object-properties and terms using existential and universal relationships. The object properties – 'isIntendedFor' and 'isSuppliedFrom' has existential relationship with the term 'HumanConsumptionActivity' and 'DistribtuionOfWater' respectively. In addition, the object-property 'isCoordinatedBy' has universal relationship with the term 'NationalAuthoritiesInWaterDomain'. It collectively expresses – WaterIntendedForHumanConsumption is intended for human consumption (a type of activity), is supplied from distribution of water (another type of activity) and is coordinated by competent national authorities in water domains (applying respective legal rules).

WaterIntendedForHumanConsumption $\sqsubseteq \exists$ shallBeUsedFor . (FoodProductionActivity) $\sqcap \exists$ shallHave . ( QualityOfWater) $\sqcap \exists$ shallNotHave . (WasteWater) *(R10)*

The restriction, R10, shows the term 'WaterIntendedForHumanConsumption' implies on three special object-properties such as 'shallBeUsedFor', 'shallHave' and 'shallNotHave' and three terms such as 'FoodProductionActivity', 'QualityOfWater' and 'WasteWater'. The reason of why these object properties are special is that they all have imperative verb 'Shall[272]' which provide mandatory sense of action in the legal domain. Only Existential relationships have been used in between these object-properties and terms. Collectively R11 expresses that 'WaterIntendedForHumanComsumption' shall be used for food production, shall have quality of water and shall not have waste water.

*WaterIntendedForHumanConsumption* $\sqsubseteq \exists$ *isUsedIn* **.** *(FoodProduct* $\sqcup$ *FoodProductionActivity)* *(R11)*

[272] The following quote is taken from the US case People v. O'Rourke, 124 Cal. App. 752, 759 (Cal. App. 1932), which gives a very good understanding of the term 'Shall' - "In common, or ordinary parlance, and in its ordinary signification, the term 'shall' is a word of command, and one which has always, or which must be given a compulsory meaning; as denoting obligation. It has a peremptory meaning, and it is generally imperative or mandatory. It has the invariable significance of excluding the idea of discretion, and has the significance of operating to impose a duty which may be enforced, particularly if public policy is in favor of this meaning, or when addressed to public officials, or where a public interest is involved, or where the public or persons have rights which ought to be exercised or enforced, unless a contrary intent appears; but the context ought to be very strongly persuasive before it is softened into a mere permission".

The above restriction, R11, displays the ‘WaterIntendedForHumanConsumption’ implies on 1 object property, that is ‘isUsedIn’ and two terms ‘FoodProduct’ or ‘FoodProductionActivity’ using an existential relationship. It articulates that ‘WaterIntendedForHumanConsumption’ is used in food products or food production activity. Hence the term ‘WaterIntendedForHumanConsumption’, applying existential and universal relationships with 7 object-properties and 8 terms, provides all necessary and essential ontological and semantic ground to be qualified as a ‘ConstitutiveRule’.

**Legal restriction over the entity ‘Human’.** The restriction, R12, shows the term ‘Human’ has a restriction applying by an ’existential relationship between object-property ‘consumes’ and term ‘WaterIntendedForHumanConsumption’. In this restriction, the term ‘WaterIntendedForHumanConsumption’ is neither similar nor equivalent to the term ‘water’. Rather it expresses that the qualified sub-classes of the ‘WaterIntendedForHumanConsumption’ such as ‘WaterAfterCompliance’, ‘WaterAfterTreatment’, ‘WaterInItsOriginalState’, ‘WaterSubstanceInFood’ and ‘FoodProdcutWhereWaterIsUsed’ are also inferably covered by this restriction.

$$Human \sqsubseteq \exists\, consumes\ .\ (\ WaterIntendedForHumanConsumption\ ) \qquad (R12)$$

In addition, in the immediate former section, it is also shown how the term ‘WaterIntendedForHumanConsumption’ is transformed the substantial characteristics of the term ‘WaterAfterCompliance’. The reverse explanation can be useful in order to articulate R12.

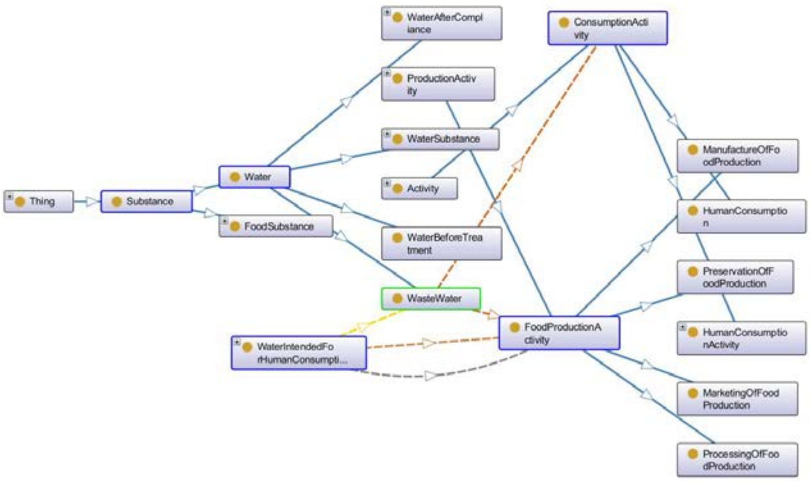



**Fig.16.** Restrictions in the terms 'WasteWater'

**Legal restriction over the term ‘FoodProduct’.** The term ‘FoodProduct’ implies over the object property ‘isConsumedBy’ with a universal relationship over the term ‘Human’, shown in R13.

$$FoodProduct \sqsubseteq \forall\ isConsumedBy\ .\ (\ Human\ ) \qquad (R13)$$

The restriction R13 might seems counter institutive with the R13 as both object-properties ‘consumes’ and ‘isConsumedBy’ provide very similar understanding with different applicationality. In the case of ‘consumes’, the term ‘Human’ is actively involved in the restriction R12, whereas in the case of ‘isConsumedBy’, the term ‘Human’ is passively involved as the targeted term of R13 is ‘FoodProduct’, not the term ‘Human’.

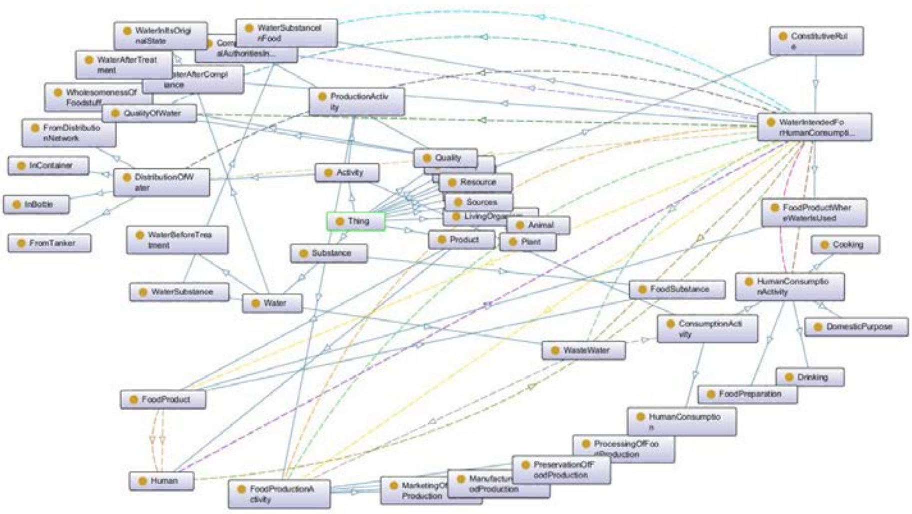



**Fig.17.** EUDefWater ontology

**Legal restriction over the term ‘QualityOfWater’.** The term ‘QualityOfWater’ implies over the object-property ‘shallNotAffect’ with an existential relationship over the term ‘WholesomenessOfFoodstuff’, shown in R14.

$$QualityOfWater\ \sqsubseteq \exists\ \ shallNotAffect\ .\ (\ WholesomenessOfFoodstuff\ ) \qquad (R14)$$

This is particular restriction as both terms ‘QualityOfWater’ and ‘WholesomenessOf-Foodstuff’ are the sub-classes of the top-class ‘Quality’ in which restriction, R4, from WEFNexusTopClasses ontology is applied.

**Legal restriction over the term ‘WasteWater’.** The term ‘WasteWater’ implies over the object-property ‘shallNotBeUsedFor’ with an existential relationship over the terms – ‘FoodProductionActivity’ or ‘ConsumptionActivity’, shown in R16 and Figure 16.

$$WasteWater \sqsubseteq \exists\ shallNotBeUsedFor\ .\ (\ FoodProductionActivity\ \sqcup\ ConsumptionActivity) \qquad (R15)$$

It is worth mentioning that as the term ‘WasteWater’ is a sub-class of ‘Substance’, it is also a sub-class of restriction R6, described in section 19.3. It might give a wrong interpretation that while ‘WasteWater’ as a ‘Substance’ is used for some ‘Product’, how comes that it shall not be used for FoodProductionActivity or ConsumptionActivity.

$$Substance \sqsubseteq \exists\, isUsedFor\ .\ (\ Product\ ) \qquad (R6)$$

In this context, Reasoners do not find it wrong as both terms ‘FoodProductionActivity’ and ‘ConsumptionActivity’ are sub-classes of the top-class ‘Activity’, not ‘Product’.

### 20.4 Reasoner’s result of EUDefWater ontology

The semantic complexity is much higher in the ontology of EUDefWater than WEF-NexusTopClasses ontology, shown in Figure 5 and 16. The reason behind it is simple as former ontology contains more classes, properties, restrictions and inferences than the latter one. Therefore reasoner’s task is very crucial. However, there is no error and inconsistency shown by reasoners. The most important inferences’ results produced by the reasoners are shown in Table 2.

**Table 2.** Reasoner’s result of EUDefWater ontology

| ***Reasoners*** ***Inference types*** | ***Fact ++*** | ***HermiT 1.3.8. and 1.3.8.3.*** | ***Pellet and Pellet (Incremental)*** |
|---|---|---|---|
| Error and inconsistency | No | No | No |
| Class inferences | Satisfied | Satisfied | Satisfied |
| Object property inferences | Satisfied | Satisfied | Satisfied |
| Axioms inferences | Sound | Sound | Sound |

However, it may seem that there are some redundant restrictions over the entities, e.g. ‘WaterIntendedForHumanConsumption’, in this ontology, shown in Figure 15 and 18. Therefore it requires proper clarifications, which is not properly detected by the reasoners. What makes this type of visual redundancy in this ontology is as follow -

- Implications of restrictions simultaneously created by using more than one mechanism, described in the section 20.3, over an entity. For example, on the one hand, by using Mechanism 2, the restrictions over the term ‘WaterIntendedForHumanConsumption’ is created as domain and range relationships, described in the section 20.2. On the other hand, by using Mechanism 3, further restrictions are created over the same entity, described in the section 20.3 and shown in R10 to 12. Logically the functionality of such restrictions over an entity created by using different mechanisms is not overlapping rather this helps to create layers of restrictions over an entity. For example, in the case of applying R10 to R12 simultaneously over the entity ‘WaterIntendedForHumanConsumption’, the entity is used as ‘sub-class’ of those restrictions. Whereas in the case of domain-range relationship, the same entity is used as a domain of an applied object-property, described in the section 20.2.

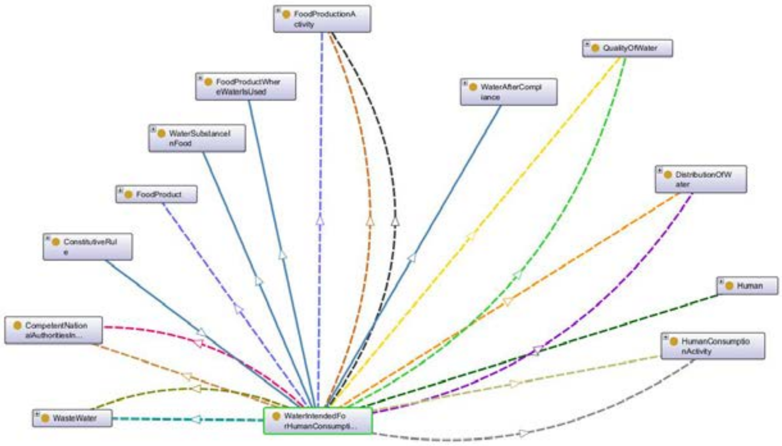



**Fig.18.** Restrictions over the term 'WaterIntendedForHumanConsumption' based on sub-class axioms and domain and range relationships

Therefore, even though the figure 18 shows with different colorful lines, representing same object-properties, that it carries double restrictions over the same entities, each of their functionalities is different and meaningful in the semantic sense.

## 21 EUDefBiofuels Ontology

Article 2 of EU Directive 2003/30/EC[273] that defines ‘biofuels’ is selected for engineering EUDefBiofuels ontology. This Article has two parts –

---

[273] Of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport . Article 2 of this legislation is as follow –

“1. For the purpose of this Directive, the following definitions shall apply:
(a) ‘biofuels’ means liquid or gaseous fuel for transport produced from biomass;

- (a) Article 2(1) basically contains all terms of constitutive rules related with the biofuels definition such as ‘Biofuels’, ‘Bio-mass’, ‘EnergyContent’ and ‘RenewableFuel’ etc.
- (b) Article 2(2) provides all, legally valid and acceptable, sub-classes of ‘Biofuels’. These two parts collectively provide a very comprehensive semantic network of Biofuels and how the EU legal definition of biofuel is connected with the EU legal definition of food, which has been demonstrated in the later part of this chapter.

Like EUDefWater ontology, WEFNexusTopClasses ontology is directly imported in this ontology. As a result, 8 out of total 15 top-classes in this ontology are imported. Rest 4 top-classes in this ontology are extracted from the respective legislative texts. They are – ‘Energy’, ‘Engines’, ‘Industry’ and ‘Value’. These entities will be explained in upcoming sections.

There are total 96 classes, 17 object-properties and 1 data-property that include 16 top-classes and 6 top object-properties imported from the WEFNexusTopClasses ontology. There are total 636 axioms including 141 logical axioms with ALCRF(D) expressivity, shown in Figure 19. In the case of class axioms, there are 119 sub-classes, 2 equivalent classes and 1 dis-joint class axioms. In addition, there are also 3 hidden GCIs. In the case of object-property axioms, there are 5 functional, 4 asym-

---

(b) ‘biomass’ means the biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste,

(c) ‘other renewable fuels’ means renewable fuels, other than biofuels, which originate from renewable energy sources as defined in Directive 2001/77/EC (2) and used for transport purposes;

(d) ‘energy content’ means the lower calorific value of a fuel.

2. At least the products listed below shall be considered biofuels:

(a) ‘bioethanol’: ethanol produced from biomass and/or the biodegradable fraction of waste, to be used as biofuel;

(b) ‘biodiesel’: a methyl-ester produced from vegetable or animal oil, of diesel quality, to be used as biofuel;

(c) ‘biogas’: a fuel gas produced from biomass and/or from the biodegradable fraction of waste, that can be purified to natural gas quality, to be used as biofuel, or woodgas;

(d) ‘biomethanol’: methanol produced from biomass, to be used as biofuel;

(e) ‘biodimethylether’: dimethylether produced from biomass, to be used as biofuel;

(f) ‘bio-ETBE (ethyl-tertio-butyl-ether)’: ETBE produced on the basis of bioethanol. The percentage by volume of bio-ETBE that is calculated as biofuel is 47 %;

(g) ‘bio-MTBE (methyl-tertio-butyl-ether)’: a fuel produced on the basis of biomethanol. The percentage by volume of bio-MTBE that is calculated as biofuel is 36 %;

(h) ‘synthetic biofuels’: synthetic hydrocarbons or mixtures of synthetic hydrocarbons, which have been produced from biomass;

(i) ‘biohydrogen’: hydrogen produced from biomass, and/or from the biodegradable fraction of waste, to be used as biofuel;

(j) ‘pure vegetable oil’: oil produced from oil plants through pressing, extraction or comparable procedures, crude or refined but chemically unmodified, when compatible with the type of engines involved and the corresponding emission requirements.”

metric, 5 object-property domains and 5 object-property ranges have been counted.

Ontology metrics:

**Metrics**

| | |
|---|---|
| Axiom | 636 |
| Logical axiom count | 141 |
| Class count | 96 |
| Object property count | 17 |
| Data property count | 1 |
| Individual count | 0 |
| DL expressivity | ALCRF(D) |

**Class axioms**

| | |
|---|---|
| SubClassOf axioms count | 119 |
| EquivalentClasses axioms count | 2 |
| DisjointClasses axioms count | 1 |
| GCI count | 0 |
| Hidden GCI Count | 3 |

**Object property axioms**

| | |
|---|---|
| SubObjectPropertyOf axioms count | 0 |
| EquivalentObjectProperties axioms count | 0 |
| InverseObjectProperties axioms count | 0 |
| DisjointObjectProperties axioms count | 0 |
| FunctionalObjectProperty axioms count | 5 |
| InverseFunctionalObjectProperty axioms count | 0 |
| TransitiveObjectProperty axioms count | 0 |
| SymmetricObjectProperty axioms count | 0 |
| AsymmetricObjectProperty axioms count | 4 |
| ReflexiveObjectProperty axioms count | 0 |
| IrrefexiveObjectProperty axioms count | 0 |
| ObjectPropertyDomain axioms count | 5 |
| ObjectPropertyRange axioms count | 5 |
| SubPropertyChainOf axioms count | 0 |

**Data property axioms**

| | |
|---|---|
| SubDataPropertyOf axioms count | 0 |
| EquivalentDataProperties axioms count | 0 |
| DisjointDataProperties axioms count | 0 |
| FunctionalDataProperty axioms count | 0 |
| DataPropertyDomain axioms count | 0 |
| DataPropertyRange axioms count | 0 |

**Individual axioms**

| | |
|---|---|
| ClassAssertion axioms count | 0 |
| ObjectPropertyAssertion axioms count | 0 |
| DataPropertyAssertion axioms count | 0 |
| NegativeObjectPropertyAssertion axioms count | 0 |
| NegativeDataPropertyAssertion axioms count | 0 |
| SameIndividual axioms count | 0 |
| DifferentIndividuals axioms count | 0 |

**Annotation axioms**

| | |
|---|---|
| AnnotationAssertion axioms count | 373 |
| AnnotationPropertyDomain axioms count | 0 |
| AnnotationPropertyRangeOf axioms count | 0 |

**Fig.19.** Metrics of EUDefBiofuels

There is no use of data-property and individual axiom. Furthermore, there are 488 annotation assertions axioms have been encountered.

## 21.1 Taxonomy of EUDefBiofuels

Besides top-classes, this ontology contains following sub-classes – ‘OilProduction’, ‘ProceduresOfOilProduction’, ‘ComparableProcedures’, ‘ExtractionProcedures’, ‘PressingProcedures’, ‘Transport’, ‘BiofuelsUnderEUDirective’, ‘BiomassUnderEUDirective’, ‘EmissionRequirement’, ‘EnergyContentUnderEUDirective’, ‘RenewableFuelsUnderEUDirective’, ‘EnergyContent’, ‘EnergySource’, ‘RenewableEnergySource’, ‘Agriculture’, ‘Forestry’, ‘OilIndustry’, ‘OilPlant’, ‘BiodegradableFraction’, ‘BiodegradableFractionOfProduct’, ‘BiodegradableFractionOfWaste’, BiodegradableFractionOfIndustrialWaste, BiodegradableFractionOfMunicipalWaste, ‘Biomass’, ‘AnimalSubstance’, ‘VegetalSubstance’, ‘Fuel’, ‘Biofuel’, ‘DieselFuel’, ‘BioDiesel’, ‘Ethanol’, ‘Bioethanol’, ‘GaseousFuel’, ‘LiquidFuel’, ‘Methanol’, ‘BioMethanol’, ‘RenewableFuel’, ‘Gas’, ‘FuelGas’, ‘BioGas’, ‘HydrogenGas’, ‘BioHydrogen’, ‘NaturalGas’, ‘WoodGas’, ‘Oil’, ‘AnimalOil’, ‘ChemicallyUnmodifiedOil’, ‘CrudeOil’, ‘RefinedButChemicaalyUnmodifiedOil’, ‘RefineOil’, ‘VegerableOil’, ‘PureVegetableOil’, ‘Waste’, ‘IndustrialWaste’, ‘MunicipalWaste’, ‘FuelProduct’, ‘SyhtheticFuel’, ‘SyntheticFuel’, ‘SyntheticBiofuel’, ‘DieselQuality’, ‘NaturalGasQuality’, ‘RenewableResource’, ‘AnimalSubstance’, ‘Carbon’, ‘Hydrocarbon’, ‘SyntheticHydrocarbon’, ‘Ether’, ‘DimethylEther’, ‘BioDimethylEther’, ‘ETBE’, ‘BioETBT’, MTBE, ‘BioMTBE’, ‘VegetalSubstance’, ‘CalorificValue’, ‘CalorificValueOfFuel’, ‘LowerCalorificValueOfFuel’.

All of these entities, explained below and shown in Figure 20, are either explicitly or implicitly mentioned in the legislative texts. A great afford has been made in order to create more classes and sub-classes in relation with the legislation, so that engineering ontology could become sound and complete in its inference reasoning, which will make the semantic networks of legal definition of biofuels more closer to the legal reasoning in reality.

**Entity ‘OilProduction’.** Article 2(3) of Directive 2013/30/EU[274] recognized oil production, as oil operation, is a type of activities by saying that "*offshore oil and gas operations’ means all activities associated with an installation or connected infrastructure, including design, planning, construction, operation and decommissioning thereof, relating to exploration and production of oil or gas, but excluding conveyance of oil and gas from one coast to another*". In addition Article 2 of EU Directive 2003/30/EC indicates that there are certain types of procedures that must be followed in order to produce certain type of biofuels. Hence, the entity ‘OilProduction’ has a sub-class named ‘ProceduresOfOilProduction’ with its respective sub-classes.

**Entity ‘ProceduresOfOilProduction’.** Article 2(2)(j) of EU Directive 2003/30/EC mentions that for producing ‘PureVegetableOil’, a particular type of procedures must be followed. Such procedures can be – ‘ComparableProcedures’, ‘ExtractionProcedures’ and ‘PressingProcedures’. These all procedures basically consisted with a series of activities as mentioned in Directive 2013/30/EU. For these reasons, these three types of procedures are used as sub-classes of this entity.

**Entity ‘ComparableProcedures’, ‘ExtractionProcedures’ and ‘PressingProcedures’.** Article 2(2)(j) of EU Directive 2003/30/EC, in compatible with Article 2(3) of Directive 2013/30/EU, defines that oil production procedures such as comparable, extraction and pressing are the required procedures for producing pure vegetable oil for only transportation purposes.

**Entity ‘Transport’.** In EU legal domain, there are many definitions of different types of transports. For example, Article 73 and 86(2) of the Treaty establish the rules related with public services in the inland transport[275]. However, it is difficult to find out a legal definition of the term ‘Transport’. Whereas Article 2(1)(a) of EU Directive 2003/30/EC clearly mentions that biofuel is for transport without defining it. However, Wikipedia mentioned that transport, synonym with transportation, is a type of

[274] Directive 2013/30/EU of the European Parliament and of the Council of 12 June 2013 on safety of offshore oil and gas operations and amending Directive 2004/35/EC

[275] See more at Regulation (EC) No 1370/2007 of the European Parliament and of the Council of 23 October 2007 on public passenger transport services by rail and by road and repealing Council Regulations (EEC) Nos1191/69 and 1107/70

activities which involves with movement of goods, animals and people from one geographical location to another by using different modes of transport such as air, rail, water, cable etc. In this ontology, the term 'Transport' is used a sub-class of the entity 'Activity' with no further sub-class as it is not required in according to the respective legislative texts.

**Entity 'BiofuelsUnderEUDirective'.** This is a sub-class of the top-class 'ConstitutiveRule', shown in Figure 21. Generally biofuel[276] is a fuel that is produced through contemporary biological processes, which is not similar with the legal notion of the term 'Biofuels'. Because, Article 2 (1) (a) of Directive 2003/30/EC clearly mentions that "*biofuels' means liquid or gaseous fuel for transport produced from biomass*". Therefore, as a legal definition, the term 'BiofuelUnderEUDirective' is depended following two conditions to be fulfilled –

- *Role to create activity/ies* – the biofuel, in the form of liquid or gaseous fuel, shall be used as 'Transport', which is a subclass of 'Activity'. Therefore, the term 'BiofuelUnderEUDirective' itself generates activities in the form of transportation.
- *Logical dependency of those activities is based on the legal rule/s* – From the EU legal point of view, biofuel is not only a type of fuel in the form of liquid or gaseous, rather it must be produced from biomass, which is a subject-matter of Article 2 (1) (b) of Directive 2003/30/EC. In the Directive, the term 'Biomass' is used is a subclass of 'Material', because it is used in order to produce biofuel. At the same time, it is also sub-class of the term 'Source', because biomass is the only source of 'BiofuelUnderEUDirective'. This shows logical dependency of the activity, e.g. using biofuels for transport, is over the legal rules designed in Article 2 (1) (a) and (b) of Directive 2003/30/EC.

Under considering above mentioned inherent features of the term 'BiofuelUnderEU-Directive', it is used as a sub-class of the entity 'ConstitutiveRule' in this ontology.

**Entity 'BiomassUnderEUDirective'.** This is another sub-class of the top-class 'ConstitutiveRule', shown in Figure 21. Generally biomass[277] is a type of biological material resulting from living organisms, which is not used as food or feed. However, European law has different perspective over the term 'biomass'[278], as Article 2(1)(b) of Directive 2003/30/EC describes the meaning of Biomass' as – "*the biodegradable fraction of products, waste and residues from agriculture (including vegetal and ani-*

[276] See also - Article 2(i) of Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

[277] See https://en.wikipedia.org/wiki/Biomass

[278] See also - Article 2(13) ofRegulation (EU) No 256/2014 of the European Parliament and of the Council of 26 February 2014 concerning the notification to the Commission of investment projects in energy infrastructure within the European Union, replacing Council Regulation (EU, Euratom) No 617/2010 and repealing Council Regulation (EC) No 736/96.

*mal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste*”. It is measured as a ‘ConstitutiveRule’ under considering following two points –

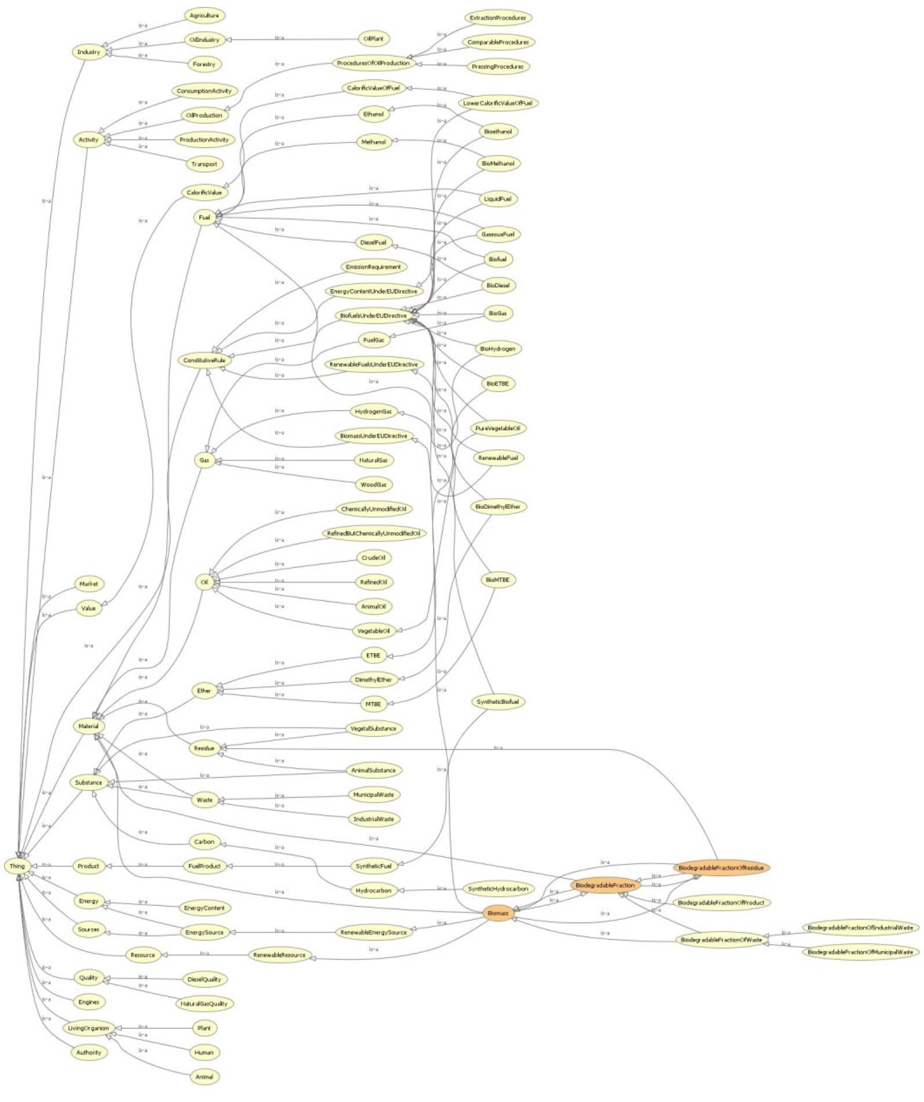


**Fig.20.** Asserted model of EUDefBiofuels ontology

- *Role to create activity/ies* – In according to Article 2(1)(a) of Directive 2003/30/EC, connecting with Article 2(1)(b), biomass shall be used as a material as well as source of the biofuel. It means the biodegradable fractions of the products, waste and residues including animal and vegetal substances are used for producing biofuels. Hence biomass, as applied and fundamental raw materials for biofuels, generates a lot of production activities.

- *Logical dependency of those activities is based on the legal rule/s* – Logical dependency of detecting ‘Biomass’ as a material is guided by Article 2(1)(b) of Directive 2003/30/EC. For example, using human substance for producing biofuels will not be considered as ‘Biomass’ as it is not defined in the respective legislation.


**Fig.21.** Subclasses of 'ConstitutiveRule' in EUDefBiofuels ontology

**Entity ‘EmissionRequirement’.** Article 2(1) (a) of Decision No 529/2013/EU[279] specifies that ‘emissions’ means anthropogenic emissions of greenhouse gases into the atmosphere by sources. Article 2(2) (j) of Directive 2003/30/EC prescribes that pure vegetable oil as a form of biofuel must correspond with the emission requirement, but did not define the parameters of emission requirement. However, one of the examples of the emission requirement can be found at Regulation (EC) No 443/2009[280]. The term ‘EmissionRequirement’ is also taken as a sub-class of ‘ConstitutiveRule’, shown in Figure 21, for following considerations –

- *Role to create activity/ies* – Measuring emission in according to the legal requirement generates a lot of activities such as installment of technological equipment, engaging technicians, and/or follow up the statistics of the emissions etc.

[279] Of the European Parliament and of the Council of 21 May 2013 on accounting rules on greenhouse gas emissions and removals resulting from activities relating to land use, land-use change and forestry and on information concerning actions relating to those activities.

[280] Of the European Parliament and of the Council of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO 2 emissions from light-duty vehicles.

- *Logical dependency of those activities is based on the legal rule/s* – All the activities need to be performed must be performed in according to the emission parameters set-up by legal instruments.

**Entity 'EnergyContentUnderEUDirective'.** Article 2(1)(d) of Directive 2003/30/EC defines 'EnergyContent' as "*the lower calorific value of a fuel*". This means that, on the one hand, the calculating calorific value of fuel is a must-activity in order to recognize the energy content of a fuel. That generates a lot of activities. On the other hand, in order to recognize the range of calorific values, whether it represents lower or higher value, legal rules are required. As a result, the term 'EnergyContentUnderEUDirective' is a sub-class of 'ConstitutiveRule' by its own right, shown in Figure 21.

**Entity 'RenewableFuelsUnderEUDirective'.** Article 2(l) of Directive 2009/28/EC[281] specifies that – "*renewable energy obligation' means a national support scheme requiring energy producers to include a given proportion of energy from renewable sources in their production, requiring energy suppliers to include a given proportion of energy from renewable sources in their supply, or requiring energy consumers to include a given proportion of energy from renewable sources in their consumption. This includes schemes under which such requirements may be fulfilled by using green certificates*". In addition, Article 2 (1) (c) of Directive 2003/30/EC mentions that "*renewable fuels originate from renewable energy sources as defined in Directive 2001/77/EC (2) and used for transport purposes*". Under considering following two points, the entity 'RenewableFuelsUnderEUDirective' is categorized as a sub-class of 'ConstitutiveRule', shown in Figure 21, -

- *Role to create activity/ies* – In the context of these two legislations, the former legislation requires the renewable biofuels must be certified by green certifying scheme and the latter legislation requires the source, e.g. biomass, and purpose, e.g. for transportation, of the biofuels. All of these generate a lot of activities to be performed in order to ensure the legislative content and context.
- *Logical dependency of those activities is based on the legal rule/s* – On one hand, the procedures that need to be follow in order to get the green certification for renewable energies are depended on the legal rules laid by EU legislations. On the other hand, if the renewable fuel is produced from other than biomass, then by law that fuels will not be considered as the 'RenewableFuelsUnderEUDirective', even though the fuels itself might be renewable.

**Entity 'Energy'.** In physics, energy is a property of objects that neither can be destroyed nor created, but can be transformed or converted into other forms. Article 2(a)

[281] Of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

of Directive 2009/28/EC[282] mentions that "*energy from renewable sources' means energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases*'". This entity is one of the new top-classes in this ontology for two important reasons. They are – (a) the definition of 'Energy' does not correspond with the definitions of other top-classes, and (b) there are few energy-related terms exist in the legislative texts of Article 2 of Directive 2003/30/EC such as 'EnergyContent', 'EnergySource', and 'RenewableEnergySource', shown in Figure 22. These terms need to be covered under a top-class.

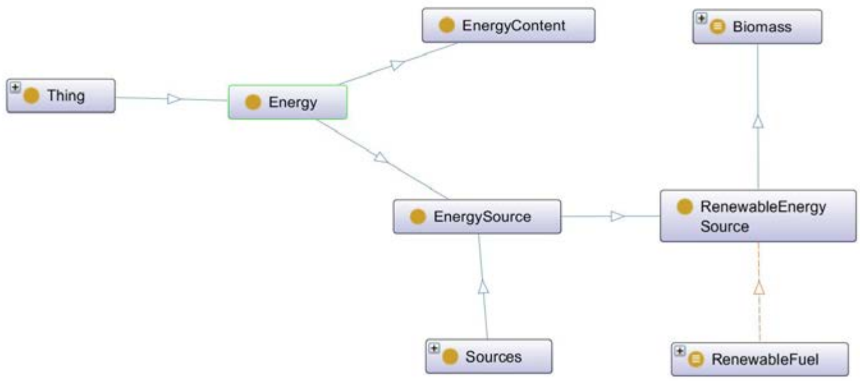



**Fig.22.** Subclasses of the term 'Energy'

**Entity 'EnergyContent'.** This is a sub-class of the top-class 'Energy'. Article 2(1)(d) of Directive 2003/30/EC clearly demonstrated the meaning of 'EnergyContent' as the lower calorific value of a fuel. In addition, Article 5(5) of Directive 2009/28/EC mentions that "*the energy content of the transport fuels listed in Annex III shall be taken to be as set out in that Annex. Annex III may be adapted to technical and scientific progress*".

**Entity 'EnergySource'.** This is another sub-class of the entity 'Energy'. The Directive 2009/28/EC defines 'EnergySource' as "*a source from which useful energy can be extracted or recovered either directly or by means of a conversion or transformation process (e.g. solid fuels, liquid fuels, solar energy, biomass, etc*". Furthermore, Article 2(13) of Regulation (EU) No 256/2014[283] indicated different types of

[282] Of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

[283] Of the European Parliament and of the Council of 26 February 2014 concerning the notification to the Commission of investment projects in energy infrastructure within the European Union, replacing Council Regulation (EU, Euratom) No 617/2010 and repealing Council Regulation (EC) No 736/96.

‘EnergySource’ such as “*(i) primary energy sources, such as oil, natural gas or coal; (ii) transformed energy sources, such as electricity; (iii) renewable energy sources including hydroelectricity, biomass, biogas, wind, solar, tidal, wave and geothermal energy; and (iv) energy products, such as refined oil products and bio-fuels*”.

**Entity ‘RenewableEnergySource’.** This is a sub-class of the entity ‘EnergySource’. Article 2(13)(iii) of Regulation (EU) No 256/2014 defines that ‘RenewableEnergySource’ is a type of ‘EnergySource’ and provided a list of ‘RenewableEnergySource’. In addition, Article 2 (a) of Directive 2009/28/EC and Article 2(1)(c) of EU Directive 2003/30/EC also defined it as a form of energy sources.

**Entity ‘Engines’.** Like entity ‘Energy’, this is a new addition as a top-class in this ontology. Article 3(1) of Regulation (EC) No 595/2009[284] specifics that engine means “*the motive propulsion source of a vehicle for which type-approval as a separate technical unit, as defined in point 25 of Article 3 of Directive 2007/46/EC[285], may be granted*”. In addition, Article 2(2)(j) of EU Directive 2003/30/EC mentions that ‘PureVegetableOil’ must be compatible with a certain types of engines. As the term ‘Engines’ has a unique definition and does not equipped with all existing top-classes of this ontology, that qualify this term to be added as a top-class.

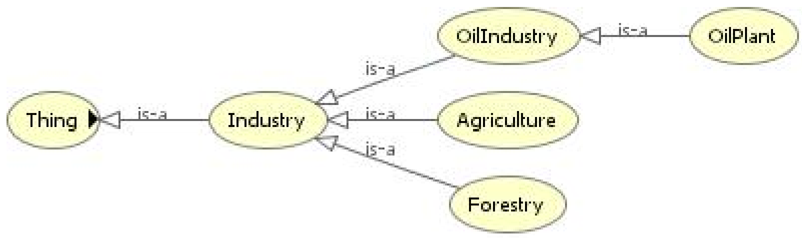



**Fig.23.** Subclasses of the top-class 'Industry'

**Entity ‘Industry’.** Article 2(1)(b) of EU Directive 2003/30/EC mentions that the source of Biomass can be waste and residues that coming from agriculture, forestry and other industries. But this legislation particularly does not define the term ‘Industry’. That requires finding out a legal definition of ‘Industry’ from EU legislation.

[284] Of the European Parliament and of the Council of 18 June 2009 on type-approval of motor vehicles and engines with respect to emissions from heavy duty vehicles (Euro VI) and on access to vehicle repair and maintenance information and amending Regulation (EC) No 715/2007 and Directive 2007/46/EC and repealing Directives 80/1269/EEC, 2005/55/EC and 2005/78/EC.

[285] Of the European Parliament and of the Council of 5 September 2007 establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles (Framework Directive).

However, Article 2 (35) of Directive 2013/30/EU[286] defines the term ‘Industry’ in the context of offshore oil and gas operations, which particularly meets the requirements to be recognized as a top-class in this ontology as the subject-matter of this ontology is biofuels. The Article 2 (35) demonstrates that “*‘industry’ means entities that are directly involved in offshore oil and gas operations covered by this Directive or whose activities are closely related to those operations*”. It has three sub-classes – ‘Agriculture’, ‘Forestry’ and ‘OilIndustry’, shown in Figure 23.

**Entity ‘Agriculture’.** Article 4 of Regulation (EU) No 1307/2013[287] defines that Agriculture, as an industry, “*encompasses preparing the soil for optimum returns, improving crops, services relating to horticulture, landscaping services, veterinary services, managing labors or farmers”*. In addition, Article 2 (1) (b) of EU Directive 2003/30/EC remarks that waste and residue from agricultural industry might be considered as Biomass and therefore can be used a source of raw materials for producing biofuels.

**Entity ‘OilPlant’.** In according to the Article 2 (2) (j) of EU Directive 2003/30/EC, sources of pure vegetable oil is ‘OilPlant’ which is used as a sub-class of ‘OilIndustry’.

**Entity ‘BiodegradableFraction’.** This is sub-class of the entity ‘Material’ as it is used in order to produce biofuels in according to the Article 2 (1) (b) of EU Directive 2003/30/EC. The same Article also specifies that ‘BiodegradableFraction’ is equivalent to the entity ‘Biomass’, shown in Figure 24. In addition, Appendix 1 of Regulation (EU) No 1233/2011[288] also indicates that biodegradable fraction is a biomass and used as a material to produce bio-energy. However, in this ontology, both ‘BiodegradableFraction’ and ‘Biomass’ have been used as two separate entities and both are sub-class of ‘Material’. It has two sub-classes – ‘BiodegradableFractionOfProduct’ and ‘BiodegradableFractionOfWaste’.

**Entity ‘BiodegradableFractionOfProduct’ and ‘BiodegradableFractionOfWaste’.** Article 2(1)(b) of Directive 2003/30/EC mentions that biodegradable fraction can be originated from both products and waste. On the basis of the source, these two sub-classes of ‘BiodegradableFraction’ are defined. The entity ‘BiodegradableFrac-

[286] Of the European Parliament and of the Council of 12 June 2013 on safety of offshore oil and gas operations and amending Directive 2004/35/EC.

[287] Of the European Parliament and of the Council of 17 December 2013 establishing rules for direct payments to farmers under support schemes within the framework of the common agricultural policy and repealing Council Regulation (EC) No 637/2008 and Council Regulation (EC) No 73/2009

[288] Of the European Parliament and of the Council of 16 November 2011 on the application of certain guidelines in the field of officially supported export credits and repealing Council Decisions 2001/76/EC and 2001/77/EC

tionOfWaste' is further sub-categorized into two groups - 'BiodegradableFractionO-fIndustrialWaste' and 'BiodegradableFractionOfMuniciplaWaste'.

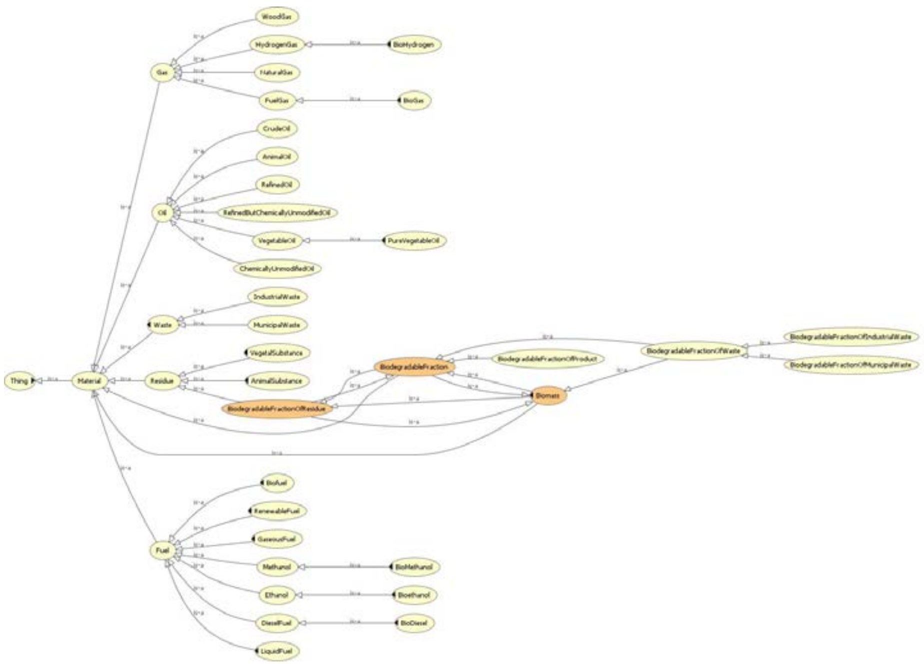


**Fig.24.** Sub-classes of the entity 'Material' in EUDefBiofuels ontology

**Entity 'Forestry' and 'OilIndustry'.** In according to the Article 2 (1) (b) of EU Directive 2003/30/EC, waste materials and residues coming from 'Forestry' and other industry such as 'OilIndustry' can be considered as industrial sources of biomass and hence can be used for producing biofuels.

**Entity 'BiodegradableFractionOfIndustrialWaste' and 'BiodegradableFractionOfMuniciplaWaste'.** Both entities are defined in Article 2 (1) (b) of Directive 2003/30/EC saying that biodegradable fractions of waste can be sourced from industrial as well as municipal waste.

**Entity 'Biomass'.** Article 5 of Regulation (EU) No 691/2011[289] provides a comprehensive list of 'Biomass' and recognized it as a source of 'RenewableEnergy'. In addition Article 2 (1) (b) of Directive 2003/30/EC specifically defines the term 'Biomass' which is mentioned and explained in the section of Entity 'BiomassUnderEU-Directive'. However, the terms 'Biomass' and 'BiomassUnderEUDirective', dis-

[289] Of the European Parliament and of the Council of 6 July 2011 on European environmental economic accounts Text with EEA relevance

cussed above, are not the same entity due to their identity principles considering following points -

- Generally normative perspective of the term 'Biomass', on the one hand, is represented as a material sourced from animal and plants that contains static energy and can be released as heat[290]. On the other hand, EU legal perspective over the term 'Biomass' is relatively more specific and well-grounded. It says 'Biomass' can be only in the form of biodegradable fraction of products, waste and/or residues. The law also includes municipal waste as a source of biomass.
- From the normative point of view, identity principles of the 'Biomass' lie with the inherent capacity of a material. Mainly based on the question – whether the material contains some form of static energy or not. However, from the legal point of view, the identity principles of the term 'Biomass' deal with the sources and types of biodegradable fraction. For example, in the case of source of 'Biomass', law says that the biomass can be obtained from agriculture, forestry and/or other related industry. Whereas normative perspective articulates that source of 'Biomass' can be only animal and plants.

**Entity 'Residue', 'BiogreadableFractionOfResidue'.** Article 2 (1) (b) of Directive 2003/30/EC says that residue is a type of 'Biomass'. Likewise, Article 3(c) of Regulation (EC) NO 396/2005[291] says '*pesticide residues' means residues, including active substances, metabolites and/or breakdown or reaction products of active substances currently or formerly used in plant protection products as defined in Article 2, point 1 of Directive 91/414/EEC*[292]*, which are present in or on the products covered by Annex I to this Regulation, including in particular those which may arise as a result of use in plant protection, in veterinary medicine and as a biocide"*. Even though, the EU legislation considered the term 'Resides' as a type of substance, in this ontology it is stated as a sub-class of 'Biomass' following former EU Directive. However, the terms 'BiogreadableFractionOfResidue', 'AnimalSubstance' and 'VegetableSubstance' is categorized as sub-classes of both – 'Residues' as well as 'Substance'. Therefore, this ontology is not contrary of rather it is in compatible with Regulation (EC) NO 396/2005.

**Entity 'Fuel'.** In according to the Article 2 (6) of Directive 2001/80/EC[293], "fuel" means "*any solid, liquid or gaseous combustible material used to fire the combustion plant"*. Hence it is used as a sub-class of the top-class 'Material'. However, even

---

290 See http://www.epa.gov/climatestudents/solutions/technologies/biomass.html

291 Of the European Parliament and of the Council of 23 February 2005 on maximum residue levels of pesticides in or on food and feed of plant and animal origin and amending Council Directive 91/414/EEC

292 This EU legislation concerns about the placing on the market of plant protection products.

293 Of the European Parliament and of the Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants

though EU Directive 2003/30/EC did not define the term ‘Fuel’, it is very important to consider it as an entity in this ontology for following reasons –

- As the first and foremost identity principle of the term ‘Biofuel’ is being qualified as ‘Fuel’.
- Article 2 of EU Directive 2003/30/EC declares the meaning of ‘Biofuel’ in the form of liquid or gaseous fuel. Therefore, from legal point of view, without the term ‘Fuel’, ontological design of the term ‘Biofuel’ would not be complete and sound.

The entity ‘Fuel’ has following sub-classes – ‘Biofuel’, ‘DieselFuel’, ‘Ethanol’, ‘GaseousFuel’, ‘LiquidFuel’, ‘Methanol’ and ‘RenewableFuel’.

**Entity ‘Biofuel’.** This is a sub-class of the entity ‘Fuel’, not the sub-class of the entity ‘ConstitutiveRule’. It means there are following differences between the terms ‘Biofuel’ and ‘BiofuelUnderEUDirective’ –

- First of all, there two fundamental differences between the identity principles that lies with these two terms.
  - Firstly, the term ‘Biofuel’, on the one hand, is a physical object that plays a role of being used as a material. On the other hand, the term ‘BiofuelUnderEUDirective’ is a legal artifact which plays a role of ‘ConstitutiveRule’, see earlier section.
  - Secondly, ‘Biofuel’, on the one hand, is type of ‘Fuel’ as well as a type of ‘Material’ and therefore it can be used in order to perform some task like driving vehicle. On the other hand, ‘BiofuelUnderEUDirective’ is a type of ‘ConstitutiveRule’ and therefore it has dual roles like a legal-loop – (a) it generates activities, and (b) the activity that has been generated by it must be logically dependent on same and/or other legal rules.
- The general term ‘Biofuel’ is not related with the activity ‘Transport’. But the term ‘BiofuelUnderEUDirective’ is for generating activity of ‘Transport’.
- The term ‘Biofuel’ is not produced from only ‘Biomass’ rather it also can be produced from any sources other than ‘Biomass’. But the term ‘BiofuelUnderEUDirective’ must be sourced from ‘Biomass’, not from any other sources.

**Entity ‘DieselFuel’ and ‘BioDiesel’.** The entity ‘DieselFuel’ is a sub-class of ‘Fuel’ and ‘BioDiesel’ is a sub-class of ‘DieselFuel’. Article 2 (2) of Directive 98/70/EC[294] recognized ‘DieselFuel’ as a type of ‘Fuel’ within the CN codes 2710 00 66 which is purposely used for self-propelling vehicles as referred to in Directive 70/220/EEC and Directive 88/77/EEC. However, Article 2 (2) (b) of DIRECTIVE 2003/30/EC defines ‘BioDiesel’ as “*a methyl-ester produced from vegetable or animal oil, of diesel quali-*

[294] Of the European Parliament and of the Council of 13 October 1998 relating to the quality of petrol and diesel fuels and amending Council Directive 93/12/EEC

*ty, to be used as biofuel"*. Therefore it is also a sub-class of the entity 'BiofuelUnderEUDirective'.

**Entity 'Ethanol' and 'Bioethanol'.** 'Ethanol' as a sub-class of 'Fuel' is ethyl alcohol, which is similar to some alcoholic beverage[295]. 'Bioethanol' is a type of 'Ethanol' as well as also sub-class of the entity 'BiofuelUnderEUDirective' as it is defined in Article 2 (2) (a) of Directive 2003/30/EC saying that "*bioethanol is a type of fuel produced from biomass and/or the biodegradable fraction of waste, to be used as biofuel"*.

**Entity 'GaseousFuel'.** Article 1(2) (c) of Directive 2009/142/EC[296] defines "'*gaseous fuel' means any fuel which is in a gaseous state at a temperature of 15 °C under a pressure of 1 bar"*. In addition, Article 2 (1) (a) of Directive 2003/30/EC clearly mentions that 'Biofuel' can be in the form of 'GaseousFuel'. Hence, this is also a sub-class of 'BiofuelUnderEUDirective'.

**Entity 'LiquidFuel'.** In according to the Council Directive 93/12/EEC[297], 'LiquidFuel' is a type of Fuel' and Article 2 (1) (a) of Directive 2003/30/EC mentions that 'Biofuel' can be in the form of 'LiquidFuel'. Therefore, it is sub-class of both terms – 'Fuel' as well as 'BiofuelUnderEUDirective'.

**Entity 'Methanol' and 'BioMethanol'.** In this ontology, the term 'Methanol' is a sub-class of 'Fuel' and 'BioMethanol' is sub-classes of both terms - 'Methanol' and 'BiofuelUnderEUDirective'. Annex III of Directive 2009/28/EC[298] specified that methanol is a type of fuel and source of biomass and used for producing bio-fuel. In addition, Article 2 (2) (d) of Directive 2003/30/EC defines 'BioMethanol' as "*methanol produced from biomass, to be used as biofuel"*.

**Entity 'RenewableFuel'.** Article 2 (1) of Directive 2014/94/EU[299] defines alternative fuel in the same way EU Directive 2003/30/EC defines 'Biofuel' as a renewable fuel. The former legislation basically indicates energy sources other than fossil fuel in order to produce alternative fuels while the latter one specifies the meaning and sources of biofuel as a renewable fuel. However, in this ontology, 'RenewableFule' is a type of 'Fuel' which is produced from renewable resources like 'Biomass'. Therefore, this term is also sub-class of 'BiofuelUnderEUDirective'.

[295] See https://en.wikipedia.org/wiki/Ethanol_fuel
[296] Of the European Parliament and of the Council of 30 November 2009 relating to appliances burning gaseous fuels
[297] Of 23 March 1993 relating to the sulphur content of certain liquid fuels
[298] Annex III mainly provided a list concerning energy content of transport fuels.
[299] Of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure

**Entity 'Gas'.** This is a sub-class of the term 'Material' as it is used to produce something. For example, EU Directive 2003/30/EC demonstrates that the gas sourced from 'Biomass' can be used in order to produce 'Biofuel'. It has following sub-classes extracted from the legislative texts – 'FuelGas', 'BioGas', 'HydrogenGas', 'BioHydrogen', 'NaturalGas' and 'WoodGas'.

**Entity 'FuelGas' and 'BioGas'.** Article 2 (2) (c) of Directive 2003/30/EC specifies both of these terms. In the case of 'FuelGas', the Directive says that is a type of gas produced from biomass. And about the other, the Directive specifically defines it "*as a fuel gas produced from biomass and/or from the biodegradable fraction of waste, that can be purified to natural gas quality, to be used as biofuel, or woodgas*". Hence the term 'BioGas' is also the sub-class of the entity 'BiofuelUnderEUDirective'.

**Entity 'HydrogenGas' and 'BioHydrogen'.** Preamble 5 of the Regulation (EC) No 79/2009 [300] indicates that 'HydrogenGas' as a 'Gas' fuel will be one of the most clearest way of powering vehicles in future which will be pollution-free as well as will be considered as renewable energy resource. Therefore, in this ontology, it used as a sub-class of 'Gas'. Likely, Article 2 (2) (i) of Directive 2003/30/EC defines 'BioHydrogen' as "*a type of hydrogen produced from biomass, and/or from the biodegradable fraction of waste, to be used as biofuel*". Therefore, the term 'BioHydrogen' is used as sub-classes of two terms – 'HydrogenGas' and 'BiofuelUnderEUDirective' in this ontology.

**Entity 'NaturalGas' and 'WoodGas'.** Both of these terms used as sub-classes of the entity 'Gas'. Article 2 (2) (c) of the EU Directive 2003/30/EC specifics particularly the quality level of both terms 'NaturalGas' and 'WoodGas' in order to qualify 'BioGas' as a type of 'BiofuelUnderEUDirective'. Therefore, why these terms are used in this ontology requires a complex legal analysis of what quality level of natural gas and wood gas is required by law for cognizing the biogas as a biofuel. However, even though the EU Directive does not clarify about that, these terms are used in order to support ontological and semantic articulations of the term 'BioGas', which is legally qualified as a sub-class of the entity 'BiofuelUnderEUDirective'.

**Entity 'Oil'.** Article 2 (a) of Regulation (EU) No 911/2014[301] defines "*oil as petroleum in any form, including crude oil, fuel oil, sludge, oil refuse and refined products as established by the International Convention on Oil Pollution Preparedness, Response and Cooperation, 1990, of the International Maritime Organisation (IMO)*". However, in according to the Article 2 (2) (b) and (j) of the EU Directive 2003/30/EC, 'Bio-

[300] Of the European Parliament and of the Council of 14 January 2009 on type-approval of hydrogen-powered motor vehicles, and amending Directive 2007/46/EC

[301] Of the European Parliament and of the Council of 23 July 2014 on multiannual funding for the action of the European Maritime Safety Agency in the field of response to marine pollution caused by ships and oil and gas installations

Diesel' as well as 'PureVegetableOil' can be produced from some kind of oil, e.g. 'AnimalOil' or 'VegetableOil'. It means that in the latter legislation, 'Oil' is used as a type of 'Material'. It has total seven sub-classes – 'AnimalOil', 'ChemicallyUnmodifiedOil', 'CrudeOil', 'RefinedButChemicallyUnmodifiedOil', 'RefinedOil', 'VegetableOil' and 'PureVegetableOil', shown in Figure 24. These sub-classes are explained below –

**Entity 'AnimalOil' and CrudeOil.** Generally 'AnimalOil' is a type of oil obtained from animal substance and 'CrudeOil' is unrefined petroleum. Both of these oils are used as 'Material'. In addition, Article 2 (2) (j) of the EU Directive 2003/30/EC specifies that 'AnimalOil' itself can be a source of 'Biodiesel' and 'PureVegetableOil' can be in the form of 'CrudeOil'. Hence the term 'AnimalOil' is also used a sub-class of the top-class 'Source'.

**Entity 'ChemicallyUnmodifiedOil'.** This is a type of 'Oil' that is chemically unmodified. Article 2 (2) (j) of the EU Directive 2003/30/EC clearly mentioned that 'PureVegetableOil' must be 'ChemicallyUnmodifiedOil'.

**Entity 'RefinedOil' and 'RefinedButChemicallyUnmodifiedOil'.** The form of 'Oil' can be various such as refined and/or refined and also chemically modified/unmodified. However, legislation regarding 'Biofuels' is very particular, specially about the sources and forms of 'PureVegetableOil' as to consider it as 'Biofuel'. Article 2 (2) (j) of the EU Directive 2003/30/EC validates only 'refinedButChemicallyUnmodifiedOil' as a right source and form of 'PureVegetableOil' in order to be categorized as 'Biofuel'.

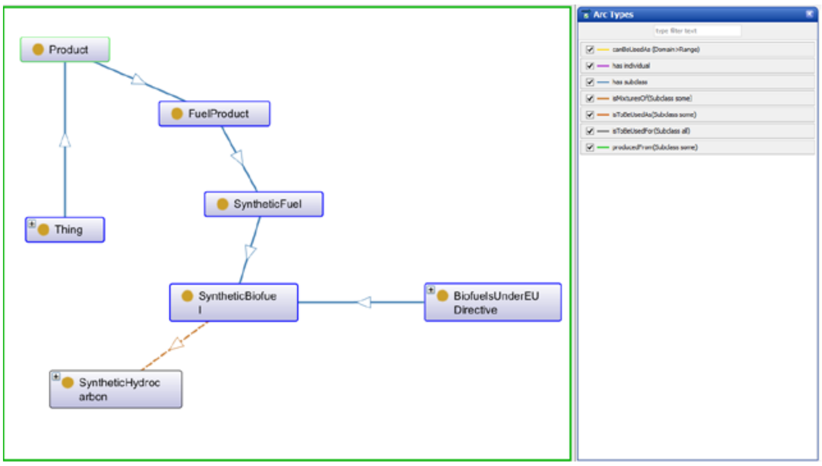



**Fig.25.** Sub-class of the entity 'Product' in EUDefBiofuels ontology

**Entity 'VegetableOil' and 'PureVegetableOil'.** Article 2 (2) of the EU Directive 2003/30/EC has two different sections about these two terms. In according to the Article 2 (2) (b), 'VegetableOil' can be used as a source of ''BioDiesel". While Article 2 (2) (j) clearly defines 'PureVegetableOil' as a type of biofuel saying that "*vegetable oil as oil produced from oil plants through pressing, extraction or comparable procedures, crude or refined but chemically unmodified, when compatible with the type of engines involved and the corresponding emission requirements*". Therefore, 'PureVegetableOil' is also sub-class of 'BiofuelUnderEUDirective'. In addition, as the identity principle of 'PureVegetableOil' is that it is type of vegetable oil, it is also addressed as a sub-class of 'VegetableOil'.

**Entity 'Waste'.** In according to the Article 3(1) of Directive 2008/98/EC[302], *'waste' means any substance or object which the holder discards or intends or is required to discard*'. The term 'Waste' is also as defined in Article 1(a) of Directive 75/442/EEC[303]. In addition, EU Directive 2003/30/EC recognized 'Waste' as a material to be used in order to produce 'Biofuel'. Considering these two legislations, the term 'Waste' is used as a sub-class of top-classes - 'Material' and 'Substance'. It has two sub-classes – 'IndustrialWaste' and 'MunicipalWaste'.

**Entity 'IndustrialWaste' and 'MunicipalWaste'.** In according to the Article 2 (1) (b) of EU Directive 2003/30/EC, both industrial and municipal waste are kind of waste materials and sources of biomass.

**Entity 'FuelProduct'.** This is a sub-class of the top-class 'product', shown in Figure 25. EU Directive 2003/30/EC does not directly mention about the term 'FuleProduct'. However it expresses the term 'SyntheticBiofuel' as a form of 'BiofuelUnderEU-Directive'. That is technically a 'FuelProduct'. Hence it requires introducing 'FuelProduct' and 'SyntheticFuel' as mother classes of the term SyntheticBiofuel'. However, in a sense, 'Biofuel' as it is sold in the market can be considered as 'FuelProduct'. But as the objective of this ontology is to represent the EU legal definition of biofuel, it used 'Biofuel' as a type of 'Fuel', but not 'FuelProduct'. Because EU Directive 2003/30/EC does not mention that 'Biofuel' is a 'FuelProduct'. However, even though the Directive also does not mention that 'SyntheticBiofuel' is a 'FuelProduct', the term 'SyntheticBiofuel' is used a sub-class of 'SyntheticFuel' and 'FuelProduct'. Because the origin of the term 'SyntheticFuel' is derived from the idea of substituting petrol commercially. Hence the importance of introducing the term 'FuelProduct' rose in this ontology and subsequently it has been used.

[302] Of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives

[303] Of 15 July 1975 on waste published in the Official Journal L 194, 25/07/1975 pp. 0039 - 0041. It says ""waste" means any substance or object which the holder disposes of or is required to dispose of pursuant to the provisions of national law in force".

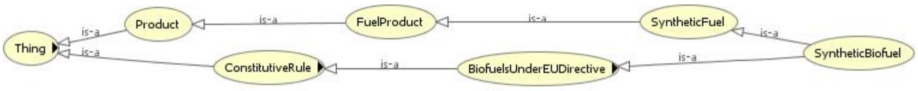



**Fig.26.** Parent-classes of the term 'SyntheticBiofuel'

**Entity 'SyntheticFuel' and 'SyntheticBiofuel'.** Preamble (6) of Directive 2014/94/EU[304] recognizes synthetic fuel as a fuel product and describes – "*synthetic fuels substituting petrol, such as methanol and other alcohols, can be blended with petrol and can be technically used with current vehicle technology with minor adaptions. Methanol can also be used for inland navigation and short-sea shipping. Synthetic and paraffinic fuels have a potential to reduce the use of oil sources in the energy supply to transport*". However, Article 2 (2) (h) of Directive 2003/30/EC defines synthetic biofuel as "*synthetic hydrocarbons or mixtures of synthetic hydrocarbons, which have been produced from biomass*". Therefore, the term 'SyntheticBiofuel' is used as subclasses of both term - 'SyntheticFuel' and 'BiofuelUnderEUDirective', shown in Figure 26.

**Entity 'DieselQuality' and 'NaturalGasQuality'.** Both of these terms are the sub-classes of the top-class 'Quality' and mentioned in Article 2 (2) (b) and (c) of Directive 2003/30/EC. The former part of the Article articulates that methyl-ester produced from vegetable or animal oil must maintain the diesel quality - a minimum standard of chemicals that diesel should have. The latter Article specifies that a fuel gas, produced from biomass and/or from the biodegradable fraction of waste, can be purified to natural gas quality - a minimum standard of chemicals that natural gas should have. Both of these terms have reasoning links with the terms - 'VegetableOil', 'AnimalOil', 'FuelGas' etc.

**Entity 'RenewableResource'.** This term is a sub-class of the top-class 'Resource'. Jean Garner Stead and W. Edward (2009) in their book named 'Management for a small plant[305]' mentioned – "*a renewable resource is an organic natural resource which can replenish to overcome usage and consumption, either through biological reproduction or other naturally recurring processes*". In this ontology, this term is used to represent the conceptual richness of the term 'Biomass'. Because primarily the term 'Biomass' is used as a sub-class of 'Material', which itself is a kind of organic natural resource used for producing renewable biofuels. Therefore, the term 'Biomass' is used also as a sub-class of 'RenewableResource'.

[304] Of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure

[305] Stead, Jean Garner/ Stead, W. Edward. Management for a Small Planet (3rd Edition), Armonk, N.Y.:M.E. 2009.

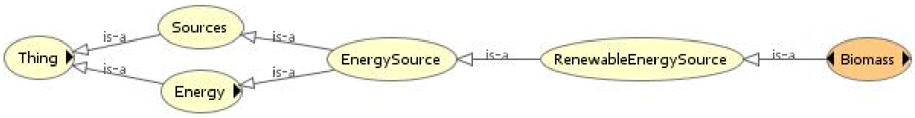



**Fig.27.** Parent and child classes of the term "EnergySource”

**Entity ‘EnergySource’.** Directive 2009/28/EC defines it as “*a source from which useful energy can be extracted or recovered either directly or by means of a conversion or transformation process (e.g. solid fuels, liquid fuels, solar energy, biomass, etc.)*”. In addition, as previously mentioned too, Article 2 (13) of Regulation (EU) No 256/2014 provides a comprehensive list showing the types of ‘EnergySource’. In this ontology, this term is used a sub-class of the top-class ‘Source’, shown in Figure 27.

**Entity ‘RenewableEnergySource’.** Article 2 (a) of Directive 2009/28/EC mentions that “‘*energy from renewable sources’ means energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases'*”. Article 2 (1) (c) of Directive 2003/30/EC also mentions that renewable fuel, e.g. biofuel, must be sourced from renewable energy sources, e.g. biomass. Hence this term is used as sub-classes of following two terms – ‘EnergySource’ and ‘Biomass’, shown in Figure 27. However, it is noteworthy to explain the differences between the terms ‘RenewableEnergySource’ and ‘RenewableResource’, which is given below –

- The term ‘RenewableEnergySource’ shows a direction of ‘where what is available to be used’, while the term ‘RenewableResource’ indicates the object itself, either in tangible or intangible form, itself that can be used renewably.
- A term can be recognized as ‘RenewableEnergySource’ and ‘RenewableResource’ simultaneously. For example, the term ‘Biomass’ can be sub-class of both of these terms. To what term it belongs as a sub-class depends on for what purpose and meaning the term carries. When the term ‘Biomass’ is a sub-class of ‘RenewableEnergySource’, it means ‘Biomass’ is a source of renewable energy. But when the term ‘Biomass’ is used as a sub-class of ‘RenewableResource’, it means the ‘Biomass’ is a resource, not only a source, that is qualified of being used as renewable energy source.
- If a term is qualified as a sub-class of ‘RenewableResource’, most reasonably it is also qualified as a ‘RenewableSource’.

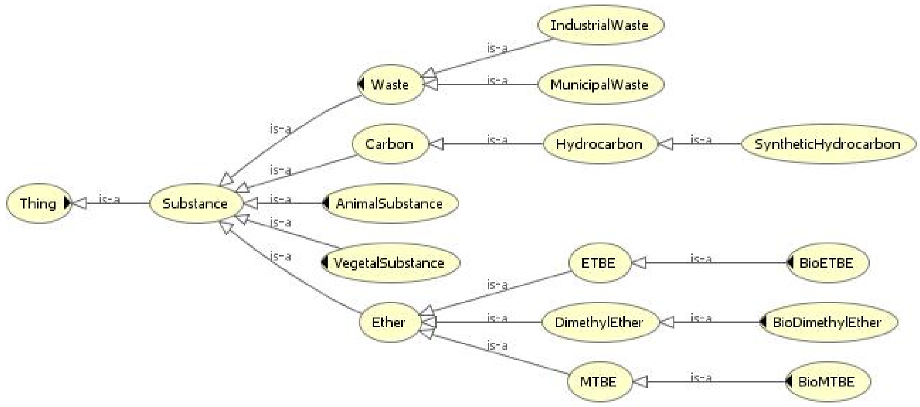



**Fig.28.** Sub-class of the top-class 'Substance' in EUDefBiofuels ontology

**Entity 'AnimalSubstance' and 'VegetalSubstance'.** Article 2 of Regulation (EC) No 396/2005[306] recognizes both 'AnimalSubstance' and 'VegetalSubstance' are sub-classes of substance known as 'Residue'. Furthermore, Article 2(1) (b) of Directive 2003/30/EC specifies that 'Residue' coming from 'AnimalSubstance' and/or 'VegetalSubstance' is 'Biomass', hence also considered as 'RenewableEnergySource'. These both terms are sub-classes of the top-class 'Substance', shown in Figure 28.

**Entity 'Carbon', 'Hydrocarbon', 'SyntheticHydrocarbon'.** In according to the Article 2(2) (h) of Directive 2003/30/EC, the term 'Carbon' is a type of 'Substance' that forms 'SyntheticHydrocarbon' and 'Hydrocarbon' can be a source of 'SyntheticHydrocarbon'. It also clearly specified that 'SyntheticHydrocarbon' is a type of 'BiofuelUnderEUDirective' that is produced from 'Biomass'. The sub-class relationships of these terms are shown in Figure 28.

**Entity 'Ether'.** Directive 2003/30/EC mentions that 'Ether' is a type of 'Substance' used for producing 'Biofuel'. From the Directive, six sub-classes have been detected for this ontology. They are – 'DimethylEther', 'BioDimethylEther', 'ETBE', 'BioETBE', 'MTBE', 'BioMTBE'.

**Entity 'DimethylEther' and 'BioDimethylEther'.** In according to the Article 2 (2) (e) of Directive 2003/30/EC 'DimethylEther' is a type of 'Substance' produced from 'Biomass' and used to produce 'BioDimethylEther'. The Directive also clearly declares that 'BioDimethylEther' is a type of 'Biofuel'.

---

[306] Of the European Parliament and of the Council of 23 February 2005 on maximum residue levels of pesticides in or on food and feed of plant and animal origin and amending Council Directive 91/414/EEC.

**Entity ‘ETBE’ and ‘BioETBE’.** Article 2 (2) (f) of Directive 2003/30/EC says that ‘ETBE’ is a type of ‘Ether’ used to produce ‘BioETBE’, which is also a type of ‘Biofuel’. Therefore, ‘BioETBE’ is also a sub-class of ‘BiofuelUnderEUDirective’, shown in Figure 28.

**Entity ‘MTBE’ and ‘BioMTBE’.** MTBE is a type of ‘Substance’ used to produce a type of ‘Biofuel’ known as ‘BioMTBE’ – mentioned in Article 2 (2) (g) of Directive 2003/30/EC. As a result, the term ‘BioMTBE’ is used sub-classes of both terms – ‘MTBE’ and ‘BiofuelUnderEUDirective’.

**Entity ‘Value’.** Directive 2003/30/EC demonstrates the legal important of ‘LowerCalorificValueOfFuel’, but does not mention anything about the term ‘Value’. Oxford dictionary defines the term ‘Value’ that represents particular quantity that is the result of applying a function or operation for some given argument. The uniqueness and identity principles of the term ‘Value’ lie with quantity of something, which is completely different than the identity principles of the term ‘Quality’. Hence the term ‘Value’ reasonably cannot be the sub-class of ‘Quality’. However, the term ‘Quality’ has a relationship with the term ‘Value’ as it can express the inherent or standard or legal amount or quantity of the parameters that the term ‘Quality’ holds or belongs. However, in this ontology, both terms ‘Value’ and ‘’Quality’ are the top-classes due to their own identity principles. In according to the Directive 2003/30/EC, there are three sub-classes of the term ‘Value’. These are - ‘CalorificValue’, ‘CalorificValueOfFuel’ and ‘LowerCalorificValueOfFuel’, shown in Figure 29.

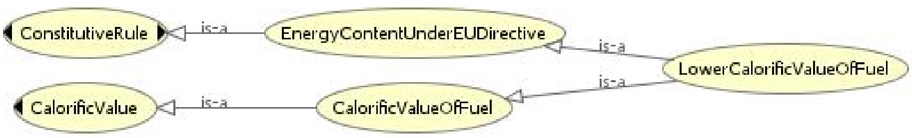



**Fig.29.** Parent-classes of the term 'LowerCalorificValueOfFuel'

**Entity ‘CalorificValue’, ‘CalorificValueOfFuel’ and ‘LowerCalorificValueOfFuel’.** The dictionary[307] defines ‘CalorificValue’ as “*the quantity of heat liberated on the complete combustion of a unit weight or unit volume of fuel*”. In addition, Article 2 (1) (d) of Directive 2003/30/EC specifies following points –

- ‘CalorificValueOfFuel’ can carry higher as well as lower value.
- Only ‘LowerCalorificValueOfFuel’ represents the ‘EnergyContent’.

Therefore, ‘LowerCalorificValueOfFuel’ is considered as the sub-classes of both terms - ‘EnergyContentUnderEUDirective’ and ‘CalorificValueOfFuel’ which is a

[307] See http://dictionary.reference.com/browse/Calorific%20Value

sub-class of ‘CalorificValue’, shown in Figure 29. However, these all three terms are sub-classes of the top-class ‘Value’.

### 21.2 Object-and-data-properties of EUDefBiofuels ontology

There are 11 object-properties, besides the top object-properties. They are – ‘’canBePurifiedTo’, ‘CanBeUsedAs’, ‘comesFrom’, ‘compatibleWith’, ‘isProducedOnTheBasisOf’, ‘isToBeUsedAs’, ‘isToBeUsedFor’, ‘mixturesOf’, ‘mustCorrespondWith’, ‘originatedFrom’, and ‘producedFrom’. There is also one data-property that is ‘isCalculatedAsBiofuel’. All of these properties are extracted from the Article 2 of Directive 2003/30/EC. They all are used in order to create restrictions over the entities. Some of them are also used as to create a special kind of restriction intended to use successively as a sub-class of some entities. This will be demonstrated in the later section. This section is dedicated to only introduce all object and data properties that have been used in this ontology. In the later sections, these properties will be discussed in detail.

**canBePurifiedTo.** Article 2 (2) (c) of Directive 2003/30/EC confirmed that ‘BioGas’ ‘canBePurifiedTo’ ‘NaturalGasQuality’ in order to be used as ‘Biofuel’. Therefore, this object-property is used as to create ‘SubClassOf’ class expression of the terms ‘BoiGas’ and ‘NaturalGas’, shown in Figure 30. Hence it object-property expresses the necessary and sufficient conditions of what makes ‘BioGas’ qualified to be used as ‘BiofuelUnderEUDirective’.

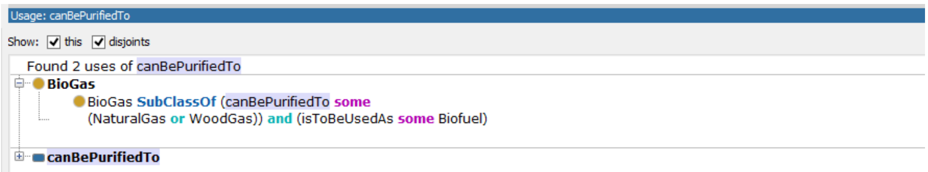



**Fig.30.** Uses of object-property 'canBePurifiedTo'

**canBeUsedAs.** In according to the Directive 2003/30/EC, ‘wood gas can be used as biogas. Consequently the object-property ‘canBeUsedAs’ is used in this ontology in order to create domain-range relationship between the terms ‘WoodGas’ and ‘BioGas’. In this legal relationship, ‘WoodGas’ can be used as ‘BioGas’, not vice versa. Therefore, the characters this object-property carries are functional and asymmetric.

**comesFrom.** Directive 2003/30/EC mentions that ‘BiodegreadableFraction’ of waste, products and residues comes from agriculture, forestry and/or biodegradable fraction of industrial and municipal waste. In this legal context, the terms ‘Biodegreadable-Fraction’ is also considered as a type of ‘Biomass’ and the sources of ‘BiodegreadableFraction’ are specified and restricted such as ‘Waste’, ‘IndustrialWaste’, ‘MunicipalWaste', 'Agriculture', 'Forestry', 'Product', 'Residues' etc. The object-property 'comesFrom' is used to handle the legal restriction employed on the term 'BiodegreadableFraction'.

**compatibleWith.** This object-property is extracted from the legislative texts in order to connect the terms - 'PureVegetableOil' and 'Engines' as Article 2 (2) (j) of Directive 2003/30/EC specifies that pure vegetable oil must be compatible with engines. This is not used as a domain-range relationships, rather this has been used to create a sub-class expression of the term 'PureVegetableOil'.

**isProducedOnTheBasisOf.** Article 2 (2) (f) and (g) of Directive 2003/30/EC clearly mentions that BioEtBE and BioETBE, some form of 'Biofuel', is produced on the basis of 'Bioethanol' and 'BioMethanol' respectively. Therefore, like the object-property 'compatibleWith', 'isProducedOnTheBasisOf' is extracted from the respective Article and used as sub-class expression over the terms – 'BioEtBE', 'BioETBE', 'Bioethanol' and 'BioMethanol'.

**isToBeUsedAs.** This object-property is taken from the Article 2 (2) (a) to (e) of Directive 2003/30/EC. In the legislative texts of all of these sections (a) to (e), 'isToBeUsedAs' is used in order to connect and represent different forms of biofuels. For example, Article 2 (2) (a) says if the ethanol is produced from the biomass and/or biodegradable fraction of waste, then this will be known as bioethanol and therefore this is to be used as biofuel. Consequently this object-property plays a very important role in order to apply conditional restrictions over the terms in this ontology. Further discussion in detail is given in later section.

**isToBeUsedFor .** The most vital condition of how to qualify 'Biofuel' is given in Article 2 (1) (a) of Directive 2003/30/EC by using the object-project 'isToBeUsedFor'. The law says – biofuels is to be used for transport, not for any other purpose. Therefore this object property is used to create sub-class expression of the terms 'BiofuelUnderEUDirective'. However, it is noteworthy to mention following differences between object properties – 'isToBeUsedAs' and 'isToBeUsedFor' -

- Generally, object property 'isToBeUsedAs', extracted from the legislative texts, transfers the 'identity principle' of one term to another. For example, Article 2 (2) (c) of Directive 2003/30/EC says that if a fuel gas is produced from biomass and then purified to the natural gas quality, then that fuel gas is to be used as biogas and therefore it is a type of biofuel. What particularly happened in this Article is that the object property 'isToBeUsedAs' is used in order to transfer the identity principle of the term from 'FuleGas' to 'BioGas' to 'Biofuel' by applying two conditions
    - Produced from 'Biomass' and
    - Purified to the natural gas quality.

- On the other hand, object-property ‘isToBeUsedFor’ is created in order to represent the legislative text ‘For’. Because Article 2 (1) (a) of Directive 2003/30/EC mentions -

  *“…‘biofuels’ means liquid or gaseous fuel **for** transport produced from biomass….”*

  Now technically speaking an object-property generally contains verb in according to the OWL 2 specification. Therefore, there is a technical limitation to use ‘*for’* as an object property in order to make a relationship between terms - ‘Biofuels’ and ‘Transport’. Therefore, the object property ‘isToBeUsedFor’ is created in order to overcome this technical limitation. However, unlike the object property ‘isToBeUsedAs’, the object property ‘isToBeUsedFor’ simply represents usages of something. For example, biofuels produced from biomass is to be used for transport.

**isMixturesOf.** Article 2 (2) (h) of Directive 2003/30/EC exhibits that synthetic biofuels is mixtures of synthetic hydrocarbons, which is produced from biomass. Therefore, the object property ‘isMixturesOf’, extracted from the legislative text, is used to create a sub-class expression of the term ‘SyntheticBiofuel’ with the term ‘SyntheticHydrocarbons’.

**mustCorrespondWith.** In order to qualify ‘pure vegetable oil’ as a biofuel under EU regulation, it must correspond with the emission requirements as prescribed in laws – said in Article 2 (2) (j) of Directive 2003/30/EC. Therefore, the object property ‘mustCorrespondWith’ is used to represent this legal restriction over the term ‘PureVegetableOil’ as its sub-class expression.

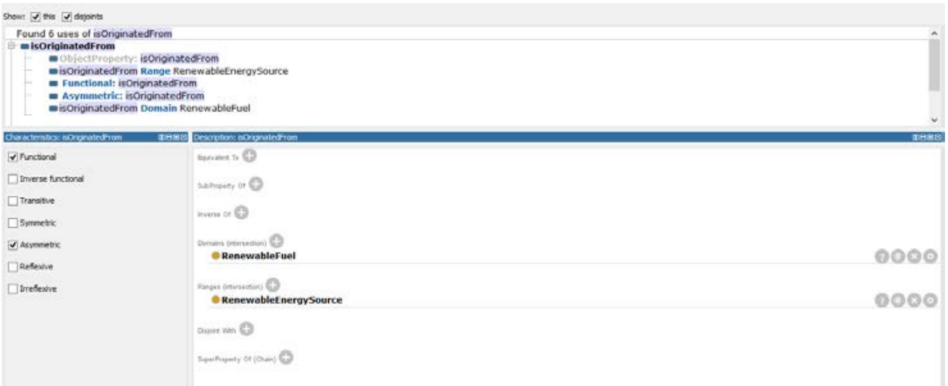



**Fig.31.** Uses of object-property 'isOriginatedFrom'

**isOriginatedFrom.** Article 2 (1) (c) of Directive 2003/30/EC prescribes as follow –

*‘‘…..other renewable fuels’ means renewable fuels, other than biofuels, which* ***__origi-nate from__*** *renewable energy sources as defined in Directive 2001/77/EC (2) and used for transport purposes…..’’*

Therfore, the object property ‘isOriginatedFrom’ is used to make relationship between the domain term ‘Renewablefuel’ and range term ‘RenewableEnergySource’, shown in figure 31. The nature of this relationship is functional and asymmetric, because renewable fuel is originated from renewable energy source, which is not the other way around.

**producedFrom.** Like the object-property ‘isToBeUsedFor’, this object-property also play very crucial role in the formation of legal meaning of biofuels under EU Regulation. Because Article 2 (1) (a) of Directive 2003/30/EC articulates that biofuel is in the form of liquid or gaseous fuel and produced from biomass for transport. In this Article, the object property is used to establish the most vital legal relationship between the terms – ‘Biofuel’ and ‘Biomass’. In addition, this object property has been also used in the Article 2 (2) (b) and (j) of the same EU Directive for initiating legal relationships between/among the terms. In the case of Article 2 (2) (b) involved terms are ‘BioDiesel’, ‘AnimalOil’ and ‘VegetableOil’ in, and in the case of the Article 2 (2) (j), the involved terms are ‘PureVegetableOil’ and ‘OilProduction’. All of these relationships are created as sub-class expressions of the domain terms such as ‘BioDiesel’, ‘BiofuelUnderEUDirective’, and ‘PureVegetableOil’, shown in Figure 32.


**Fig.32.** Uses of the object-property 'producedFrom'

However, even though the object properties - ‘isOriginatedFrom’ and ‘producedFrom’ are extracted from the legislative texts, they have following differences –

- The object property ‘isOriginatedFrom’ indicates the source as well as transfer the identity principles from one term to another. For example, ‘RenewableFuel’ ‘isOriginatedFrom’ ‘RenewableEnergySource’. Here As ‘RenewableFule’ is originated from the renewable energy source, the term ‘Fuel’ has received its identity principle ‘*renewable*’ from the terms – ‘RenewableEnergySource’ and became ‘RenewableFule’.
- The object-property ‘producedFrom’ indicates the material that is used to produce. For example, biodiesel is produced from animal and/or vegetable oil. Here the object-property does not transfer the identify principles of one terms to another.

**isCalculatedAsBiofuel.** This is the only data-property in this ontology. Article 2 (2) (f) and (g) of Directive 2003/30/EC says as follow –

> *"…..(f) 'bio-ETBE (ethyl-tertio-butyl-ether)': ETBE produced on the basis of bio-ethanol. The percentage by volume of bio-ETBE that **is calculated as biofuel** is 47 %;*
>
> *(g) 'bio-MTBE (methyl-tertio-butyl-ether)': a fuel produced on the basis of bio-methanol. The percentage by volume of bio-MTBE that **is calculated as biofuel** is 36 %;…."*

In both of these Articles, the underlined bold legislative texts are common. Herewith this ontology, therefore, 'isCalculatedAsBiofuel' is used as a data-property with a value restriction, shown in Figure 33.

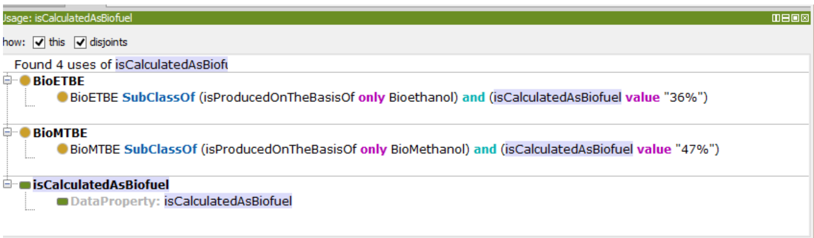



**Fig.33.** Uses of the data property 'isCalculatedAsBiofuel'

### 21.3 Legal Restrictions over the entities in EUDefBiofuels ontology

All three mechanisms, discussed in the section 20.3, have been applied in order to create restrictions over the entities in EUDefBiofuels ontology. There are asserted as well as inferred restrictions simultaneously perform their reasoning operations in this ontology. In this section, only asserted restrictions have been explained.

**Legal restriction over the entity 'BiofuelsUnderEUDirective'.** The Article 2 (1) (a) of Directive 2003/30/EC clearly mentions following two legal conditions that the term 'Biofuel' must correspond with –

- *Legal condition 1* – it must be produced from biomass as defined in Article 2 (1) (b) of Directive 2003/30/EC,
- *Legal condition 2* – it must be used for transports.

The Directive itself is silence if the biofuel is produced from any other sources other than biomass and is used for any other purposes other than transportation. Therefore, in order to formulate the ontology of this definition, these two conditions are engineering as restriction in the form of SubClassOf class expression, shown in R16.

$$BifuelsUnderEUDirective \sqsubseteq \exists\, producedFrom\,.\,(BiomassUnderEUDirective) \sqcap \forall\, isToBeUsedFor\,.\,(Transport) \qquad (R16)$$

In this restriction, the term ‘BifuelsUnderEUDirective’ implies with existential relationships to the term ‘BiomassUnderEUDirective’ using the object property ‘producedFrom’. It also implies with universal relationship to the term ‘Transport’ using the object-property ‘isToBeUsedFor’.

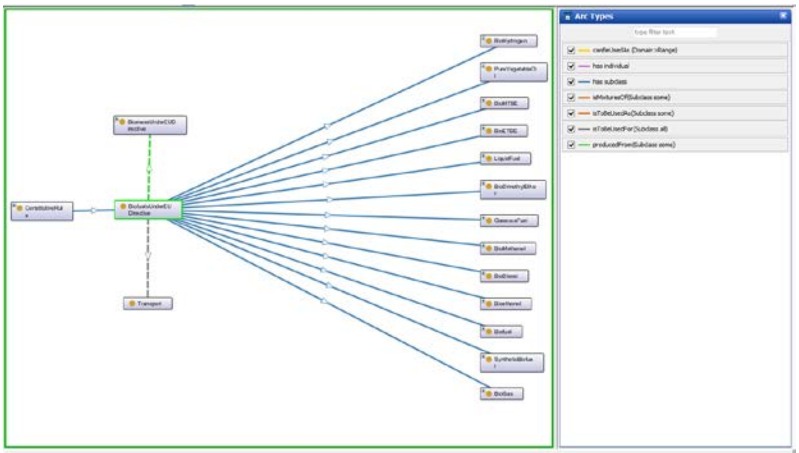


**Fig.34.** Sub-class and restrictions over the entity 'BiofuelsUnderEUDirective'

In addition, the term ‘BiofuelsUnderEUDirective’ is the parent-class of following terms – ‘BioDiesel’, ‘BioDimethylEther’, ‘BioETBE’, ‘Bioethanol’, ‘Biofuel’, ‘BioGas’, ‘BioHydrogen’, ‘BioMethanol’, ‘BioMTBE’, ‘GaseousFuel’, ‘LiquidFuel’, ‘PureVegetableOil’, and ‘SyntheticBiofuel’, shown in Figure 34. These all sub-classes are extracted from the legislative texts of Article 2 of Directive 2003/30/EC. However, implication of these sub-classes’ relationships are also based on a number of restrictions.

**Legal restriction over the entity ‘Biomass’.** Article 2 (1) (b) of Directive 2003/30/EC defines the term ‘Biomass’. Legal text of this definition is very complexly designed which may lead different-interpretations of the terms, properties and their relationships. For example, it says, biomass means biodegradable fraction of waste, products and residues that comes from agriculture, forestry and other industry. The definition also includes the waste coming from industrial and municipal day to day operations. However, it may give different meaningful interpretation such as – Biomass comes from industrial waste as biodegradable fraction of waste may come from industrial operations. That might be a misleading interpretation of the term ‘Biomass’. Because it is very clear from the Directive is that if industrial waste does not contain biodegradable fraction, then the waste does not represent the term ‘Biomass’ under this Directive. Therefore, the most acceptable and convincing interpretation would be that – the term ‘Biomass’ is an equivalent term to ‘BiodegradableFraction’, which has three different forms – ‘BiodegradableFractionOfWaste’, ‘BiodegradableFraction-OfProducts’ and ‘BiodegradableFractionOfResidues’, shown in Figure 35.

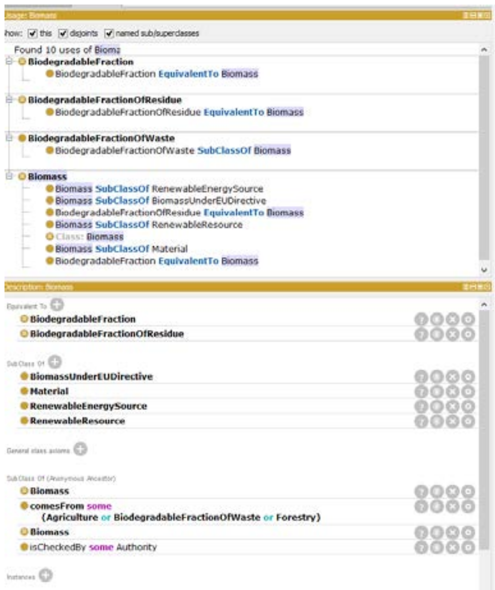



**Fig.35.** Sub-classes and restrictions over the entity 'Biomass'

These different forms of ‘BiodegradableFraction’ can be obtained from various industrial sectors such as ‘Agriculture’, ‘Forestry’ and various forms of the waste such as ‘IndustrialWaste’ and/or ‘MunicipalWaste’. As a result, legal restrictions that are provided in the Article 2 (1) (b) are related with the term ‘BiodegradableFraction’, not the term ‘Biomass’. Consequently, in this ontology, the term ‘Biomass’ is used as an equivalent term to ‘BiodegradableFraction’, shown in R18, and all the restrictions extracted from the legislative text are used as restrictions over the different sub-classes of the term ‘BiodegradableFraction’.

$$\textit{Biomass} \equiv \textit{BiodegradableFraction} \equiv \textit{BiodegradableFractionOfResidue} \qquad \textit{(R17)}$$

In the restriction, R17, the terms ‘BiodegradableFractionOfWaste’, ‘BiodegradableFractionOfProducts’ are not used, because these terms are already used as sub-classes of the term ‘BiodegradableFraction’. Therefore, these terms automatically inferred by the reasoner. In addition, the term ‘Biomass’ is used as a sub-class of the term ‘BiomassUnderEUDirective’, shown in Figure 35. These equivalent classes are also shown in Figure 20 and 38 with red colors boxes.

**Legal restriction over the entity 'BiodegradableFractionOfResidue'.** The restriction R18 shows that *SubClassOf* classes of the term 'BiodegreadableFractionOfResidue' and the restriction R19 shows it's existential relationship with the terms 'Agriculture', 'BiodegreadableFractionOfWaste' or 'Forestry' using object-property 'comesFrom'.

$$BiodegradableFractionOfResidue \sqsubseteq \exists\ comesFrom\ .\ (Agriculture \sqcup Biodegradabl\ FractionOfWaste \sqcup Forestry) \qquad (R18)$$

This restriction is extracted from Article 2 (1) (b) of Directive 2003/30/EC and is inferred over the terms those are subclasses and equivalent classes of the term 'BiodegreadableFractionOfResidue', e.g. 'Biomass'.

**Legal restriction over the entity 'RenewableFuel'.** Like the definition of 'Biofuel', Article 2 (1) (c) of Directive 2003/30/EC prescribes two legal conditions over the term 'RenewableFuel'. They are –

- *Legal Condition 1* - It is originated from renewable energy source, and
- *Legal Condition 2* - It is to be used for transport.

In the case of 'Biofuel', condition 1 was different, as it is required to be produced from biomass. However, restriction R19 expresses these two conditions over the term 'RenewableFuel'.

$$RenewableFuel \sqsubseteq \exists\ isOriginatedFrom\ .\ (RenewableEnergySource) \sqcap \forall\ isToBeUsedFor\ .\ (Transport) \qquad (R19)$$

In this restriction, existential relationship is used to connect the terms – 'RenewableFuel' and 'RenewableEnergySource' using object-property 'isOriginatedFrom' and universal relationship is used with the term 'Transport' using object-property 'isToBeUsedFor'.

**Legal restriction over the entity 'SyntheticBiofuel'.** SyntheticBiofuel is a subclasses of 'SyntheticFuel' and 'BiofuelsUnderEUDirective'. Article 2 (2) (h) of Directive 2003/30/EC specifics that

"….*'synthetic biofuels': synthetic hydrocarbons or* ***mixtures of synthetic hydrocarbons****, which have been* ***produced from biomass****'……*"

Therefore, restriction R20 expresses that the term 'SyntheticBiofuel' has existential relationship with the term 'SyntheticHydrocarbon' using object-property 'isMixturesOf', shown in R20 and Figure 36.

$$SyntheticBiofuel \sqsubseteq \exists\ isMixturesOf\ .\ (SyntheticHydrocarbon) \qquad (R20)$$

Now considering the above mentioned underlined bold legislative texts, there is another legal restriction over the term ‘SyntheticBiofuel’ is - *produced from biomass*. Nevertheless this restriction is not given on the term ‘SyntheticBiofuel’, because ‘SyntheticBiofuel’ is already a subclass of ‘BiofuelsUnderEUDirective’, shown in Figure 35, and therefore the restriction R16 will be inferred over this term. This approach decreases the level of redundancy in the ontology.

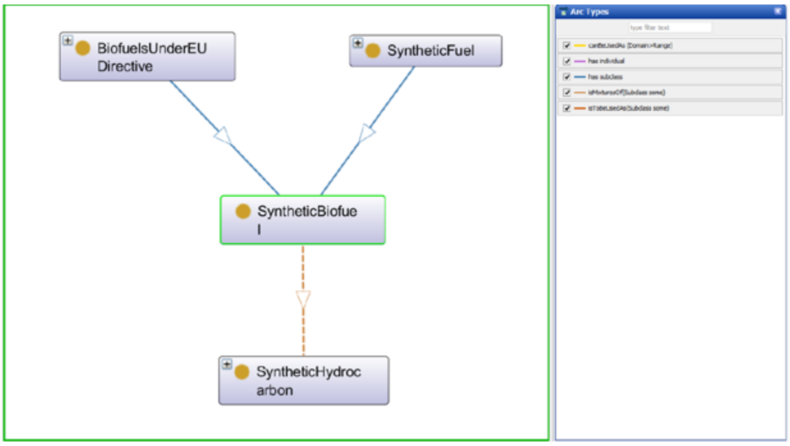



**Fig.36.** Restriction over the term SyntheticBiofuel

**Legal restriction over the entity ‘BioDiesel’.** Biodiesel can be produced from either animal or vegetable oil in order to be used as biofuel – mentioned in Article 2 (2) (b) of Directive 2003/30/EC. On the basis of the legislative texts of that Article, the restriction R21 is designed.

$$BioDiesel \sqsubseteq \exists\ isToBeUsedAs\ .\ (\ Biofuel\ )\ \sqcap\ \exists\ producedFrom\ .\ (\ AnimalOil\ \sqcup\ VegetableOil) \qquad (R21)$$

The term ‘BioDiesel’, in the restriction R21, has two existential relationships. First one is with the term ‘Biofuel’ using the object property ‘isToBeUsedAs’ and the second one is with two terms using disjunction relationship – ‘AnimalOil’ and ‘VegetableOil’ using object property ‘producedFrom’.

**Legal restrictions over the entities ‘BioETBE’ and ‘BioMTBE’.** Article 2 (2) (f) and (g) of Directive 2003/30/EC mentions that the percentage by volume of bio-ETBE and bio-MTBE is calculated as biofuel is 47% and 36% respectively. Considering the fact that these particular legislative texts contain both - data-type as well as object-type properties, both types of properties are used to create restrictions over these two terms, shown in Figure 33 and in the Restriction R22 and R23.

*BioETBE* $\sqsubseteq \forall$ *isProducedOnTheBasisOf . ( Bioethanol)* $\sqcap$ ***value*** *isCalculatedAsBiofuel . (36%)* *(R22)*

In the restriction R23, the term ‘BioETBE’ has universal relationship with the term ‘Bioethanol’ using the object-property ‘isProducedOnTheBasisOf’. It also has cardinal value relationship with “36%” using data-type property ‘isCalculatedAsBiofuel’.

*BioMTBE* $\sqsubseteq \forall$ *isProducedOnTheBasisOf . ( BioMethanol )* $\sqcap$ ***value*** *isCalculatedAsBiofuel . ( 47% )* *(R23)*

Like R22, the restriction R23 expresses universal relationship between the terms ‘BioMTBE’ and ‘BioMethanol’ using object-property ‘isProducedOnTheBasisOf’ and the term ‘BioMTBE’ has cardinal value relationship with ‘47%’ using data-property ‘isCalculatedAsBiofuel’.

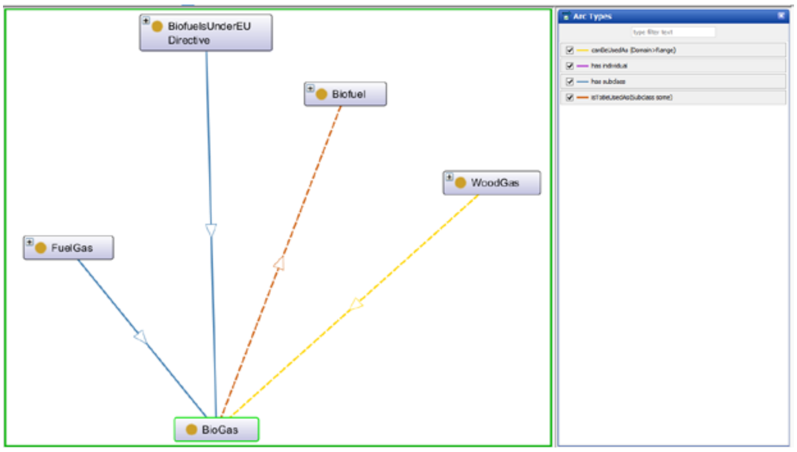


**Fig.37.** Restriction over the entity 'BioGas'

**Legal restriction over the entity ‘BioGas’.** The restriction R24 has taken from Article 2 (2) (c) of Directive 2003/30/EC. In this restriction, the term ‘BioGas’ has existential and disjunction relationships with the terms – ‘NaturalGas’ and ‘WoodGas’ using object property – ‘canBePurifiedTo’ and the term ‘BioGas’ also implies to the term ‘Biofuel’ with existential relationship using the object-property ‘isToBeUsedAs’, shown in R24 and Figure 37.

*BioGas* $\sqsubseteq \exists$ *canBePurifiedTo . (NaturalGas* $\sqcup$ *WoodGas))* $\sqcap$ $\exists$ *isToBeUsedAs . ( Biofuel)* *(R24)*

**Legal restrictions over the entity ‘PureVegetableOil’.** Article 2 (2) (j) of Directive 2003/30/EC mentions three explicit conditions in order to consider pure vegetable oil as biofuels. These three legal conditions are –

- *Legal condition 1* - Produced from oil production from oil plants through following procedures - pressing, extraction or comparable
- *Legal condition 2* – compatible with the engines
- *Legal condition 3* – correspond with the emission requirements

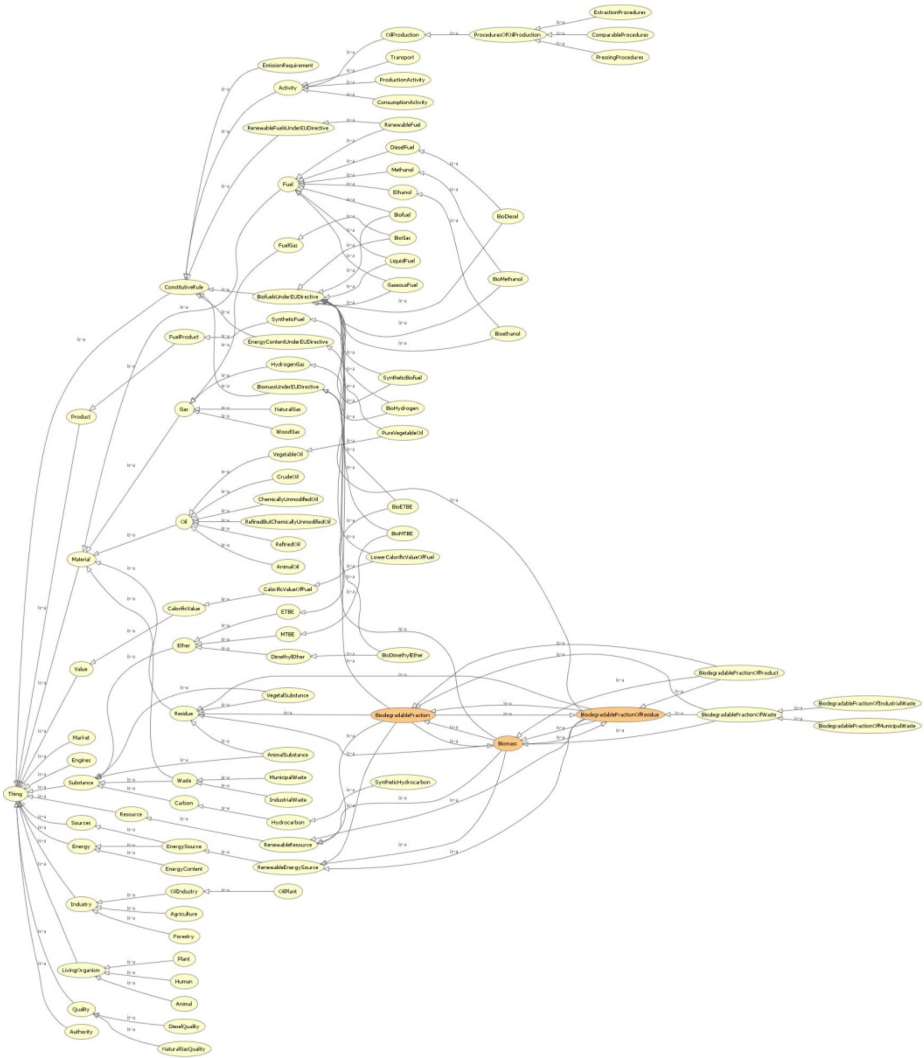



**Fig.38.** Asserted Model of EUDefBiofuels ontology

Above mentioned three conditions put together as a restriction, shown in R25, over the term ‘PureVegetableOil’ in order to qualify it as a sub-class of ‘BiofuelsUnderEUDirective’.

$PureVegetableOil \sqsubseteq \exists\ compatibleWith\ .\ (\ Engines\ )\ \sqcap\ \exists\ mustCorrespondWith\ .\ (\ EmissionRequirement)\ \sqcap\ \exists\ producedFrom\ .\ (\ OilProduction\ )$ (R25)

In the restriction, R25, the term 'PureVegetableOil' implies with existential relationship to the terms 'Engines', 'EmissionRequirement' and 'OilProduction' using object-properties 'compatibleWith', 'mustCorrespondWith' and 'producedFrom' respectively. It is noteworthy to mention that in the case of above mentioned condition 1, the term 'OilProduction' is used in order to cover the restrictions over all procedural terms of oil plants such as pressing, extraction or comparable etc. Because these all procedural terms are the sub-classes of the term 'OilProduction'. Since the restriction R26 is executed over the parent-class, e.g. 'OilProduction', it will be inferred to all of its child-classes, e.g. 'PressingProcedures'.

## 21.4 Reasoners' result of EUDefBiofuels ontology

The complexity in this ontology is much higher than 'WEFNexusTopClasses' and 'EUDefWater' ontologies due to increased number of classes, subclasses, properties and their relationships. Like other ontologies, reasoners found no error or inconsistency, shown in Table 3.

**Table 3.** Reasoners' result of EUDefBiofuels Ontology

| ***Reasoners*** ***Inference types*** | ***Fact ++*** | ***HermiT 1.3.8. and 1.3.8.3.*** | ***Pellet and Pellet (Incremental)*** |
|---|---|---|---|
| Error and inconsistency | No | No | No |
| Class inferences | Satisfied | Satisfied | Satisfied |
| Object property inferences | Satisfied | Satisfied | Satisfied |
| Axioms inferences | Sound | Sound | Sound |

Inferences of classes, object and data properties, and SubClassOf restrictions are found satisfied and sound by reasoners. The inferred model of EUDefBiofuels ontology is shown in Figure 38 in order to compare the assert model of this ontology, shown in Figure 20. However, it is noteworthy to mention that few of the 'SubClassOf' restrictions, e.g. the restriction R19, were used as 'EquivalentTo' restrictions. Even though that did not produce any error by the reasoners, it increased a lot of inferred Sub Class of anonymous ancestor. However, in order to avoid inference related internal complicacy and redundancy, maximum of the restrictions are used as 'SubClassOf' expression. In the case of Snorocket reasoner, it finds no error and/or inconsistency. However, the Table 3 shows the summary of reasoners' result. In addition, in the case of using ACE, it shows consistent and error free list of axioms.

# 22 EUDefFood Ontology

Even though there are many EU Regulations regarding food and common agricultural policies, Article 2 of EU Regulation 178/2002/EC[308] has been selected for engineering the ontology of 'EUDefFood' for following reasons –

- EU Regulation 178/2002/EC is considered as a foundational Regulation for installing European Food Safety Authority[309] with a specific food definition.
- Article 2 of this Regulation, which defines the legal meaning of food, plays the most important connecting role in WEF Nexus. Because it is the foremost legal instrument where 'Water' is declared as 'Food', which is equivalent to the term 'WaterIntendedForHumanConsumpio' defined in Article 2 of EU Directive 98/83/EC, and 'Biomass' is declared as 'NotFood', which is equivalent to the term 'BiomassUnderEUDirective' and used as the only legally permitted raw material for producing 'BiofuelUnderEUDirective' defined in Article 2 of EU Directive 2003/30/EC. This is how legal ontological relationships have been formed and established in WEF nexus. More detail is discussed in the section 23.

---

[308] Of the European Parliament and of the Council of 28 January2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety. Article 2 of this Regulation is as follow -

Definition of 'food' For the purposes of this Regulation, 'food' (or 'foodstuff') means any substance or product, whether processed, partially processed or unprocessed, intended to be, or reasonably expected to be ingested by humans.

'Food' includes drink, chewing gum and any substance, including water, intentionally incorporated into the food during its manufacture, preparation or treatment. It includes water after the point of compliance as defined in Article 6 of Directive 98/83/EC and without prejudice to the requirements of Directives 80/778/EEC and 98/83/EC.

'Food' shall not include:

(a) feed;
(b) live animals unless they are prepared for placing on the market for human consumption;
(c) plants prior to harvesting;
(d) medicinal products within the meaning of Council Directives 65/65/EEC (1) and 92/73/EEC (2);
(e) cosmetics within the meaning of Council Directive 76/768/EEC (3);
(f) tobacco and tobacco products within the meaning of Council Directive 89/622/EEC (4);
(g) narcotic or psychotropic substances within the meaning of the United Nations Single Convention on Narcotic Drugs,1961, and the United Nations Convention on Psychotropic Substances, 1971;
(h) residues and contaminants.

[309] See http://www.efsa.europa.eu/

Ontology metrics:

Metrics

| | |
|---|---|
| Axiom | 464 |
| Logical axiom count | 119 |
| Class count | 63 |
| Object property count | 13 |
| Data property count | 0 |
| Individual count | 0 |
| DL expressivity | ALCRF |

Class axioms

| | |
|---|---|
| SubClassOf axioms count | 81 |
| EquivalentClasses axioms count | 2 |
| DisjointClasses axioms count | 1 |
| GCI count | 0 |
| Hidden GCI Count | 4 |

Object property axioms

| | |
|---|---|
| SubObjectPropertyOf axioms count | 0 |
| EquivalentObjectProperties axioms count | 0 |
| InverseObjectProperties axioms count | 0 |
| DisjointObjectProperties axioms count | 0 |
| FunctionalObjectProperty axioms count | 9 |
| InverseFunctionalObjectProperty axioms count | 0 |
| TransitiveObjectProperty axioms count | 0 |
| SymmetricObjectProperty axioms count | 0 |
| AsymmetricObjectProperty axioms count | 8 |
| ReflexiveObjectProperty axioms count | 0 |
| IrrefexiveObjectProperty axioms count | 0 |
| ObjectPropertyDomain axioms count | 9 |
| ObjectPropertyRange axioms count | 9 |
| SubPropertyChainOf axioms count | 0 |

Data property axioms

| | |
|---|---|
| SubDataPropertyOf axioms count | 0 |
| EquivalentDataProperties axioms count | 0 |
| DisjointDataProperties axioms count | 0 |
| FunctionalDataProperty axioms count | 0 |
| DataPropertyDomain axioms count | 0 |
| DataPropertyRange axioms count | 0 |

Individual axioms

| | |
|---|---|
| ClassAssertion axioms count | 0 |
| ObjectPropertyAssertion axioms count | 0 |
| DataPropertyAssertion axioms count | 0 |
| NegativeObjectPropertyAssertion axioms count | 0 |
| NegativeDataPropertyAssertion axioms count | 0 |
| SameIndividual axioms count | 0 |
| DifferentIndividuals axioms count | 0 |

Annotation axioms

| | |
|---|---|
| AnnotationAssertion axioms count | 258 |
| AnnotationPropertyDomain axioms count | 0 |
| AnnotationPropertyRangeOf axioms count | 0 |

**Fig.39.** Metrics of EUDefFood ontology

‘WEFNexusTopClasses’ ontology is, however, directly imported into this ontology and used as the fundamental basis of its all classes, sub-classes and their relationships. It entails following metrics, shown in Figure 39 -

- There are total 464 axioms including 119 logical axioms.
- 63 classes with 81 SubClassOf, 2 EquivalentClasses and 1 DisjointClass axioms.
- There are 13 object-properties with 9 functional and 8 asymmetric object properties. It also contains 9 object-property domains and 9 object-property ranges.
- There is no data property used.
- There are 258 annotation assertion axioms.
- ALCRF DL expressivity is used.

However, it is noteworthy to mention the above mentioned number of axioms also include all axioms used in WEFNexusTopClasses ontology.

Like section 18 to 20, this section is dedicated to describe ‘EUDefFood’ ontology following the same structure – first explaining the taxonomy of this ontology through describing concept-definitions of all classes and sub-classes, and then describing object-properties and restrictions. Eventually it explains also reasoners’ result. A number of figures have been generated by OntoGraf and OWLViz in order to make easy explanation of this ontology. Furthermore, it is also important to note that all justifications of arguments used in this section are based on legal perspective of selected

EU Regulations.

### 22.1 Taxonomy of EUDefFood Ontology

All classes and sub-classes of this taxonomy are extracted from Article 2 of EU Regulation 178/2002/EC. This Article is composed with two components –

- *Component 1* – consists with the first two paragraphs which describes the legal meaning of the term 'Food'.
- *Component 2* – specifically designed to explain the legal understanding of the term 'NotFood' with a list. It might be confusing enough to grasp the legal notion of such term 'NotFood'. However, it plays multiple important legal roles from WEF nexus point of view, which is explained in detail in the section 23.

As a result, the concepts' definitions that this taxonomy holds are carefully designed with many supporting EU legislative texts in order to reduce the level of legal complexity. Besides WEFNexusTopClasses, however, it contains following terms – 'HumanConsumption', 'ExpectedToBeIngested', 'Feed', 'IntendedToBeIngested', 'PlantAfterHarvesting', 'PlantPriorToHarvesting', 'FoodProductionActivity', 'ManufactureOfFoodProduction', 'PreparationOfFoodProduction', 'ProcessingOfFoodProduction', 'CompletelyProcessedFoodProduct', 'FoodTreatment', 'PartiallyProcessedFoodProduct', 'UnprocessedFoodProduct', 'FoodUnderEURegulation', 'NotFoodUnderEURegulation', 'PointOfCompliance', 'WaterIntendedForHumanConsumption', 'LiveAnimal', 'LiveAnimalPreparedForHumanConsumption', 'LiveAnimalPreparedForNotHumanConsumption', 'Tobacco', 'Biomass', 'Residue', 'Cosmetic', 'FoodProduct', 'ChewingGum', 'Drink', 'MedicinalProduct', 'TobaccoProducts', 'MaintenanceOfQuality', 'QualityOfWater', 'Contaminant', 'Food', 'Foodstuff', 'FoodSubstance', 'NarcoticSubstance', 'PsychotropicSubstance', 'SubstanceInFood', 'TobaccoSubstance', 'Water', 'WasteWater', 'WaterAfterCompliance', 'WaterAfterTreatment', 'WaterInItsOriginalState', 'WaterSubstance', and 'WaterSubstanceInFood', shown in Figure 40. Many of these terms or entities are explained in the section 19, 20 and 21. Therefore, the entities that are not discussed before are discussed below –

**Entity 'HumanConsumption'.** This entity already exists in the EUDefWater ontology and explained in section 20. However, Article 2 of EU Regulation 178/2002/EC does not mention explicitly the term 'HumanConsumption', but it explains the term 'HumanConsumption' implicitly by using following phase -

*"…Intended to be, or reasonably expected to be ingested by humans…"*

Considering this legislative text, following two terms can be extracted - 'ExpectedToBeIngested' and 'IntendedToBeIngested'. Both of these terms implicitly explain identity principles of the term 'HumanConsumption', which is not mentioned in the Article 2 of EU Directive 98/83/EC. Hence these terms are not part of EUDef-Water ontology, but here used as sub-classes of the term ‘HumanConsumption’ for following reasons –

- The term ‘HumanConsumption’ itself, on one hand, is a sub-class of ‘ConsumptionActivity’. Therefore, the identity principle of the term ‘HumanConsumption’ lie with mental or physical activity primarily for performing human consumption.
- The identity principles of the terms - ‘ExpectedToBeIngested’ and ‘IntendedToBe-Ingested’, on the other hand, lie with only the mental activity for performing human consumption, but not the physical activity.
- Therefore, fundamentally the terms - ‘ExpectedToBeIngested’ and ‘IntendedToBe-Ingested’ belongs the same identity principle of the term ‘HumanConsumption’. Hence they are considered as sub-classes of the term ‘HumanConsumption’, even though it is not mentioned in the EU Regulation 178/2002/EC.

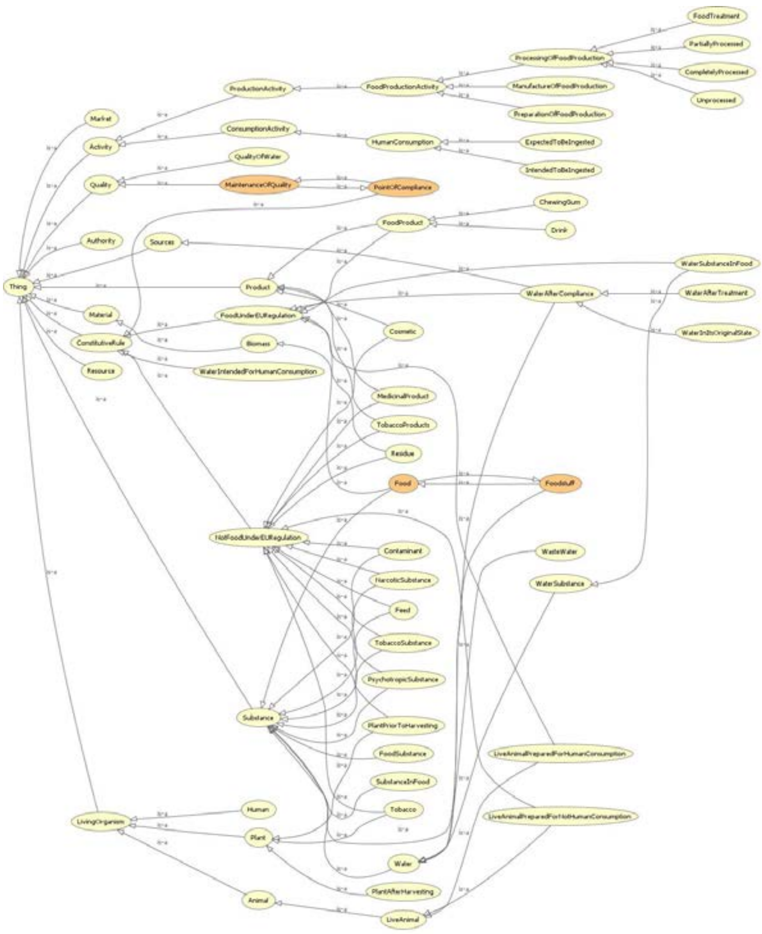



**Fig.40.** Asserted model of EUDefFood ontology

**Entity 'ExpectedToBeIngested' and 'IntendedToBeIngested'.** The Article 2 of EU Regulation 178/2002/EC implicitly demonstrates that both of these terms represent mental performance of human consumption and play an important role in order to legally qualify any substance as food. The differences and similarities between these two terms as follow –

- The term 'ExpectedToBeIngested', on the one hand, shows positive eagerness in order to consume food that is legally permitted. The term 'IntendedToBeIngested', on the other hand, shows targeted behavior in order to consume food that is legally permitted.
- However, both of these terms express the mental performances of prior human consumption that must be legally checked in order to qualify the substance as food.

**Entity 'PlantAfterHarvesting' and 'PlantPriorToHarvesting'.** Harvesting is a type of 'Activity' that involves gathering mature crops from the field[310]. Likewise, in the Article 33 (4) (a) of Regulation (EU) No 1308/2013[311] specifies the meaning of green harvesting as harvesting activity of unripe non-marketable products. However, it does not define any of these terms - 'PlantAfterHarvesting' and 'PlantPriorToHarvesting'. Even though, Article 2 of EU Regulation 178/2002/EC does not also define these terms, but it demonstrates that

*"….**Plants prior to harvesting** is not food….."*

Therefore, it implicitly categorized the entire world of plants into two broad but distinct groups. The first is an explicit term, as it is mentioned in the legislative texts, the 'PlantPriorToHarvesting' which legally means that any plant before harvesting is performed is not food. The other one is implicit term, as it is extracted from the meaning of the legislative texts, the 'PlantAfterHarvesting', which legally means that any plant after harvesting is food. Thus, these two terms have been introduced, as a subclass of the term 'Plant', in order to design ontology of this legislative text and their relationships with term 'FoodUnderEUDirective' and 'NotFoodUnderEUDirective'.

**Entity 'FoodProductionActivity', 'ManufactureOfFoodProduction', 'PreparationOfFoodProduction' and 'ProcessingOfFoodProduction'.** These entities are already discussed in the section 20 from the perspective of 'EUDefWater' ontology. These all terms also represent same definitions under the Article 2 of EU Regulation 178/2002/EC. Because it specifics that the water used in food production activities, e.g. manufacture, preparation, treatment and processing, is also considered as food. However, in addition, this Regulation mentions four different types of food pro-

[310] https://en.wikipedia.org/wiki/Harvest

[311] Of the European Parliament and of the Council of 17 December 2013 establishing a common organisation of the markets in agricultural products and repealing Council Regulations (EEC) No 922/72, (EEC) No 234/79, (EC) No 1037/2001 and (EC) No 1234/2007

cessing activities such as ‘FoodTreatment’, ‘Unprocessed’, ‘’PartiallyProcessed, and ‘CompletelyProcessed’, shown in Figure 41.

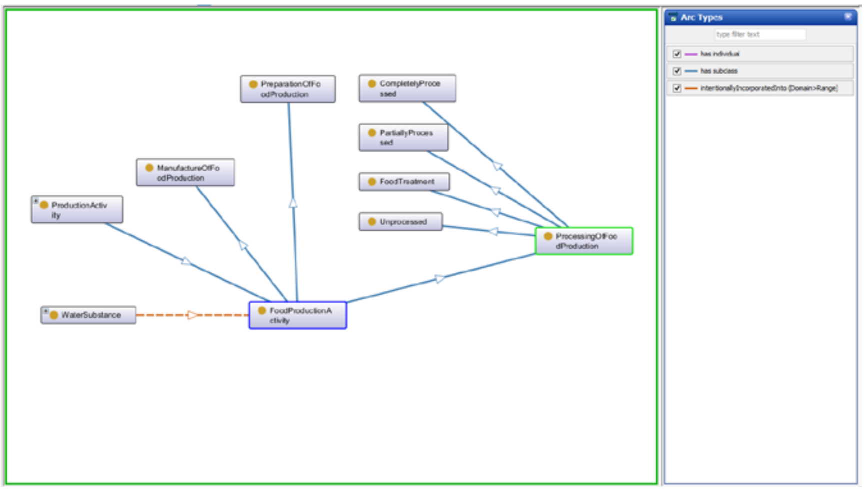



**Fig.41.** Class-relationships of the entity 'FoodProductionActivity'

**Entity ‘CompletelyProcessedFoodProduct’, ‘PartiallyProcessedFoodProduct’ and ‘UnprocessedFoodProduct’.** These three terms are sub-classes of the entity ‘FoodProduct’. In order to understand this complex sub-classes relationships, it requires a critical analysis of following underlined bold legislative texts, given in Article 2 of EU Regulation 178/2002/EC -

*“….‘Food’ (or ‘foodstuff’) means any substance or product, **whether processed, partially processed or unprocessed**, intended to be, or reasonably expected to be ingested by humans.….”*

**Entity ‘FoodTreatment’.** This is another sub-class of ‘ProcessingOfFoodProduction’, shown in Figure 41, and defined in Article 4 (4) (a) of Directive 1999/2/EC mentioning that – food treatment activity is subject to a favorable opinion of the Scientific Committee for Food. In addition, Article 2 of EU Regulation 178/2002/EC demonstrates that if the water is intentionally incorporated into the food treatment activity, then it will be legally considered as food.

**Entity ‘FoodUnderEURegulation’.** Conceptually the term ‘Food’ is a ‘Substance’ like ‘Water’ in EUDefWater ontology. First two paragraphs of Article 2 of EU Regulation 178/2002/EC describe comprehensively legal conception of the term ‘Food’, which goes far behind of the general scientific and constructive notion of food. Because the term ‘FoodUnderEURegulation’ does not only mean ‘Substance’ rather it generates a number of activities and logical dependency of performing those activities lies with some legal rules. Therefore, this term is a sub-class of the top-class 'ConstitutiveRule' for following reasons –

- *Role to create activity/ies* – Since this Regulation enforced, the term 'Food' does not remain only a physical entity. Rather 'FoodUnderEURegulation' plays an important role to generate, on the one hand, a number of mental activities such as involvement of human intention and expectation in order to qualify a substance or product as a food. On the other hand, it also establishes that any substance or product manipulated by human's food production processes does not affect the legal value of accepting that substance or product as food. Hence, it helps to legalize all activities perform in the food processing industry. Figure 42 shows the relationships between the term 'FoodUnderEURegulation' and different sub-classes of the term 'Activity'.

- *Logical dependency of those activities is based on legal rule/s* – The second paragraph of Article 2 of EU Regulation 178/2002/EC specifies that

  *"'Food' includes drink, chewing gum and any substance, including water, intentionally incorporated into the food during its manufacture, preparation or treatment."*

Under this legal context, all food manufacturing, preparation or treatment activities, where the water is intentionally incorporated into the food, are subject to EU Directive 98/83/EC (not only to this Regulation). Because logical dependency of the activity 'intentionally incorporating water into the food' depends on the legal rules that are related with the quality of 'WaterIntendedForHumanConsumption', which is prescribed in that Directive.

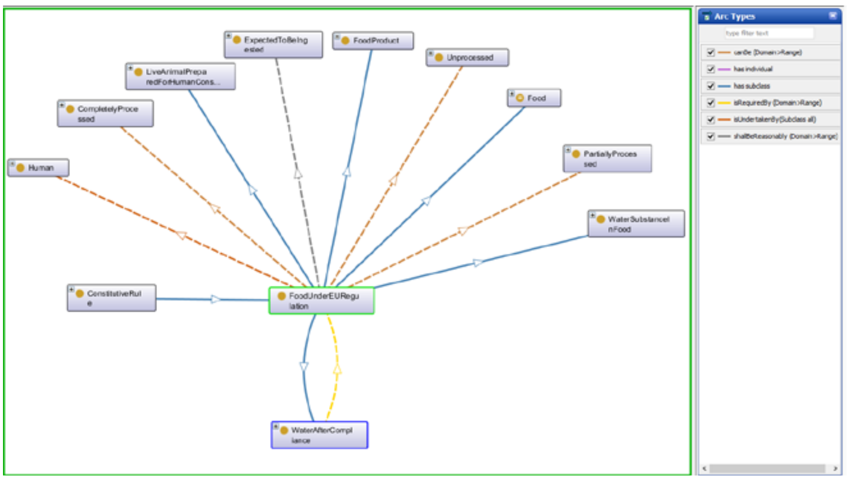



**Fig.42.** Constitutive rule - 'FoodUnderEURegulation'

**Entity 'NotFoodUnderEURegulation'.** Third paragraph of Article 2 of EU Regulation 178/2002/EC provides a list of those substances or products are not legally considered as food by using following legislative text –

*"…..'Food' shall not include:…."*

In order to conceptualize and terminologize this legislative text, the term 'NotFoodUnderEURegulation' is introduced in this ontology. This is also a sub-class of the term 'ConstitutiveRule', shown in Figure 43, for following reasons –

- *Role to create activity/ies* – From the legal point of view, both commission and omission of anything are considered as to constitute performance of something[312]. Therefore, omission of something legally requires performing some activity or no activity. Now considering the list no (b) of Article 2 of EU Regulation 178/2002/EC, it says that -

  *"…..(b) Live animals unless they are prepared for placing on the market for human consumption"* shall not include as food….."

  Under this context, commission of preparing live animal for the market, on the one hand, generates a lot of activities, e.g. rearing the live animal through maintaining certain quality standard. On the other hand, omission from the sales of live animal that was not prepare for the market also requires maintaining a number of activities, e.g. to make sure that the live animal not prepared for the market is now placed in market to sale. However, this Article also directs 'live animal farmer' to prepare live animal for the market in order to make sure that live animal is legally considered as food. This also requires a lot of activities, e.g ensuring animal health and welfare rules as given in EU Regulation (EC) no 882/2004[313].

- *Logical dependency of those activities is based on legal rule/s* – considering list no (h) of Article 2 of EU Regulation 178/2002/EC, it says that

  "…*(h) Residues and contaminants*" – shall not include as food…"

  That allows using biodegradable fractions of residues and contaminants in order to produce biofuel under EU Directive 2003/30/EC, as by law residues cannot be considered as food. It means that the activity of producing biofuel by using residues is guided by both – EU Directive 2003/30/EC and EU Regulation 178/2002/EC.

[312] See https://en.wikipedia.org/wiki/Omission_(criminal_law)
[313] Of the European Parliament and of the Council of 29 April 2004 on official controls performed to ensure the verification of compliance with feed and food law, animal health and animal welfare rules

**Entity 'PointOfCompliance'.** The second line of second paragraph of Article 2 of EU Regulation 178/2002/EC says –

"…..*It includes water after the point of compliance as defined in Article 6 of Directive 98/83/EC and without prejudice to the requirements of Directives 80/778/EEC and 98/83/EC….*"

In this legislative text, the word '*It*' means 'Food' and it clearly specifies that water itself, after the compliance, is a food. Under this legal context, the legal phrase 'point of compliance' is considered as a type of 'ConstitutiveRule', shown in Figure 43, for following reasons –

- *Role to create activity/ies* – it might seem that the term 'PointofCompliance' represents only the values of certain parameters that must be maintained. However, from the legal context of this Regulation, the term 'PointOfCompliance' is equivalent term to 'MaintenanceOfQuality', shown in Figure 43 with red colored boxes. Considering the above mentioned legislative text, it means that in order to qualify water as a food, its quality must be ensued and maintained as it is prescribed in the laws. And in order to do so, it requires generating a lot of activities, e.g. initiating water treatment.


**Fig.43.** Sub-classes of the term 'ConstitutiveRule' in EUDefFood ontology

- *Logical dependency of those activities is based on legal rule/s* – Considering again the above mentioned legislative text, logical dependency of the activities related with the maintenance and assurance of the quality of water, e.g. performing water treatment, is based on *Article 6 of Directive 98/83/EC and without prejudice to the requirements of Directives 80/778/EEC and 98/83/EC.*

**Entity 'WaterIntendedForHumanComsumption'.** See section 20.

**Entity 'LiveAnimal', 'LiveAnimalPreparedForHumanConsumption', 'LiveAnimalPreparedForNotHumanConsumption'.** Even though there are a number of legislations in EU related with the term 'LiveAnimal'[314] such as aquaculture, bees, equine, ovine and caprine etc, it is very hard to find a unique definition of 'LiveAnimal'. However, in according to the Article 2 of EU Regulation 178/2002/EC, live animals are not food unless they are prepared to sale in the market for human consumption. Therefore, two further classes are added as the sub-classes of the term 'LiveAnimal'. They are – (a) 'LiveAnimalPreparedForHumanConsumption' means a type of live animal, such as cow, pigs etc, are reared to sale in the market with a particular purpose for human consumption, and therefore such live animal is considered as food. (b) 'LiveAnimalPreparedForNotHumanConsumption' is a type of live animal which is reared neither for sale in market nor for human consumption, and therefore they are sub-class of 'NotFoodUnderEURegulation'.

**Entity 'Tobacco'.** Article 2(1) of Directive 2014/40/EU[315] specifics that the 'Tobacco' means leaves and other natural processed or unprocessed parts of tobacco plants, including expanded and reconstituted tobacco. This is a sub-class of the term 'Plant'. In addition, in according to the Article 2 of EU Regulation 178/2002/EC and Council Directive 89/622/EEC[316], tobacco is not considered as food. Therefore, this is also sub-class of the term 'NotFoodUnderEURegulation'.

**Entity 'Biomass' and 'Residue'.** See section 21.

**Entity 'Cosmetic'.** Article 2 (a) of Regulation (EC) No 1223/2009[317] defines - '*cosmetic product' means any substance or mixture intended to be placed in contact with*

---

[314] See the list of the legislations in EU related with live animals - http://ec.europa.eu/food/animal/zootechnics/legislation_en.htm

[315] Of the European Parliament and of the Council of 3 April 2014 on the approximation of the laws, regulations and administrative provisions of the Member States concerning the manufacture, presentation and sale of tobacco and related products and repealing Directive 2001/37/EC

[316] Of 13 November 1989 on the approximation of the laws, regulations and administrative provisions of the Member States concerning the labelling of tobacco products

[317] Of the European Parliament and of the Council of 30 November 2009 on cosmetic products.

*the external parts of the human body (epidermis, hair system, nails, lips and external genital organs) or with the teeth and the mucous membranes of the oral cavity with a view exclusively or mainly to cleaning them, perfuming them, changing their appearance, protecting them, keeping them in good condition or correcting body odours*'. Furthermore, Article 2 of EU Regulation 178/2002/EC and Council Directive 76/768/EEC[318] defines that cosmetic products are not food and therefore it is a sub-class of 'NotFoodUnderEURegulation'.

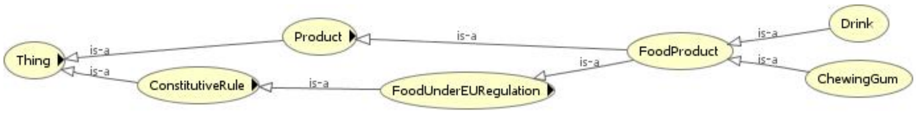



**Fig.44.** Parent and child -classes of the term 'FoodProduct'

**Entity 'FoodProduct', 'ChewingGum', 'Drink'.** In according to the Article 2 of EU Regulation 178/2002/EC, 'FoodProduct' is a type of 'Product' and used as a food. Therefore it is also considered as a sub-class of 'FoodUnderEURegulation', shown in Figure 44. It has two sub-classes – 'Drink' and 'ChewingGum'. By the same Regulation, these two types of food product are also recognized as a food, but they are not directly asserted sub-classes of 'FoodUnderEURegulation'. Because as their parent-class - 'FoodProduct' is asserted sub-class of 'FoodUnderEURegulation', its child-classes become inferred sub-classes of 'FoodUnderEURegulation'.

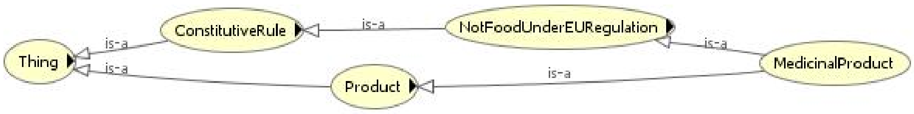



**Fig.45.** The term 'MedicinalProduct' is a sub-class of 'NotFoodUnderEURegulation'

**Entity 'MedicinalProduct'.** Article 3 (3) of Regulation (EC) No 726/2004[319] recognizes that medicinal product is a type of 'Product'. However, Article 2 of EU Regulation 178/2002/EC declared that medicinal product, within the meaning of Council Directives 65/65/EEC[320] and 92/73/EEC[321], is not food. Therefore, the term 'Medici-

[318] Of 27 July 1976 on the approximation of the laws of the Member States relating to cosmetic products

[319] Of the European Parliament and of the Council of 31 March 2004 laying down Community procedures for the authorisation and supervision of medicinal products for human and veterinary use and establishing a European Medicines Agency.

[320] Of 26 January 1965 on the approximation of provisions laid down by Law, Regulation or Administrative Action relating to proprietary medicinal products

[321] Of 22 September 1992 widening the scope of Directives 65/65/EEC and 75/319/EEC on the approximation of provisions laid down by law, regulation or administrative action relating to

nalProduct’ is a sub-class of the constitutive rule ‘NotFoodUnderEURegulation’, shown in Figure 45.

**Entity ‘TobaccoProducts’.** Article 2 (4) of EU Directive 2014/40/EU[322] says that tobacco products’ represents such type of products that can be consumed and consist, even partly, of tobacco, whether genetically modified or not. However, in according to the Article 2 of EU Regulation 178/2002/EC, ‘TobaccoProducts’ is not declared as food. Hence this is another sub-class of the entity ‘NotFoodUnderEURegulation’.

**Entity ‘MaintenanceOfQuality’.** Maintenance of quality is a sub-class of the term ‘Quality’, which is mentioned specifically in many regulations of EU. The preamble of one of such regulations is Directive 2006/7/EC[323], which says that - "*Community policy on the environment should aim at a high level of protection, and contribute to pursuing the objectives of preserving, protecting and improving the quality of the environment and of protecting human health*". Here legal phrase ‘*objective of preserving, protecting and improving the quality*’ is used to express the term ‘MaintenanceOfQuality’, which is an equivalent class to the term ‘PointOfCompliance’, shown as the red colored boxes in Figure 43.

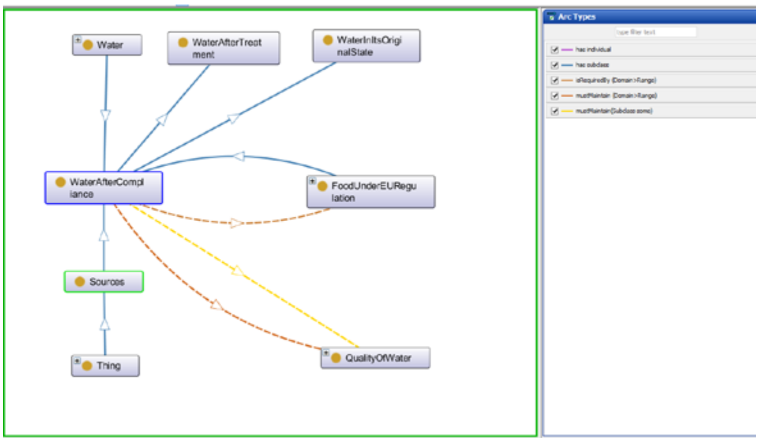



**Fig.46.** Class-relationships of the terms - 'Source', 'WaterAfterCompliance' and 'QualityOfWater'

medicinal products and laying down additional provisions on homeopathic medicinal products

322 Of the European Parliament and of the Council of 3 April 2014 on the approximation of the laws, regulations and administrative provisions of the Member States concerning the manufacture, presentation and sale of tobacco and related products and repealing Directive 2001/37/EC

323 Of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC.

**Entity 'QualityOfWater'.** In according to the EU Directive 98/83/EC, 'QualityOfWater' refers to the chemical, physical, biological, and radiological characteristics of water. It is also expressed as a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose. It is most frequently used by reference to a set of standards against which compliance can be assessed[324]. In addition, Article 2 of EU Regulation 178/2002/EC mentions that quality of water must be ensured in order to consider water as a food. It also specifies that water-substance used in food manufacturing activities must maintain the quality mentioned in the respective laws. In this ontology, this is a sub-class of the term 'Quality', shown in Figure 46.

**Entity 'Water', 'WaterAfterCompliance', 'WaterAfterTreatment', 'WaterInItsOriginalState', 'WaterSubstance', 'WaterSubstanceInFood', 'FoodSubstance'.** All of these entities have been described in the section 20. However, as Article 2 of EU Regulation 178/2002/EC stipulates that water after the point of compliance is food, 'WaterAfterCompliance' and its sub-classes – 'WaterAfterTreatment' and 'WaterInItsOriginalState' are also considered as sub-classes of the top-class 'Source', shown in Figure 46, which relationship is absent in the EUDefWater ontology.

**Entity 'Contaminant'.** Article 1 (2) of Directive 2009/32/EC[325] mentions that 'Contaminant' is a substance may be used in food as solvent and, however, Article 2 of EU Regulation 178/2002/EC clearly indicates that contaminant is not itself food. Therefore, this is sub-classes of both terms – 'Substance' and 'NotFoodUnderEURegulation', shown in Figure 43.

**Entity 'Feed'.** In according to the EU Regulation No 767/2009[326], the term 'Feed' is used to represent such substance that is prepared for animal consumption. However, Article 2 of EU Regulation 178/2002/EC clearly indicated that food shall not include feed. Hence, as shown in Figure 43, the term 'Feed' is sub-classes of two terms – 'Substance' and 'NotFoodUnderEURegulation'.

---

[324] See http://ec.europa.eu/environment/water/water-drink/reporting_en.html

[325] Of the European Parliament and of the Council of 23 April 2009 on the approximation of the laws of the Member States on extraction solvents used in the production of foodstuffs and food ingredients

[326] Of the European Parliament and of the Council of 13 July 2009 on the placing on the market and use of feed, amending European Parliament and Council Regulation (EC) No 1831/2003 and repealing Council Directive 79/373/EEC, Commission Directive 80/511/EEC, Council Directives 82/471/EEC, 83/228/EEC, 93/74/EEC, 93/113/EC and 96/25/EC and Commission Decision 2004/217/EC

**Entity ‘Food’, ‘Foodstuff’.** The very first line of first paragraph of Article 2 of EU Regulation 178/2002/EC expresses following legal expression about the term ‘Food’ and ‘Foodstuff’ -

*“….For the purposes of this Regulation, ‘food’ (or ‘foodstuff’) means any substance….”*

Considering this legislation text, it is clear that both of these terms are equivalent and sub-classes of the entity ‘Substance’, shown in Figure 47. However, the same Regulation also prescribes following two groups of substances and products under two broad terms – ‘FoodUnderEURegulation’ and ‘NotFoodUnderEURegulation’.

- ‘FoodUnderEURegulation’ includes food like drink, chewing gum, water etc.
- ‘NotFoodUnderEURegulation’ includes substance like contaminant, medicinal and tabacco products etc.

Consequently, the term ‘Food’ itself is a sub-class of ‘FoodUnderEURegulation’.

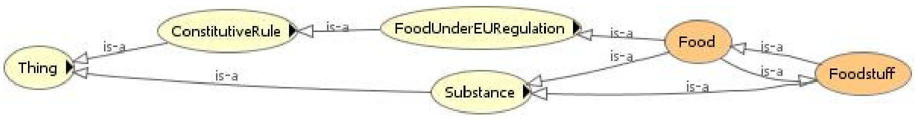



**Fig.47.** Equivalent terms - 'Food' and 'Foodstuff'

**Entity ‘FoodSubstance’.** The terms – ‘FoodSubstance’ and ‘Food’ are two different entities in this ontology due to their own identity principle. The EU Regulation No 1925/2006[327] specifies that ‘FoodSubstance’ is a type of ‘Substance’ that can be used itself as a food or as ingredient to be used in the food production processes, e.g. certain types of chemical such as vitamin or fruits. As a result, they are not disjoint terms. However, in according to the Article 2 of EU Regulation 178/2002/EC, water can be used as a food substance in the food preparation. More discussion can be found in the section 20 of this chapter.

**Entity ‘NarcoticSubstance’.** Council Regulation (EC) No 111/2005[328] recognize narcotic as a substance and Article 2 of EU Regulation 178/2002/EC established that narcotic substance is not food, shown in Figure 43. As a result, this term is subclasses of two entities simultaneously – ‘Substance’ and ‘NotFoodUnderEURegulation’.

[327] Of the European Parliament and of the Council of 20 December 2006 on the addition of vitamins and minerals and of certain other substances to foods

[328] Of 22 December 2004 laying down rules for the monitoring of trade between the Community and third countries in drug precursors

**Entity 'PsychotropicSubstance'.** Council Decision 90/611/EEC[329], in where it is mentioned that psychotropic is a substance and provided a list of this type of substances. However, Article 2 of EU Regulation 178/2002/EC says that psychotropic substance is not food. Hence this is sub-classes of 'Substance' and 'NotFoodUnderEURegulation', shown in Figure 43.

**Entity 'SubstanceInFood'.** 'FoodSubstance' and 'SubstanceInFood' has their own identity principle and therefore they are different entity. 'FoodSubstance' can be a 'SubstanceInFood', but a 'SubstanceInFood' may not be necessarily a 'FoodSubstance'. The preamble no 10 of the Regulation (EC) No 1925/2006[330] demonstrates the importance of this term saying that –

"…*The chemical substances used as sources of vitamins and minerals which may be added to foods should be safe and also be bio-available i.e. available to be used by the body. For this reason a positive list of these substances should also be established. Such substances that have been approved by the Scientific Committee on Food in an Opinion expressed on 12 May 1999, on the basis of the above criteria of safety and bio-availability, and can be used in the manufacture of foods intended for infants and young children, other foods for particular nutritional uses or food supplements should appear in this positive list. Although sodium chloride (common salt) does not appear among the substances in this list, it may continue to be used as an ingredient in the preparation of food….*"

However, Article 2 of EU Regulation 178/2002/EC indicates that if water is used as a 'SubstanceInFood', it must be after the point of compliance. In this legal context, the term 'Water' is not considered as 'Food', hence the 'Water' is not equivalent to the term 'FoodSubstance '.

**Entity 'TobaccoSubstance'.** The terms 'TobaccoProduct', which is a sub-class of 'Product,' and 'TobaccoSubstance' are distinct by their identity principles. Because on the one hand, 'TobaccoSubstance' can be used to produce 'TobaccoProduct'. On the other hand, 'TobaccoProduct' also can be used as a 'TobaccoSubstance' in order to produce other types of products, not necessarily 'FoodProduct'. In the line of this argument, Article 2 (18) of Directive 2014/40/EU[331] mentions that "*tobacco sub-*

[329] The United Nations Convention against Illicit Traffic in Narcotic Drugs and Psychotropic Substances, adopted in Vienna on 19 December 1988, hereinafter referred to as the "United Nations Convention", was concluded by the Community by Council Decision 90/611/EEC .

[330] Of the European Parliament and of the Council of 20 December 2006 on the addition of vitamins and minerals and of certain other substances to foods

[331] Of the European Parliament and of the Council of 3 April 2014 on the approximation of the laws, regulations and administrative provisions of the Member States concerning the manufacture, presentation and sale of tobacco and related products and repealing Directive 2001/37/EC

*stance are substance or ingredients that are present in a finished tobacco product or related products, including paper, filter, ink, capsules and adhesives"*. However, Article 2 of EU Regulation 178/2002/EC clearly specifies that 'TobaccoSubstance' is not food. Therefore this term is sub-classes of 'Substance' and 'NotFoodUnderEURegulation', shown in Figure 43.

## 22.2 Object-properties in EUDefFood ontology

There are total 13 object-properties that include all 6 object-properties of WEFNexusTopClasses ontology. Most of them are explicitly mentioned in the legislative text of Article 2 of EU Regulation 178/2002/EC, except the object-properties 'canBe' and ''isAssociatedWith. Most of them have implied over their domain and range terms with functional and asymmetric characteristics, shown in Figure 48. They are introduced below. More detail explanation of their usages is given in the later section.

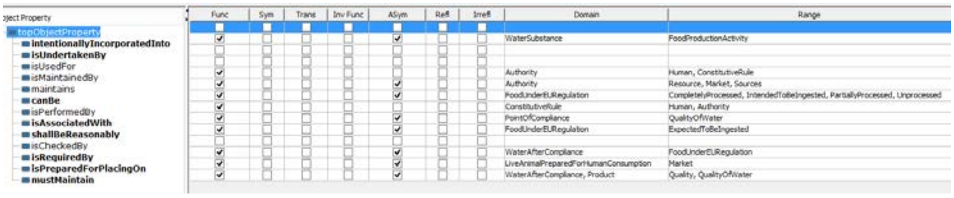



**Fig.48.** Object-properties in EUDefFood ontolgoy

**intentionallyIncorporatedInto.** Article 2 of EU Regulation 178/2002/EC prescribes that food also includes -

*".....any substance, including water, **intentionally incorporated into** the food......"*

The above mentioned bold underlined legislative text 'intentionallyIncorporatedInto' is used as an object-property in order to establish functional relationship between 'WaterSubstance' and 'FoodProductionActivity'.

**isAssociatedwith.** The EU Regulation 178/2002/EC mentions about the water that is after the point of compliance referring Article 6 of EU Directive 98/83/EC[332], which is particularly designed for describing 'QualityOfWater' using the legal phrase 'PointOfCompliance'. Therefore, it is very clear that by referring the EU Directive, it im-

[332] Article 6 (1) of EU Directive 98/83/EC specifies - "The parametric values set in accordance with Article 5 shall be complied with: (a) in the case of water supplied from a distribution network, at the point, within premises or an establishment, at which it emerges from the taps that are normally used for human consumption; (b) in the case of water supplied from a tanker, at the point at which it emerges from the tanker; (c) in the case of water put into bottles or containers intended for sale, at the point at which the water is put into the bottles or containers; (d) in the case of water used in a food-production undertaking, at the point where the water is used in the undertaking".

plicitly established the associated relationship between these two terms. In this ontology, the object property ‘isAssociatedWith’ is used in order to express this implicit relationship.

**isPreparedForPlacingOn.** Article 2 of EU Regulation 178/2002/EC states that if the live animal is prepared for placing in the market to be sold in order to be consumed by human can be addressed as a food, otherwise not. Hence, the object property ‘isPreparedForPlacingOn’ plays an important role in order to recognize which live animal is legally considered as food. The specific legislative text is as follow -

*“....live animals unless they **are prepared for placing on** the market for human consumption....”*

In this ontology, this object property has established the functional and asymmetric relationship between following terms – ‘LiveAnimalPreparedForHumanConsumption’, which is a sub-class of ‘LiveAnimal’, and ‘Market’, which is a top class.

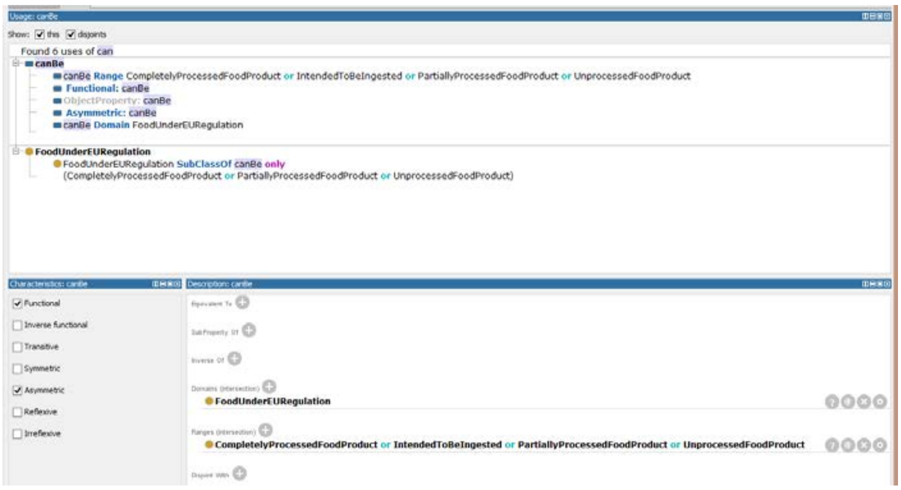



**Fig.49.** Uses of the object-property 'canBe'

**isRequiredBy.** In according to the Article 2 of EU Regulation 178/2002/EC, in order to qualify water as a food, it is required that the water must have the qualities as described in law by mentioning the following legislative texts -

*“.....It **includes** water after the point of compliance......”*

Here the word ‘*It*’ means ‘Food’ and the object-property ‘isRequiredBy’ used instead of the bold underlined legislative word ‘*includes*’. By using this object property, a functional and asymmetric relationship is made between the terms – ‘WaterAfter-Compliance’ and ‘FoodUnderEURegulation’.

**canBe.** Article 2 of EU Regulation 178/2002/EC mentions that food can be any of these forms - processed, partially process and/or unprocessed by mentioning following legislative text -

*“....whether processed, partially processed or unprocessed, intended to be, or reasonably expected to be ingested by humans....”*

Even though the Regulation does not use the word ‘*canBe*’, it is used to create an artificial object-property in order to build functional relationships between following terms – ‘FoodUnderEURegulation’, ‘PartiallyProcessedFoodProduct’, ‘Unprocessed-FoodProduct’, ‘IntendedToBeIngested’, and ‘CompletelyProcessedFoodProduct’, shown in Figure 49.

**isUndertakenBy.** There is a fundamental obligation created over the term ‘FoodUnderEUregulation’ is that food must be intended to be ingested and/or reasonably expected to be ingested by human, prescribed in Article 2 of EU Regulation 178/2002/EC. In this legal context, the object-property ‘isUndertakenBy’ is used to make functional relationship with the term ‘FoodUnderEURegulation’ and ‘Human’.

**mustMaintain.** Article 2 of EU Regulation 178/2002/EC specifies that water and/or food substance and/or any substance or product used in the food preparation must maintain certain level of qualities prescribed by the respective laws. Therefore, the object property ‘mustMaintain’ is used to create functional relationships between following terms – ‘Product’, ‘WaterAfterCompliace’, ‘Quality’ and ‘QualityOf-Water’.

**shallBeReasonably.** The food shall be reasonably expected to be ingested by human, otherwise it will not be considered as food in the eyes of EU law. In order to design ontology of this legal expression, the object property ‘shallBeReasonably’ is used to crate functional and asymmetric relationship between following terms – ‘FoodUnderEURegulation’ and ‘ExpectedToBeIngested’.

In addition, all of these object-properties have been used in order to create a number of ‘SubClass Of’ restrictions over many terms, described in the next section.

### 22.3 Legal restrictions over the entities in EUDefFood ontology

Three mechanisms have been used, discussed in section 20.3, in order to create restrictions over the entities in this ontology. All restrictions have taken from the legislative text of Article 2 of EU Regulation 178/2002/EC. There are asserted as well as inferred restrictions. In this section, only asserted restrictions have been explained.

**Legal restriction over the entity 'FoodUnderEURegulation'.** There are three restrictions, shown in R26 to R28, over this entity.

$$FoodUnderEURegulation \sqsubseteq \forall\ isAssociatedWith\ .\ (\ IntendedToBeIngested\ ) \sqcup \forall\ shallBeReasonably\ .\ (\ ExpectedToBeIngested) \quad (R26)$$

The restriction R26 deals with following two legal restrictions –

- Legal restriction 1 – the term 'FoodUnderEURegulation' has universal relationship with the term 'IntendedToBeIngested' using object-property 'isAssociatedWith'.
- Legal restriction 2 - the term 'FoodUnderEURegulation' implies to the term 'ExpectedToBeIngested' with universal relationship using object-property 'shallBeReasonably'.

The term 'FoodUnderEURegulation' implies to both of these separated legal restrictions with disjunction. Because fulfillment of any of these restrictions is good enough for proving food under EU Regulation.

$$FoodUnderEURegulation \sqsubseteq \forall\ canBe\ .\ (\ CompletelyProcessedFoodProduct \sqcup PartiallyProcessedFoodProduct \sqcup UnprocessedFoodProduct\ ) \quad (R27)$$

In the case of restriction R27, the term 'FoodUnderEURegulation' implies to the following terms 'CompletelyProcessedFoodProduct' 'PartiallyProcessedFoodProduct' or 'UnprocessedFoodProduct' with universal relationship using the object property 'canBe'. In this restriction, the terms 'CompletelyProcessedFoodProduct','PartiallyProcessedFoodProdcut' and 'UnprocessedFoodProduct' has disjunction relationship among them.

$$FoodUnderEURegulation\ \sqsubseteq \forall isUndertakenBy\ .\ (\ Human\ ) \quad (R28)$$

In the case of restriction R28, the term 'FoodUnderEURegulation' implies to the term 'Human' with universal relationship using object property 'isUndertakenBy'.

In addition, the term 'FoodUnderEURegulation' has following sub-classes – 'Food', 'Foodstuff', 'FoodProduct', 'ChewingGum', 'Drink', 'LiveAnimalPreparedForHumanConsumption', 'WaterAfterCompliance', 'WaterAfterTreatment', 'WaterInItsOriginalState', 'WaterSubstanceInFood'. These all sub-classes are extracted from EU Regulation, therefore they are recognized as legal sub-class restrictions over this term.

**Legal restriction over the entity 'PointOfCompliance' and 'MaintenanceOfQuality'.** As it was discussed in earlier session that the term 'PointOfCompliance' is equivalent to the term 'MaintenanceOfQuality', shown in the R29.

$$PointOfCompliance \equiv MaintenanceOfQuality \qquad (R29)$$

**Legal restriction over the entity 'Food' and 'Foodstuff'.** The restriction R30 expresses that food and foodstuff is equivalent terms.

$$Food \equiv FoodStuff \qquad (R30)$$

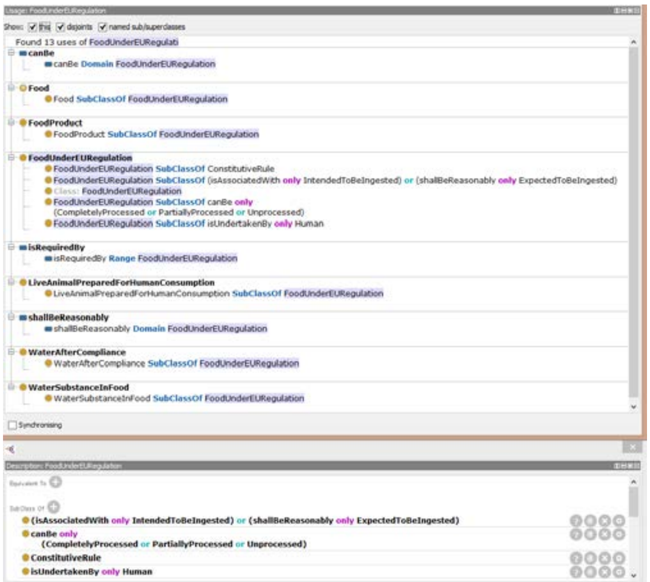



**Fig.50.** Legal sub-class restriction over the entity 'FoodUnderEURegulation'

**Legal sub-classes restrictions over the entity 'NotFoodUnderEURegulation'.** Generally, Article 2 of EU Regulation 178/2002/EC does not provide any legal explicit restriction over this term, except providing a list of substances and products those are not recognized as food by law. Therefore, they are called legal sub-classes


**Fig.51.** Legal sub-class restrictions over the term 'NotFoodUnderEURegulation'

Restrictions over the term ‘NotFoodUnderEURegulation’. These sub-classes are – ‘Contaminant’, ‘Cosmetic’, ‘Feed’, ‘LiveAnimalPreparedForNotHumanConsumption’, ‘MedicinalProduct’, ‘NarcoticSubstance’, ‘PlantPriorToHarvesting’, ‘PsychotropicSubstance’, ‘Residue’, ‘Tobacco’, ‘TobaccoProducts’, and ‘TobaccoSubstance’.

**Table 4.** Reasoners' result of EUDefFood ontology

| ***Reasoners Inference types*** | ***Fact ++*** | ***HermiT 1.3.8. and 1.3.8.3.*** | ***Pellet and Pellet (Incremental)*** | ***Snorocket*** |
|---|---|---|---|---|
| Error and inconsistency | No | No | No | No |
| Class inferences | Satisfied | Satisfied | Satisfied | Satisfied |
| Object property inferences | Satisfied | Satisfied | Satisfied | Satisfied |
| Axioms inferences | Sound | Sound | Sound | Sound |

**Legal restriction over the term 'WaterAfterCompliance'.** In the restriction R31, the term 'WaterAfterCompliance' implies over the term 'QualityOfWater' with existential relationship using the object property 'mustMaintain'.

$$WaterAfterCompliance \sqsubseteq \exists\ mustMaintain\ .\ (\ QualityOfWater\ ) \qquad (R31)$$

Ontology metrics:

Metrics

| | |
|---|---|
| Axiom | 1178 |
| Logical axiom count | 314 |
| Class count | 157 |
| Object property count | 35 |
| Data property count | 1 |
| Individual count | 0 |
| DL expressivity | ALCRIF(D) |

Class axioms

| | |
|---|---|
| SubClassOf axioms count | 213 |
| EquivalentClasses axioms count | 4 |
| DisjointClasses axioms count | 8 |
| GCI count | 0 |
| Hidden GCI Count | 7 |

Object property axioms

| | |
|---|---|
| SubObjectPropertyOf axioms count | 2 |
| EquivalentObjectProperties axioms count | 0 |
| InverseObjectProperties axioms count | 1 |
| DisjointObjectProperties axioms count | 0 |
| FunctionalObjectProperty axioms count | 22 |
| InverseFunctionalObjectProperty axioms count | 0 |
| TransitiveObjectProperty axioms count | 0 |
| SymmetricObjectProperty axioms count | 0 |
| AsymmetricObjectProperty axioms count | 20 |
| ReflexiveObjectProperty axioms count | 0 |
| IrrefexiveObjectProperty axioms count | 0 |
| ObjectPropertyDomain axioms count | 22 |
| ObjectPropertyRange axioms count | 22 |
| SubPropertyChainOf axioms count | 0 |

Data property axioms

| | |
|---|---|
| SubDataPropertyOf axioms count | 0 |
| EquivalentDataProperties axioms count | 0 |
| DisjointDataProperties axioms count | 0 |
| FunctionalDataProperty axioms count | 0 |
| DataPropertyDomain axioms count | 0 |
| DataPropertyRange axioms count | 0 |

Individual axioms

| | |
|---|---|
| ClassAssertion axioms count | 0 |
| ObjectPropertyAssertion axioms count | 0 |
| DataPropertyAssertion axioms count | 0 |
| NegativeObjectPropertyAssertion axioms count | 0 |
| NegativeDataPropertyAssertion axioms count | 0 |
| SameIndividual axioms count | 0 |
| DifferentIndividuals axioms count | 0 |

Annotation axioms

| | |
|---|---|
| AnnotationAssertion axioms count | 663 |
| AnnotationPropertyDomain axioms count | 0 |
| AnnotationPropertyRangeOf axioms count | 0 |

**Fig.52.** Metrics of EUWEFNexus ontology

### 22.4 Reasoners' result of EUDefFood ontology

The reasoners found no error and inconsistency. Class, object property and axioms inferences are found satisfied and sound. Inferred class axioms found complete, shown in Table 4.

## 23 Legal ontology for EUWEFoodNexus

Following ontologies are merged in order to construct legal ontology for WaterEnergyFoodNexus -

- WEFNexusTopClasses ontolgy
- EUDefWater Ontology
- EUDefBiofuels Ontology
- EUDefFood Ontology

Neither new entity and property nor restriction has been added. After merging, no change has been made too. However, this merged ontology metrics, shown in Figure 52, show that there are –

- 1178 axioms that includes 314 logical axioms.
- 157 classes with 213 sub-classes axioms, 4 equivalent and 8 disjoint classes' axioms.
- 7 hidden GCI.
- 35 object-properties and 2 sub-object properties with 22 functional and 20 asymmetric object property axioms.
- 22 object-property domains and 22

object-property ranges axioms.

- 1 inverse object property and 1 data property axioms.
- 663 annotation assertion axioms.
- ALCRIF(D) is denoted as Description logic expressivity.

Even though, it is clearly mentioned in the introduction of this chapter, it is noteworthy to mention it again that following three EU legislations are used in order to build this ontology - Article 2 of EU Directive 98/83/EC that defines water intended for human consumption, Article 2 0f EU Directive 2003/30/EC that defines bio-fuels, and Article 2 of EU Regulation 178/2002/EC that defines food. In addition, there are inputs from many EU legislations in order to construct most appropriate legal concept definitions for all entities.

However, as this ontology is a result of merging all entities, properties and legal restrictions that have been discussed in section 19 to 22, this section is dedicated to provide all missing information and/or explanations that did not discuss enough in the previous sections of this chapter but requires to understand well this ontology.

### 23.1 Taxonomy of legal EUWEFNexus ontology

Taxonomy of legal ontology for EUWEFNexus represents a collection of all taxonomies that discussed in section 19 to 22, shown in Table 5 and Figure 53. It shows that WEFNexusTopClasses ontology has 16, EUDefWater ontology has 47, EUDefFood ontology has 63 and EUDefBiofuels ontology has 96 entities with 6, 17, 13 and 17 object-property entities respectively.

**Table 5.** Statistics of all entities and properties with WEFNexusTopClasses ontology

| ***Name of ontology*** | ***Number of Classes and sub-classes*** | ***Number of properties*** |
|---|---|---|
| WEFNexusTopClasses | 16 | 6 object properties |
| EUDef Water ontology | 47 | 17 object properties |
| EUDefFood ontology | 63 | 13 object properties |
| EUDefBiofuels ontology | 96 | 17 object and 1 data property |
| Total | 222 | 53 Object-property and 1 data property. |

In addition, EUDefBiofuels also has 1 data-property entity. It is noteworthy to mention that WEFNexusTopClasses ontology is directly imported and used as basis ontology for all other ontologies. However, there are following two types of entities exist in the legal ontology of EUWEFNexus –

- *Independent or uncommon entities* – are those entities that only present in any of one ontology. For example, the entity NationalCompetentAuthorityInWaterDomain is an entity that only belongs to EUDefWater ontology, not to other ontologies. Therefore it is an independent or uncommon entity in the legal ontology for EUWEFNexus. Table 6 shows the number of independent or uncommon entities that are present in each of above discussed ontology.

- *Dependent or common entities* – are those entities that are present simultaneously in all ontologies or more than one ontologies and therefore these entities are not independent with their origin ontology, rather they are dependent to be reused for multiple ontologies in parallel. For example, all entities, e.g. 'Activity', 'Product', 'Material', 'ConstitutiveRule' etc, of WEFNexusTopClasses ontology are common or dependent entities in the legal ontology for EUWEFNexus. Table 5 shows all common and uncommon entities that are present in each of above discussed ontologies.

**Table 6.** Statistics of all entities and properties without WEFNexusTopClasses ontology

| *Name of ontology* | *Number of classes and sub-classes* | *Number of properties* |
|---|---|---|
| WEFNexusTopClasses | 16 | 6 object properties |
| EUDefWater ontology | 31 | 11 object properties |
| EUDefFood ontology | 47 | 7 object properties |
| EUDefBiofuels ontology | 80 | 11 object and 1 data property |
| Total | 174 | 35 Object-property and 1 data property. |

These two types of entities play very important roles in order to ensure interoperability among water, energy and food domains and therefore in the legal ontology for EUWEFNexus. They are discussed below -

**Independent or uncommon entities in the legal ontology for EUWEFNexus.** Except 16 class entities and 6 object properties entities of WEFNexusTopClasses ontology, there are 31 class and sub-class entities in EUDefWater ontology, 47 class and sub-class entities in EUDefFood ontolgoy, and 80 class and sub-class entities in EUDefBiofuels ontology with 11, 7, and 11 object properties respectively, shown in Table 6. In addition, EUDefBiofuels ontology also contains 1 data-property entity.

These uncommon entities play following functions in the legal ontology for EU-WEFNexus in order to –

- *Establish legal internal semantic networks for respective legal definition*. For example, 'BioGas' is an independent or uncommon entity in Legal ontology of EU-WEFNexus, because it only belongs to the EUDefBiofuels ontology and carries semantic networks of the terms, properties, relationships and restrictions that are mentioned in Article 2 (2) (c) of EU Directive 2003/30/EC.
- *Ensure and compute internal interoperability*. For example, first and second paragraphs of Article 2 of EU Regulation 178/2002/EC are inter-dependent and therefore internal inter-operability of legal meaning of the term 'Food', which is given in the first paragraph, must be ensured in order to understand the legal meaning of the second paragraph. Because without exchanging the meaning of the term Food from the first paragraph into the interpretation exercises of the terms, properties and their relationships for the second paragraph will be legally inappropriate.

**Dependent or common entities in the legal ontology for EUWEFoodNexus.** The metrics of the legal ontology for EUWEFNexus, given in Figure 52, shows that there are 157 classes, 35 object-property and 1 data-property entities. In contrast, Table 5 shows that there are altogether 222 classes, 53 object-properties and 1 data property entities where all independent or common entities, e.g. all entities of WEFNexusTopClasses, are recounted. However, Table 6 shows more accurate number of independent and/or uncommon entities that exist in all ontologies, because total number of dependent or common entities, e.g. the entity 'Activity', has been deducted from each of other ontologies. It means that, except the entities of WEFNexusTopClasses ontology, there are total 17 dependent or common class entities (total 174 class, shown in Table 6, entities minus 157 class entities) and 1 object property entity exist in the legal ontology of EUWEFNexus. For example, the entity 'Residue' is present in EUDefBiofuels as well as in EUDefFood ontologies with the un-contrasting legal meaning. Therefore, this is a dependent entity in the legal ontology for EUWEFNexus. However, these common entities play following important roles in order to –

- *Ensure and compute external interoperability between/among domains*. For example, the term 'Residue' is an important term in Article 2 (1) (b) of EU Directive 2003/30/EC as well as in the third paragraph of Article 2 of EU Regulation 178/2002/EC. In the former EU legislation, it says that biodegradable fraction of residue is biomass and therefore considered as the only mandatory source to produce biofuels. In the latter EU legislation, it says residue is not food. Therefore, the common term 'Residue' extracted from both of these legislations collectively makes a meaning of energy-food nexus though ensuring inter-operability between these two EU legislations.

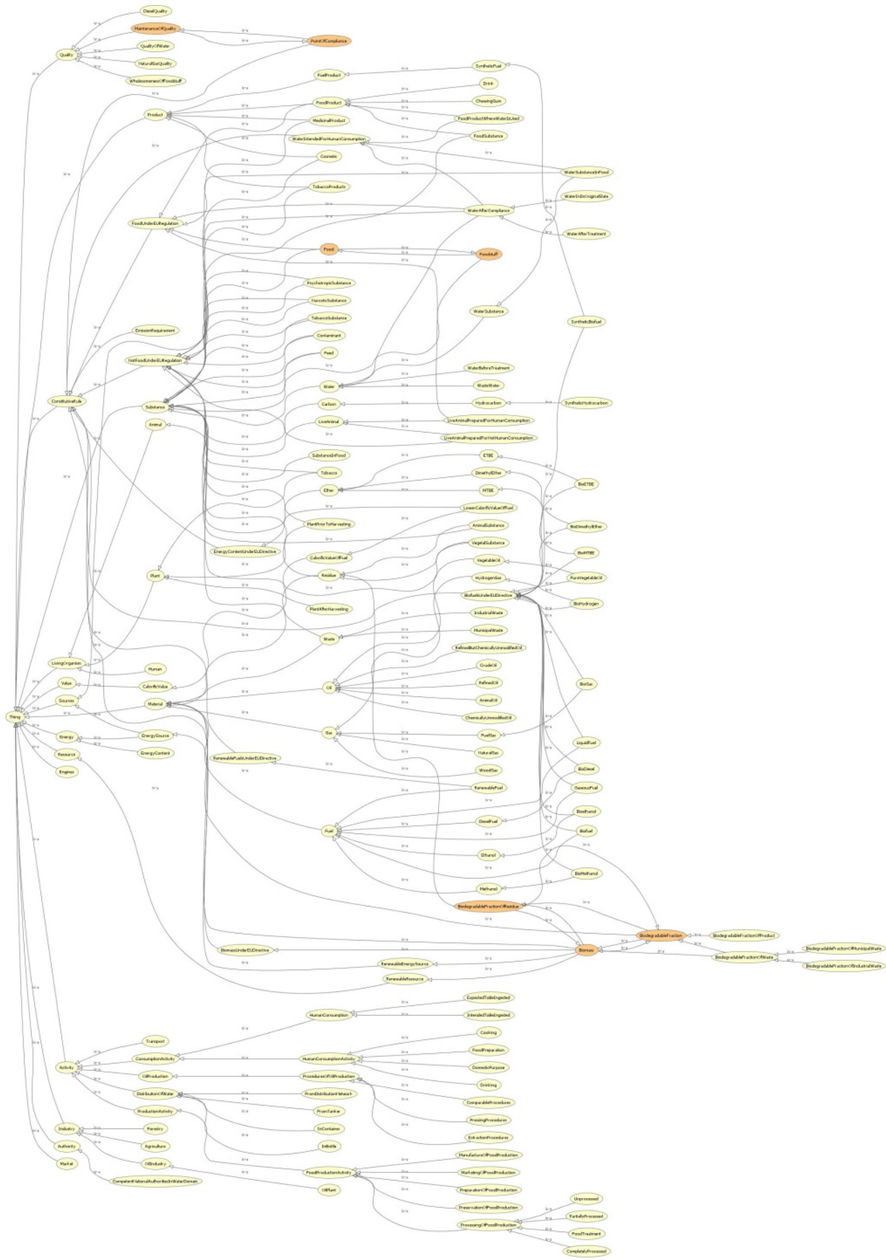


**Fig.53.** Asserted model of the legal ontology for EUWEFNexus

- *Establish legal external semantic networks of water-energy-food nexus.* For example, the term 'WaterAfterCompliance' is a common term in Article 2 of EU Regulation 178/2002/EC and EU Directive 98/83/EC. It gives legal understanding of when water is legally permitted to be used – (a) for human consumption, (b) in the food, and/or (c) as food. Therefore, these common entities establish legal semantic networks for external domains.

Except 17 entities of WEFNexusTopClasses, the common or dependent entities are in the legal ontology for EUWEFNexus –

**Entity ‘HumanConsumption’.** This is a common entity, as a sub-class of the term ‘Activity’, in EUDefWater and EUDefFood ontologies. In the former case, the term ‘HumanConsumption’ does not have any subclass but in the case of latter ontology it has two sub-classes – ‘ExpectedToBeIngested’ and ‘IntendedToBeIngested’, which are used in Article 2 of EU Regulation 178/2002/EC in order to explain the term ‘HumanConsumption’. This term generally indicates the fundamental relationship between EU Regulation 178/2002/EC and EU Directive 98/83/EC, because both deal with ‘HumanConsumption’ of food and water respectively.

**Entity ‘FoodProductionActivity’, ‘ManufactureOfFoodProduction’, ‘PreparationOfFoodProduction’ and ‘ProcessingOfFoodProduction’.** Generally both EU Regulation 178/2002/EC and EU Directive 98/83/EC uses these terms in order to make relationship with other terms – ‘Water’, ‘WaterSubstance’, ‘WaterSubstanceInFoodProduct’ etc. These all terms are sub-classes of the top-class ‘Activity’. In addition, in the EUDefFood, the term ‘ProcessingOfFoodProduction’ has four sub-classes –‘CompletelyProcessed’, ‘PartiallyProcessed’, ‘Unprocessed’ and ‘FoodTreatment’. These entities collectively established legal nexus of ‘FoodProductionActivity’ and ‘WaterAfterCompliance’.

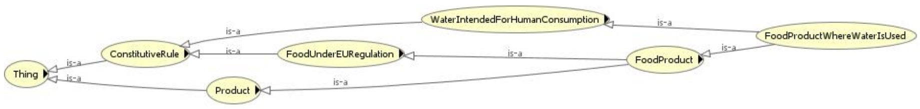



**Fig.54.** The term 'FoodProductWhereWaterIsUsed'

**Entity ‘FoodProduct’.** This is another common term in both - EUDefWater and EUDefFood ontologies, as a sub-class of the term ‘Product’. In the former ontology, this term is used to describe the types of food products those are considered legally as food. It has two sub-classes – ‘ChewingGum’ and ‘Drink’. In the latter ontology, this term is used in order to establish the legal nexus between ‘water used in the food production’ and ‘food product’, which also has two sub-classes – ‘FoodProductWhereWaterIsUsed’ and ‘FoodSubstance’, shown in Figure 54. It means both legislations EU Regulation 178/2002/EC and EU Directive 98/83/EC use the common term ‘FoodProduct’ for describing different sub-classes and relationships. However, the legal background of using this term is to establish the nexus between food and water, because the term ‘Drink’ itself represents the term ‘WaterSubstance’ into it.

**Entity ‘QualityOfWater’.** Article 2 of both legislations - EU Regulation 178/2002/EC and EU Directive 98/83/EC uses the term ‘QualityOfWater’, as a sub-class of the term ‘Quality’. In the former legislation, it uses term ‘WaterAfterCompliance’ which particularly expresses the legal importance and pursuits of maintenance of quality of water in order to qualify water as a food for human consumption. In the latter legislation, it uses the term ‘WholesomenessOfFoodstuff’ in order to make better meaning of the term ‘QualityOfWater’. It also specifies that quality of water shall not affect the wholesomeness of the foodstuff. Hence it legally establishes the legal nexus between the ‘QualityOfWater’ and ‘Food’.

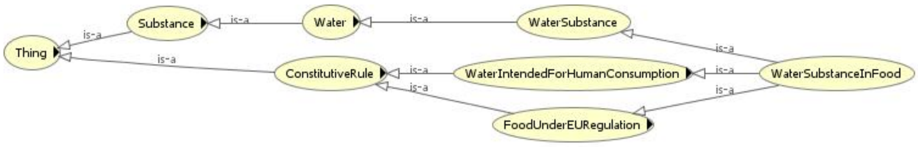



**Fig.55.** 'WaterSubstanceInFood' in the legal ontology of EUWEFNexus

**Entity ‘Water’and ‘FoodSubstance’.** Both of these terms are used as a sub-class of the top-class ‘Substance’ in EUDefWater and EUDefFood ontologies. The second paragraph of Article 2 of EU Regulation 178/2002/EC specifies the legal nexus between ‘FoodSubstance’ and ‘Water’ mentioning that if water is used as a food substance in the food production, it is considered as food too. In the latter ontology, Article 2 of EU Directive 98/83/EC demonstrates that water itself is a substance and humanly consumable. In addition, EU Regulation 178/2002/EC refers EU Directive 98/83/EC in order to describe the uses of the term ‘Water’ as a ‘FoodSubstance’ in the food processing activities. Hence collectively these terms produce the legal nexus of ‘Water’ and ‘FoodSubstance’. In both ontologies, the term ‘FoodSubstance’ does not have any sub-class. In the case of the term ‘Water’, both ontology have common number of sub-classes. They are – ‘WasteWater’, ‘WaterAfterCompliance’, ‘WaterAfterTreatment’, ‘WaterInItsOriginalState’, ‘WaterSubstance’ and ‘WaterSubstanceInFood’, shown in Figure 55. In addition, the term ‘WasteWater’ is also a sub-class of the term ‘Water’ in the former ontology.

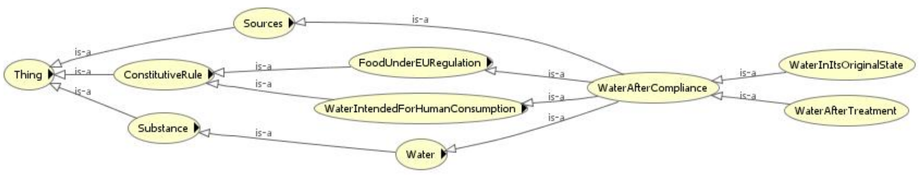



**Fig.56.** Parents and Child classes of the term 'WaterAfterCompliance'

**Entity 'WaterAfterCompliance'.** This common term in the legal ontology for EU-WEFNexus plays the most important role in proving the legal nexus between water and food domains, shown in Figure 56. Both legislations - EU Regulation 178/2002/EC and EU Directive 98/83/EC, do not merely describe the term 'Water', rather they provide a legal structure of the water after compliance. In the former legislation, it clearly indicates that water after compliance is food. In the latter legislation, it provides the legal basis of water after compliance that can be used as a substance in the food production. In both - EUDefWater and EUDefFood ontologies, this term come with two sub-classes – 'WaterAfterTreatment' and 'WaterInItsOriginalState'. The latter legislation specifics that if the water in its original state maintains the quality parameters mentioned in the respective legislation, it is equivalent to the term WaterAfterCompliance and therefore can be used directly for human consumption and also as a substance for using in the food production.  Otherwise, it will be considered as 'WasteWater' and hence shall not be included in food as well as not humanly consumable. Therefore, implicitly the uses of the term 'WasteWater' establish the legal nexus between 'WasteWater', 'FoodProduction' and 'HumanConsumption'.

**Entity 'WaterIntendedForHumanConsumption'.** This is a common entity in both - EUDefWater and EUDefFood ontologies. It has been used as a sub-class of the top-class 'ConstitutiveRule'. From the nexus perspective, it plays following important roles in the legal ontology for EUWEFNexus –

- *Role to create activity/ies* – Article 2 of EU Directive 98/83/EC implicitly enunciates that water intended for human consumption' shall not be waste water' by explicitly mentioning that water intend for human consumption shall maintain the quality of water, as prescribed by law, that shall not affect the wholesomeness of the foodstuff when it is used in the food production activity which is also mentioned in Article 2 of EU Regulation 178/2002/EC. Therefore, it generates a lot of activities such as water treatment, implementing water checking mechanism in food production activities etc.

- *Logical dependency of those activities is based on legal rule/s* – As the logical dependency of these terms - 'QualityOfWater', 'WaterAfterCompliance', 'PointOfCompliance', 'MaintenanceOfQuality', are based on legal rules coming from respective legislations. One of such legislations is EU Directive 98/83/EC where the qualities for the water intended human consumption is prescribed in its Annexes. Therefore, the activities need to be initiated in order to make sure that the 'waste water' is properly treated in order to make legally acceptable for human consumption entirely depends on the legal rules mentioned the Annexes of EU Directive 98/83/EC, which is also mandatory by the legal rules of Article 2 of EU Regulation 178/2002/EC.

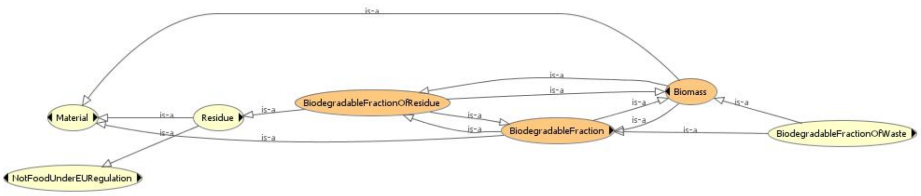



**Fig.57.** The term 'Residue' in the legal ontology of EUWEFNexus

**Entity ‘Biomass’ and ‘Residue’.** Both of these entities are sub-classes of the top-class ‘Material’ in both - EUDefBiofuels and EUDefFood ontologies. In the former ontology, these two terms are fundamental terms because they express the only material source of biofuel production, mentioned in Article 2 of EU Directive 2003/30/EC. The term ‘Biomass’ is equivalent class to the term ‘BiodegradableFraction’ and ‘BiodegradableFractionOfResidue’ with four sub-classes – ‘BiodegradableFractionOfProduct’, ‘BiodegradableFractionOfWaste’, BiodegradableFractionOfIndustrialWaste’ and BiodegradableFractionOfMunicipalWaste, shown in Figure 58.

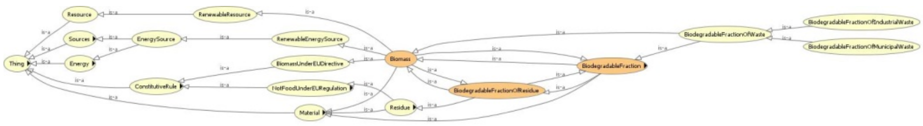


**Fig.58.** The term Biomass in the legal ontology of EUWEFNexus

The term ‘Residue’ has following three sub-classes – ‘AnimalSubstance’, ‘VegetalSubstance’, and BiodegradableFractionOfResidue’, shown in Figure 57. In the latter ontology, they are not considered as food, mentioned in the Article 2 of EU Regulation 178/2002/EC. Collectively these terms express the legal nexus between ‘Residue’ and ‘Biofuel’, hence the legal nexus between ‘Energy’ and ‘Food’.

## 23.2 Object and data properties in the legal ontology of EUWEFNexus

Table 6 shows that there are total 37 object-properties and 1 data-property entities in the legal ontology of EUWEFNexus, described in sections 19 to 22. Except the data property, they all are shown in Figure 59. However, they play following important roles in this ontology in order to -

- *Exchange and/or reuse legal restriction of food domain over water domain* – For example, paragraph two of Article 2 of EU Regulation 178/2002/EC specifies the importance of the object-property ‘intentionallyIncorporatedInto’, which creates legal restriction over the terms - ‘WaterSubstance’ and ‘FoodProductionActivity’. Now, both of these terms also are belonged to the Article 2 of EU Directive 98/83/EC and are entities of EUDefWater ontology. Therefore, this restriction is semantically inter-exchanged in the legal ontology of EUWEFNexus as EUDef-Water and EUDefFood ontologies are merged in this new ontology.

- *Establish legal semantic relationships between/among the terms coming from energy and food domains –* Article 2(1)(a) of EU Directive 2003/30/EC, on the one hand, specifics the object property ‘producedFrom’, which establish semantic functional and asymmetric relationship between the terms – ‘Biomass’ and ‘biofuel’. Article 2 of EU Regulation 178/2002/EC, on the other hand, declares the term

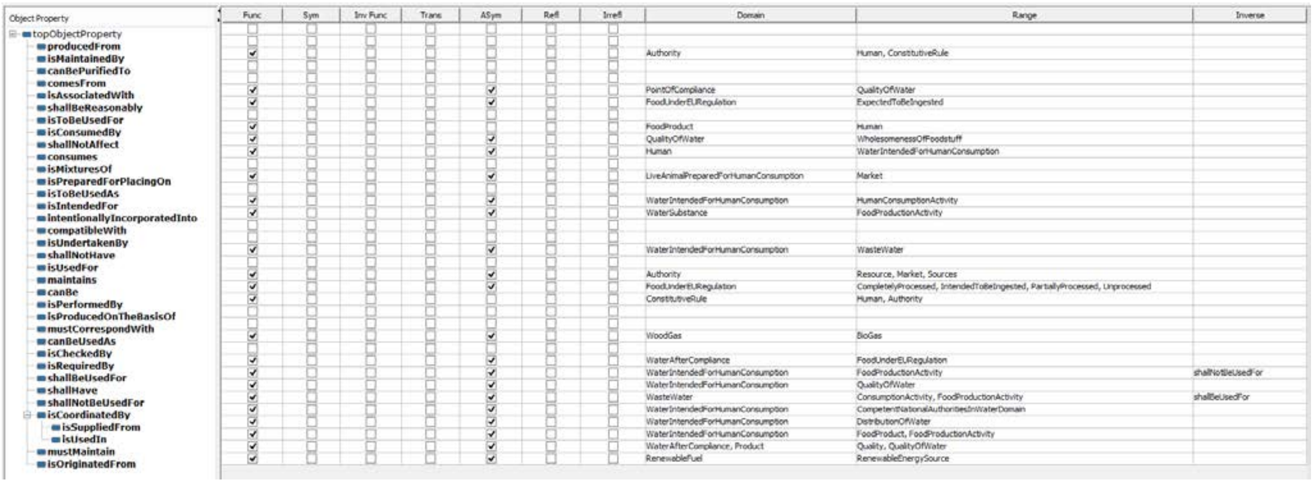



**Fig.59.** All object properties in the legal ontology of EUWEFNexus

residue is not food, but did not mention about the term ‘Biomass’ or residue is a type of biomass. However, this object property helps to establish the semantic relationships between respective EU legislations.

- *Establish legal semantic networks of various terms coming from water, energy and food legislations -* There are a number of object-properties such as ‘isConsumedBy’, ‘isCheckedBy’, ‘isIntendedFor’ etc provides semantic networks of various common entities such as ‘CompetentNationalAuthorityInWaterDomains’, ‘Water’, ‘WaterIntendedForHumanConsumption’, ‘WaterSubstanceInFoodProduct’, ‘QualityOfWater’ etc. For example, if ‘QualityOfWater’ isCheckedBy, ‘CompetentNationalAuthorityInWaterDomains’, then semantic connections of these used terms and properties with other terms and properties, e.g. ‘FoodPreparationActivity’, and ‘isAssociatedWith’ respectively, collectively establish Water-Energy-Food semantic legal networks.

- *Enhance internal and external interoperability –* The semantic networks established by using of 37 object-properties and 1 data-property over about 159 class entities enhance the internal and external interoperability between/among domains in the legal ontology of WaterEnergyFoodNexus. For example, the meaning and usages of the object property ‘isRequiredBy’, ‘shallHave’ and/or ‘shallNotHave’ in relation with the term ‘WaterAfterCompliance’ in EUDefWater ontology maintains its external interoperability with the term ‘FoodUnderEURegulation’ of EUDef-Food ontology.

### 23.3 Role of legal restrictions in the legal ontology of EUWEFNexus

All legal restrictions, R1 to R31, are merged in the legal ontology of EUWEFNexus. No new restriction has been added in order to maintain the limited expressivity within the scope of the restrictions only exist in respective used EU legislative texts. However, in order to understand the roles of these merged legal restrictions in the legal ontology of EUWEFNexus, it is important to critically examine following legal general or major roles, not limited to, of each of the definitions, those have been used for this ontology, of water-energy-food domains.

- *Article 2 of EU Directive 98/83/EC* defines water that is intended for human consumption. In addition, it pronounces that water used for food production shall also be qualified to the water intended for human consumption. Therefore it establishes the legal nexus between ‘water after compliance’ and ‘food production’.

- *Article 2 of EU Directive 2003/30/EC* defines biofuels and its types, source and purpose. It specifies that the source and purposes of biofuels shall be biomass and transport respectively. Consequently, since it articulates that ‘biodegradable fraction of residue’ is biomass, which shall be used in order to produce biofuel, it establishes the legal nexus between ‘biofuel’ and ‘what shall not be included as food’.

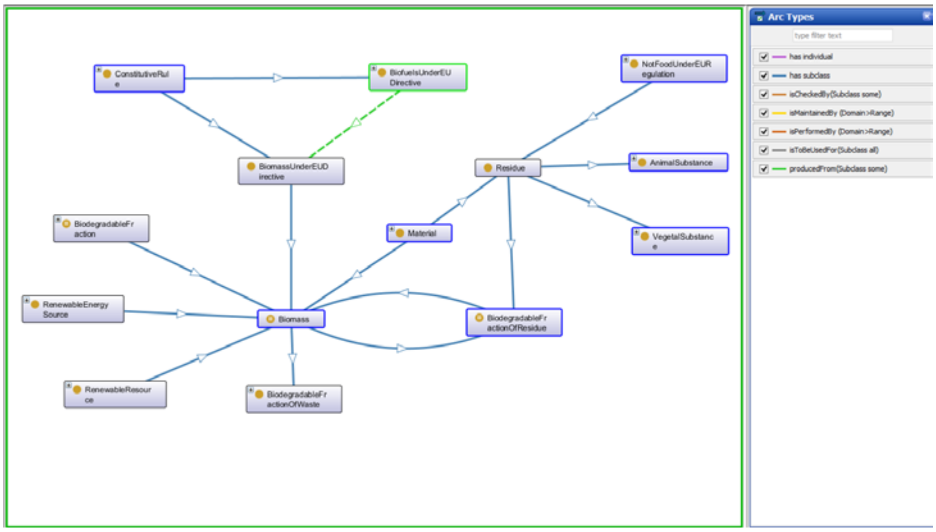



**Fig.60.** Roles of restrictions over the term 'Biomass' and 'Residue'

- *Article 2 of EU Regulation 178/2002/EC* defines food and what shall not be food. In the case of ‘what is food’, it clearly establishes the legal nexus between ‘water’ and ‘food’, because it states that water, after the point of compliance, itself is a food. In addition, if water-substance is used in food production, it shall be considered as food too. However, in the case of ‘what shall not be food, it clearly establishes the legal nexus between ‘Food’ and ‘Biofuels’, as it mentions that ‘residue’ shall not be food. Therefore, Article 2 of EU Regulation 178/2002/EC plays the most important legal role in the water-energy-food nexus, as it establishes legal nexus between ‘water and food’ and also in between ‘what shall not be food’ and ‘biofuels’.

From the above mentioned legal nexus context, the roles of few major asserted restrictions are discussed below -

**Role of restrictions over the entities ‘Residue’ and ‘Biomass’.** There are following sub-class restrictions over the terms ‘Biomass’ and ‘Residue’ – (a) the term ‘Biomass’ is an equivalent term to the term ‘BiodegradableFractionOfResidue’, (b) ‘Residue’ is a sub-class of ‘NotFoodUnderEURegulation’, (c) the term ‘Biomass’ is sub-class of the term ‘BiomassUnderEUDirective’ and ‘RenewableEnergySource’. And the term ‘BiomassUnderEUDirective’ has universal relationship with the term ‘BiofuelsUnderEUDirective’ using object-property ‘producedFrom’, shown in Figure 60. These roles of restrictions over these terms manipulate the meaning of the legal nexus between food and energy in following directions –

- Biofuel is produced from ‘biodegradable fraction of residue’ and therefore it does not affect the food domain. Because neither ‘biodegradable fraction of residue’ nor biomass is food by law.
- As ‘biodegradable fraction of residue’ is not food by law and is used for biofuel production, therefore water used in the production of biofuel, unlike food production, shall not be the water intended for human consumption.

**Role of restrictions over the entity ‘WaterIntendedForHumanConsumption’.** The term ‘WaterIntendedForHumanConsumption’ has following 12 sub-classes restrictions extracted from Article 2 of EU Directive 98/83/EC and EU Regulation 178/2002/EC, shown in Figure 61 -

- The term ‘WaterIntendedForHumanConsumption’ is a sub-class of the entity ‘ConstitutiveRule’ and has universal relationship with the term ‘Human’ using object property ‘consumes’.
- The terms ‘WaterSubstanceInFood’, ‘WaterAfterCompliance’, ‘FoodProductWhereWaterIsUsed’ and ‘FoodProduct’ are the sub-classes of the entity ‘WaterIntendedForHumanConsumption’.
- The term ‘WaterIntendedForHumanConsumption’ has existential relationship with the term ‘CompetenNationalAuthorityInWaterDomains’ using object property ‘isCoordinatedBy’.

- The term ‘WaterIntendedForHumanConsumption’ implies to the terms ‘HumanConsumptionActivity’ and ‘DistributionOfWater’ with existential relationship using object property ‘isIntendedFor’ and ‘isSuppliedFrom’ respectively.
- The term ‘WaterIntendedForHumanConsumption’ implies with existential relationships to the terms ‘FoodProduct’ and ‘FoodProductionActivity’ using object property ‘isUsedIn’.
- The object-property ‘shallBeUsedFor’ is used to create universal restriction over the relationship between the terms - ‘WaterIntendedForHumanConsumption’ and ‘FoodProductionActivity’.
- The term ‘WaterIntendedForHumanConsumption’ implies to the terms ‘QualityOfWater’ and ‘WasteWater’ with universal relationships using object properties ‘shallHave’ and ‘shallNotHave’ respectively.

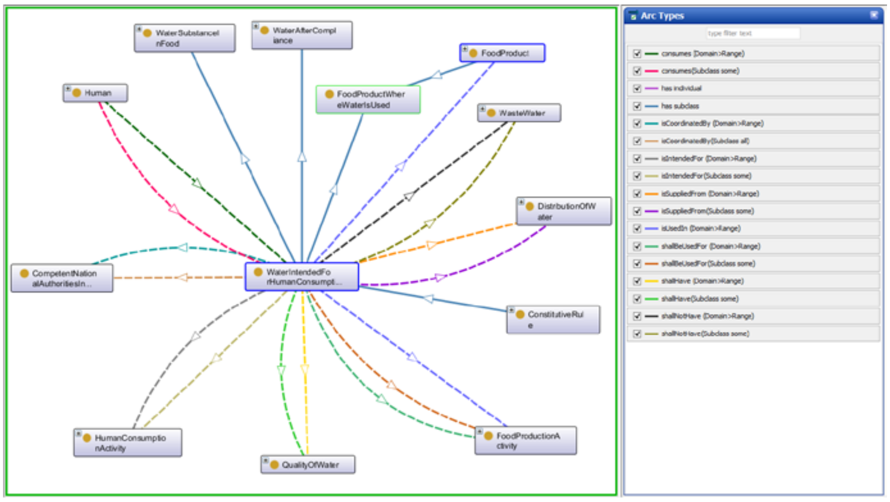



**Fig.61.** Role of restriction over the term 'WaterIntendedForHumanConsumption'

There would have a multiple number of legal nexuses between ‘Water’ and ‘Food’ domain by using above mentioned restrictions. The most general, but legal, two examples are given here –

- Water intended for human consumption is a type of food and used in food production activity.
- Waste water is not the water intended for human consumption and therefore shall not be used in food product and/or food production activity.

**Role of restrictions over the entity ‘QualityOfWater’.** The asserted model of the legal ontology for EUWEFNexus and the term ‘QualityOfWater’, shown in Figure 53 and 62 respectively, shows that there are following six restrictions play important role in order to establish legal nexuses between water and food domains –

- The term ‘QualityOfWater’ implies to the term ‘WholesomenessOfFoodstuff’ with universal relationships using object-property ‘shallNotAffect’. Therefore, it has universal relationship with the term ‘WaterIntendedForHumanConsumption’ using object property ‘shallHave’. That ensures the role of semantic networks of these terms and properties in order to establish critical legal reasoning of water and food nexus that water intended for human consumption shall have such quality that shall not affect wholesomeness of the foodstuff.
- Both terms ‘PointOfCompliane’, which is equivalent term to ‘MaintenanceOfQuality’, and ‘Product’, which is a parent-class of the term ‘FoodProduct’, have functional and asymmetric relationships with the term ‘QualityOfWater’ using object property ‘isAssociatedWith’ and ‘mustMaintain’ respectively. It shows another important legal nexus between water and food domains is that food product, as a class of product, must maintain the quality of water used in it. And that will be coordinated by competent national authorities as the quality of water is in associated with maintenance of quality and/or point of compliance.

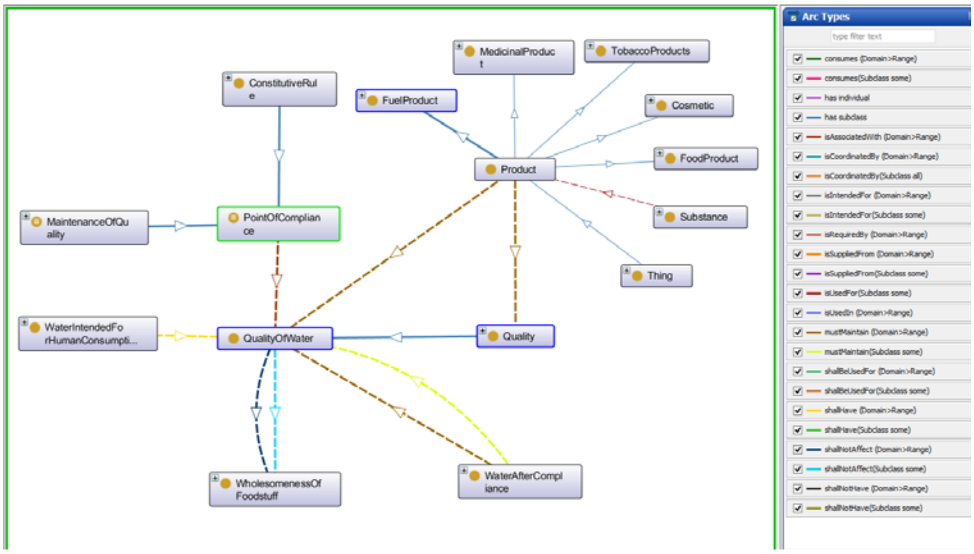



**Fig.62.** Asserted model of restrictions over the term 'QualityOfWater'

**Role of restrictions over the entity ‘PureVegetableOil’.** In according to the Article 2 of both legislations - EU Directive 2003/30/EC and EU Regulation 178/2002/EC, there is a plenty of legal nexuses exist between the sub-classes of term ‘BiofuelsUnderEUDirective’ and ‘NotFoodUnderEURegulation’. One of such examples is legal nexus between ‘PureVegetableOil’ and ‘Residue’ or ‘Biomass’, shown in Figure 63, with following restrictions over it –

- The term ‘PureVegetableOil’ is a child-class of the entity ‘VegetableOil’ and ‘BiofuelsUnderEUDirective’.

- The term ‘BiofuelsUnderEUDirective’ implies to the term ‘Transport’ and ‘BiomassUnderEUDirective’ with universal and existential relationship respectively using object-properties ‘isToBeUsedFor’ and ‘producedFrom’ respectively. Under this context, as ‘PureVegetableOil’ is a sub-class of ‘BiofuelsUnderEUDirective’, these both universal and existential restrictions infer to the term ‘PureVegetableOil’ too.
- The term ‘PureVegetableOil’ also implies to the terms ‘Engines’, ‘OilProduction’ and ‘EmissionRequirement’ with existential relationship using object-properties ‘compatibleWith’, ‘producedFrom’ and ‘’mustCorrespondWith’ respectively.

Above restriction over the term ‘PureVegetableOil’ also shows that even though pure vegetable oil can be produced from oil production, it must be sourced from biomass, e.g. residue of vegetal substance which is biodegradable.

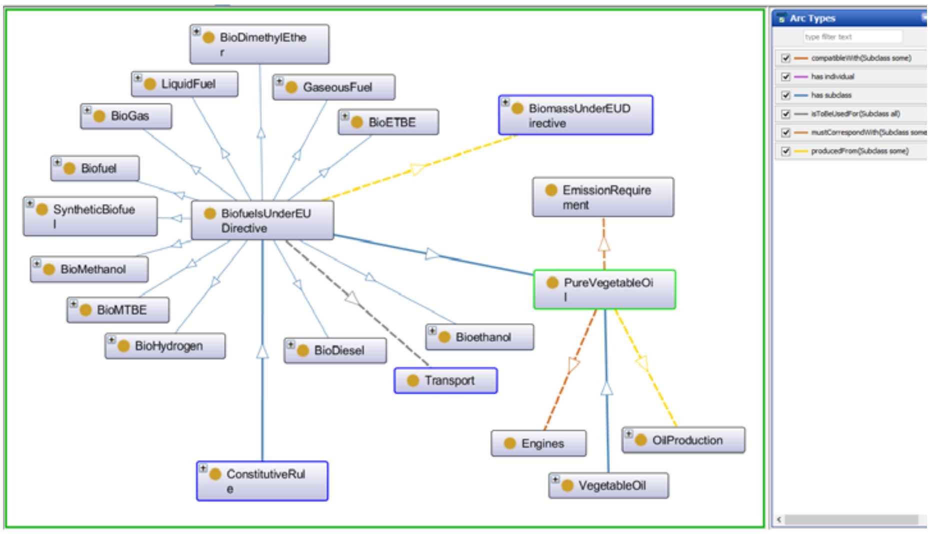



**Fig.63.** Role of restrictions over the term 'PureVegetableOil'

Like above mentioned four examples, shown in Figure 60 to 63, there exists a plenty of semantic networks of legal nexuses between and among water, energy and food domains in the legal ontology of EUWEFNexus.

**Table 7.** Reasoners' result on the legal ontology for EUWEFNexus

| ***Reasoners*** / ***Inference types*** | ***Fact ++*** | ***HermiT 1.3.8. and 1.3.8.3.*** | ***Pellet and Pellet (Incremental)*** | ***Snorocket*** |
|---|---|---|---|---|
| Methodology | Tableau | Hypertableau | Tableau | Completion rules |

| | | | | |
|---|---|---|---|---|
| Error and inconsistency | No | No | No | No |
| Class inferences | Satisfied | Satisfied | Satisfied | Satisfied |
| Object property inferences | Satisfied | Satisfied | Satisfied | Satisfied |
| Axioms inferences | Sound | Sound | Sound | Sound |
| Soundness | Satisfied | Satisfied | Satisfied | Satisfied |
| Completeness | Satisfied | Satisfied | Satisfied | Satisfied |
| Justification | Doesn't support | | Satisfied | Doesn't support |

### 23.4 Reasoners' result of the legal ontology for EUWEFNexus

Reasoners found no error and/or inconsistency in the inferences among the classes and properties, shown in Table 7. All reasoners also are satisfied with the soundness and completeness of the ontology. Snorocket reasoner did not show any justification note as it found no error. However, none of other reasoners, the list of reasoners given in the Table 7, found any such error. Therefore, this error has been considered as not expected and therefore ignored. In the case of inferred anonymous ancestor, partially shown in Figure 64, there is no inconsistency and anomalies too. Rather inferred anonymous ancestor provides aids for ensuing implicit reasoning of legal nexuses by executing asserted restrictions of one term and/or property, discussed in R1 to R31, over other terms and properties.

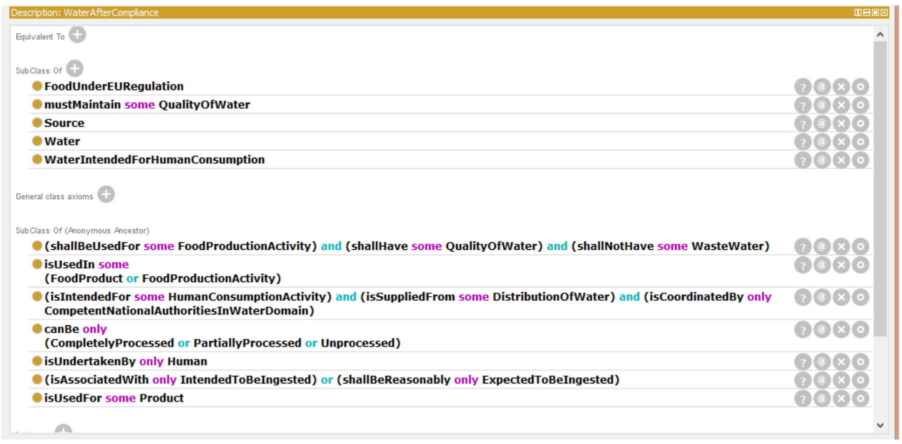



**Fig.64.** Subclass of anonymous ancestor of the term 'WaterAfterCompliance'

For example, the term 'WaterAfterCompliance' is sub-class of 8 anonymous ancestors, shown in Figure 64, which was not asserted to this term manually. However, considering applying all of these restrictions over the term 'WaterAfterCompliance' satisfies legal reasoning requirements mentioned in Article 2 of both legislations -

Article 2 of EU Directive 98/83/EC and EU Regulation 178/2002/EC. It also proves ontological consistency in the legal ontology for Nexus.

# Chapter 5

## Evaluation of Legal Ontology for Nexus: Knowledge Acquisition, Ontology Construction and its Application to the Legal Documents

*..... (2) Properties describing each legislative act*

*While a structured URI can already identify acts using a set of defined components, the attribution of additional metadata established in the framework of a shared syntax will set the basis to promote interchange and enhance interoperability between legal information systems…….*

- EU Council's conclusions inviting the introduction of the European Legislation Identifier (ELI)(2012/C 325/02)

## 24 Overview: Evaluation of Legal Ontology for Nexus

In order to evaluate legal ontology for nexus, beside the reasoners' result described in chapter 4, following two points are considered –

- First, evaluation has been performed manually as the legal ontology of nexus is constructed manually. Here 'constructed manually' means that from legal knowledge acquisition to taxonomy development to concept definition to property relationship for nexus all are mapped and constructed manually. At the later stage, protégé 5 editor, which is complied with OWL full language, has been used in order to build the ontology.
- Second, the evaluation has been performed through critical analysis of evaluative criteria presented in chapter two. That is broadly divided into two phrases – legal knowledge acquisition and ontology construction. The former is sub-divided into explicit and implicit knowledge acquisition and the latter is primarily focused on epistemological adequacy, operation-ability and reusability for the legal ontology of nexus.

This chapter is primarily devoted to present analytic evaluative results of legal ontology of nexus. In addition, at the later, it also explains various document based legal information systems such as FAOLEX[333], ECOLAX[334], WaterLax[335], WISH[336],

[333] FAOLEX is a comprehensive and up-to-date legislative database, one of the world's largest electronic collection of national laws and regulations on food, agriculture and renewable natural resources. See for detail at http://faolex.fao.org/

[334] ECOLEX is an information service on environmental law, operated jointly by FAO, IUCN and UNEP. Its purpose is to build capacity worldwide by providing the most comprehensive possible global source of information on environmental law. See for detail at www.ecolex.org/

EurLeX[337], legislation.gov.uk[338] and their limitations. Successively, it demonstrates how legal ontology for nexus can be integrated to the legal documents in order to improve the services a legal knowledge or information system provides.

## 25 Reintroduce of Evaluative Criteria: Legal Knowledge Acquisition and Ontology Construction

Chapter two provides in detail the evaluative criteria those are, in principle, considered to be used as main principles in order to evaluate legal ontology for nexus. In order to make the content of this chapter easier to readers, here all evaluative criteria are reintroduced briefly. Overall, there are two broad evaluative criteria. There are – legal knowledge acquisition and ontology construction. The implementation of these criteria into the legal ontology for nexus was chronological. It means task of ontology construction has started after concluding the tasks of legal knowledge acquisition for nexus.

However, on the one hand, the legal knowledge acquisition criteria deal with the processes that are used to define legal concepts and their class and property relationships. It has been sub-categorized into explicit and implicit knowledge. On the other, ontology construction criteria deal with three inter-related aspects of the legal ontology for nexus. They are – epistemological adequacy, operation-ability and reuse-ability. Each of these sub-criteria has further categorized. The epistemological adequacy criterion is based on following five features – clarity, intuitiveness, relevance, completeness and discriminative power. The operation-ability criterion deals with encoding bias, coherence and computation-ability of the ontology. Furthermore, the reuse-ability criterion evaluates domain, task and method reuse-ability.

In the following section, analytic evaluative results of each of these criteria have been presented with examples taken from legal ontology for nexus.

---

[335] The WaterLex Legal Database Project (WLDP) is an initiative connecting academics and water-governance practitioners from around the world to articulate evolving law and legal doctrine to multi-level water governance practices in a dynamic online platform. See for detail at http://www.waterlex.org/waterlex-legal-database/

[336] The Water Information System for Europe or more commonly known as WISE – is your gateway to information on European water issues. It comprises a wide range of of data and information collected by EU institutions to serve several stakeholders. For detail see at http://water.europa.eu/

[337] Eur-Lex provides EU law and other public EU documents, authentic electronic Official Journal of the EU – in 24 languages. For more detail, see at http://eur-lex.europa.eu/homepage.html

[338] Is managed by The National Archives which is a United Kingdom government department and an executive agency of the Ministry of Justice. It is considered as a centre of expertise in every aspect of creating, storing, using and managing official information. For more detail, see at http://www.legislation.gov.uk

## 26 Evaluation of the taxonomy of Legal Ontology for Nexus

Four domain independent meta-properties as proposed by OntoClean and discussed in Chapter 3 such as identity, unity, dependent and rigidity are used for evaluating taxonomy developed for the legal ontology for nexus. In this section, one example of such crucial comprehensive human reasoning exercise is presented and explained in Table 1, which is comprised with following 10 concepts out of total 174 concepts used in the legal ontology for nexus, and shown in Figure 1 with the state of their corresponding meta-properties. All of these meta-properties are discussed in Table 1 under the context of legal ontology for nexus, for detail see Chapter 4.

**Table 1.** Use of OntoClean for evlating a curical part of taxonomy of legal ontology for nexus

| ***Concept*** | ***Source of the concept*** | ***Identity*** | ***Unity*** | ***Dependent*** | ***Rigidity*** | ***Onto-Clean in notation*** |
|---|---|---|---|---|---|---|
| Constitutive Rule | Searle. J.[339] | +I as it is informative, in the context of legal ontology for nexus it is originated from legislative texts and generate some not trivial tasks. | -U as performance of one single activity derived from respective constitutive rule necessarily not whole. | +D as it is externally dependent on other concepts such as water after compliance etc. | -R as it is not essential to some of its instances. Because legal rule evolves. | +I-U+D-R |
| Biofuels under EU Directive | Article 2 of EU Directive 2003/30/EC | +I as it provides all necessary legal information in order to make the legal meaning for | -U as there exists biofuel which is not covered by this constitutive | +D as the concept is externally dependent on the concept | -R as it is not essential to the concept 'Biomass' as described in Chapter 4. | +I-U+D-R |

[339] Searle, J., 1969. Speech Acts: An Essay in the Philosophy of Language. Cambridge: Cambridge University Press, and C. Dahlman and E. Feteris (eds.), Legal Argumentation Theory: Cross-Disciplinary Perspectives, Law and Philosophy Library 102, DOI 10.1007/978-94-007-4670-1 11, Springer, 2013.

| | | | | | | |
|---|---|---|---|---|---|---|
| | | biofuels which is legally operable in the single market of EU. | rule. | ‘Biomass’. | | |
| Renewable Fuels under EU Directive | Article 2 of EU Directive 2003/30/EC | +I as it helps us to identity legal requirements for renewable fuels for EU. | -U as some of its instances is not whole, e.g. biodegradable fraction of residue. | +D as it is externally dependent on the concept ‘transportation’. | -R as the concept may not be essential for all transportation and biodegradable fraction of biomass. | +I-U+D-R |
| Biofuel | Article 2 of EU Directive 2003/30/EC | +I as it makes the legal meaning of biofuel and helps us to identify its legal relationship with other concepts. | | +D as it is externally dependent on other concepts such as ‘renewable source’. | | +I-U+D-R |
| Biomass Under EU Directive | Article 2 of EU Directive 2003/30/EC | +I as it gives us understanding of legal source for producing biofuels. | -U as some biodegradable fraction may not be biomass, e.g. fossil fuels. | +D as it is externally dependent on the biological materials. | -R as it is not essential to many biological materials, e.g. dead human body. | +I-U+D-R |
| Biodegradable Fraction of Resi- | Article 2 of EU Directive 2003/30/EC and EU Regula- | +I as it provides legal identity relations with the concept | -U as some of it may be treated as food for fishes, | | | +I-U+D-R |

| | | | | | | |
|---|---|---|---|---|---|---|
| due | tion 178/2002 | ‘not food under EU Regula-tion’. | even though it is consid-ered as not food for hu-man. | | | |
| Not Food Under EU Regu-lation | Article 2 of EU Regula-tion 178/2002 | +I as it gives us clear in-formation about what is not food for human in the EU. | -U as some of its in-stances are not whole as not food, e.g. bio-degrada-ble frac-tion of residue. | +D as it is exter-nally depend-ent on other concept, e.g. biode-grada-ble fraction of bio-mass. | -R as now-a-days there are cosmetic which is consuma-ble by hu-man but not legally permitted as food for human consump-tion. | +I-U+D-R |
| Water intend-ed for human con-sump-tion | Article 2 of EU Directive 98/83/EC | +I as it provides a legal identi-ty criteria of water that is con-sumable by human. | -U as water in its origi-nal form can be legally treated as water intended for human consump-tion but in reality it may be not as such e.g. salty wa-ter. | +D as it is exter-nally depend-ent on the concept water after compli-ance. | -R as the parametric values of it changes over time, e.g. mercu-ry. | +I-U+D-R |
| Food Under EU Regu-lation | Article 2 of EU Regula-tion 178/2002 | +I as it constructs legal identi-ty criteria of what is known as | -U as all water regardless its quality is not food, but | +D as it is exter-nally depend-ent on many | -R as plant prior har-vesting and animal without intending | +I-U+D-R |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | food for EU single market and all agricultural policy. | only water after compliance is legally considered as food. | other concepts, e.g. human consummation. | to seal them in the market are not legally considered as food, even though they can be used as food. | |
| Water after compliance | Article 2 of EU Directive 98/83/EC and EU Regulation 178/2002 | +I as it helps us to understand legal identical parameters of water intended for human consumption, e.g. when water is legally considered as food. | -U as it may not carry all parametric values as prescribed in the law after waste water treatment, even though it may consider consumable. | +D as it is externally dependent on various water quality parameters e.g. iron. | -R as the parametric values of it changes over time, e.g. lead. | +I-U+D-R |

Considering analyzes given in Table 1, it is now evident that all subsumed concepts by ‘constitutive rule’ have same status of their corresponding meta-properties. That is that all above mentioned concepts carry identity +I, particularly form legal point of view, with no unity –U but dependent on some external concepts +D while they carry no rigidity –R. The subsumed relationships have illustrated in Figure 1, which completely corresponds with the assumption based principles of OntoClean, as described in Chapter 3 for following reasons:

- All concepts that carry identity criteria subsume other concepts that carry similar identity criteria. For example, the concept ‘biofuels under EU Directive’ is subsumed by the concept ‘constitutive rule’ while ‘biofuel’ is subsumed by two concepts with similar identity criteria ‘biofuels under EU Directive’ and ‘renewable fuels under EU Directive’. All of these concepts carry +I.
- All concepts that carry no unity criteria subsume other concepts that also carry no unity criteria. For example, the concept ‘not food under EU Regulation’ is subsumed by the concept ‘constitutive rule’ as both of them carry no unity while the

concept ‘biodegradable fraction of residue’ is subsumed by following two concepts with no unity – ‘biomass under EU Directive’ and ‘not food under EU Regulation’.

- All concepts that are externally dependent on other concepts subsume those concepts that are also externally dependent on other concepts. For example, the concept ‘water after compliance’ is subsumed by the concept ‘food under EU Regulation’ as both of them externally dependent on ‘parametric values’ and ‘human consumption’.

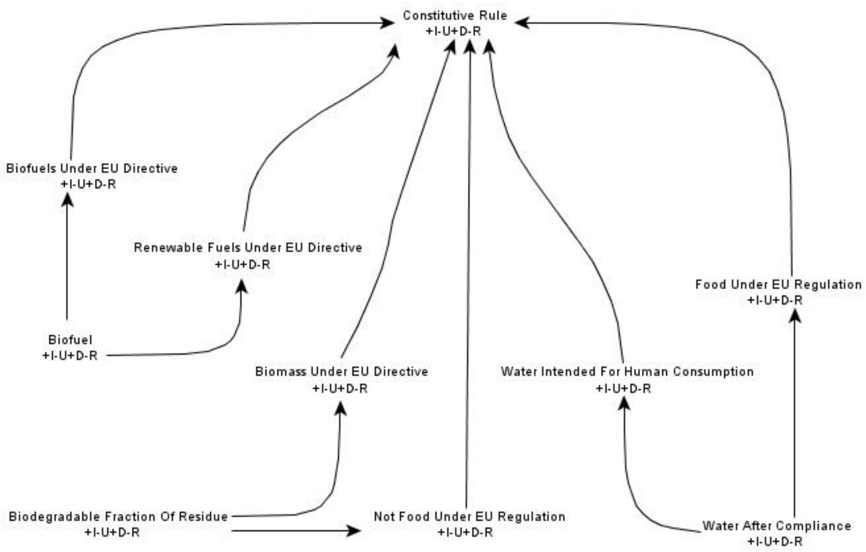



**Fig.1.** Use of OntoClean in the legal ontology for nexus

- All concepts that carry no rigidity subsume the concepts that also carry no rigidity. For example, ‘biomass under EU Directive’ is subsumed by the concept ‘Constitutive rule’ as both of them carries no rigidity.
- In addition as there are no contrasting meta-properties, they are not necessarily disjoint.

# 27 Evaluation of Legal Ontology for Nexus

## 27.1 Knowledge Acquisition of Legal Ontology for Nexus

The knowledge acquisition for legal ontology for nexus is extracted manually from respective legislative texts. There are following two sets of legislative texts have been used in order to do so –

- Primary legislative texts - following three legislations have been used as a core legislative texts or documents from where legal definitions of water intended for human consumption, food and biofuel are extracted – (a) Article 2 of EU Directive 98/83/EC defines the water intended for human consumption, (b) Article 2 of EU Directive 2003/30/EC defines bio-fuels, and (c) Article 2 of EU Regulation 178/2002/EC defines food.

- Secondary legislative texts – there are a number of legislative documents have been used in order to extract the missing legal definition of some concepts that exist in the body of legislative texts of above mentioned legislative documents but does not have legal definition into the same body of legislative texts in order to express its identity principles. For example, Article 2 (1) (b) of EU Directive 98/83/EC demonstrates that competent national authorities are supposed to be satisfied with the quality of water by mentioning that

“*.... unless the **competent national authorities** are satisfied that the quality of the water cannot affect the wholesomeness of the foodstuff in its finished form*....”

But the same legislative document does not provide legal definition of the competent national authority. Therefore, it was necessary to look for secondary legislative text from where a legal definition of the competent national authority can be extracted. Hence Article 2(19) of Regulation (EC) no 1946/2003 has been considered in order to fill this gap.

In addition, definitions of few concepts that used in the legal ontology for nexus are extracted from the popular literatures, mainly from legal dictionaries and academic literatures, because the definitions of such concepts are the subjects of unavailability in entire EU legislative body. One example of such used concepts in the legal ontology for nexus is ‘constitutive rule’. Even though, Article 9(6) of Directive 2014/65/EU[340] clearly indicated the important of application of constitutive rules in business administration, there is no legal definition of this concept found in the EU legislative texts. Therefore, the definition of the term ‘constitutive rule’ is drawn from the academic works[341] of Prof. John Searle.

Furthermore, both types of knowledge acquisition, explicit as well as implicit, have been performed. They are demonstrated below with examples -

### 27.1.1 Explicit Knowledge Acquisition of Legal Ontology for Nexus

It has been observed in the legal ontology for nexus that there are mainly two types of explicit knowledge acquisitions. The first category, on the one hand, is mainly based on primary legislative texts from where both, the legal concept as well as their definition, have been extracted. For example, Article 2 (1) of EU Directive 98/83/EC explicitly mentions that

[340] of the European Parliament and of the Council of 15 May 2014 on markets in financial instruments and amending Directive 2002/92/EC and Directive 2011/61/EU,

[341] John Searle, Speech Acts, Cambridge University Press 1969, ISBN 0-521-09626-X. and John Searle, "Indirect speech acts." In Syntax and Semantics, 3: Speech Acts, ed. P. Cole & J. L. Morgan, pp. 59–82. New York: Academic Press. (1975). Reprinted in Pragmatics: A Reader, ed. S. Davis, pp. 265–277. Oxford: Oxford University Press. (1991)

“.....‘***water intended for human consumption***’ shall mean.....”

Therefore, both the legal term and definition of ‘water intended for human consumption’ has been extracted from legislative texts, shown in Figure 2.

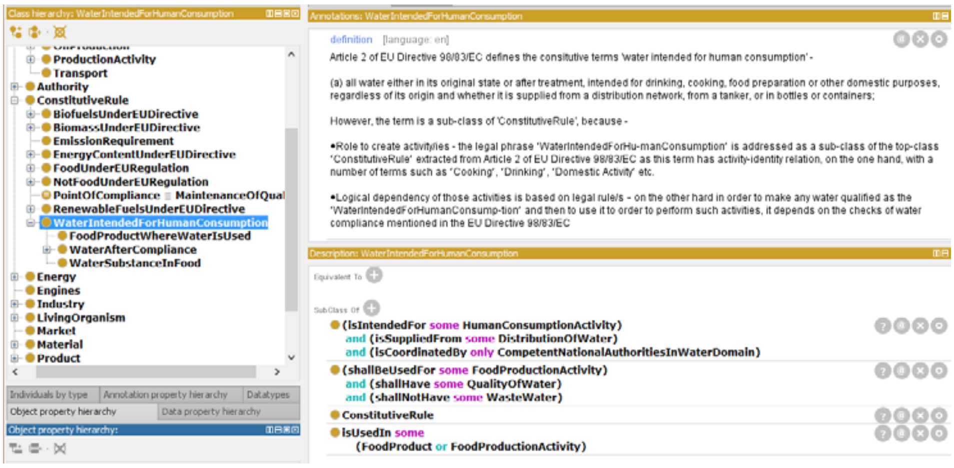



**Fig.2.** Explicit knowledge acquisition of the term ‘Human Intended for Human Consumption ’

On the other hand, the second category of explicit knowledge acquisition has two sources of legislative texts. Because the term or legal concept is identified in primary legislative texts and its definition has been extracted from secondary legislative texts. For example, the term ‘Market’ is extracted from Article 2 of EU Regulation 178/2002/EC as follow –

“....Food’ shall not include:........... (b) live animals unless they are prepared for placing on the ***market*** for human consumption..........”

However, the definition of the term ‘Market’ is not given in the same legislative texts. Consequently, second legislative texts Regulation (EU) No 596/2014[342] is used in order to define this term.

### 27.1.2 Implicit Knowledge Acquisition of Legal Ontology for Nexus

Implicit knowledge acquisition also played a big role in the legal ontology for nexus. There are two ways by which implicit knowledge acquisitions have been used.

[342] of the European Parliament and of the Council of 16 April 2014 on market abuse (market abuse regulation) and repealing Directive 2003/6/EC of the European Parliament and of the Council and Commission Directives 2003/124/EC, 2003/125/EC and 2004/72/EC.

First, all Nexus Top Classes, shown in Figure 3, are identified as an implicit knowledge acquisition taken from primary legislative texts.

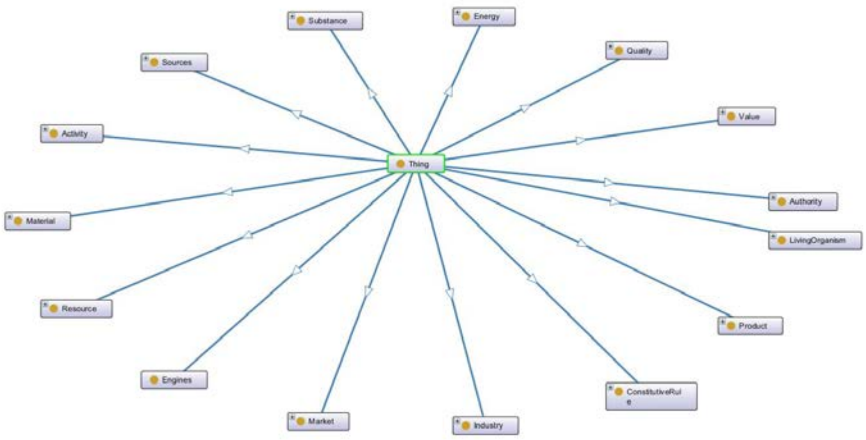



**Fig.3.** WEF Nexus Top Class as implicit knowledge acquisition

For example, Article 2 of EU Directive 98/83/EC explicitly mentions many types of activities without mentioning the term ‘Activity’, considering following legislative texts –

“... intended for ***drinking, cooking, food preparation or other domestic purposes***...”

In this legislative sentence, the bold and underlined terms ‘Drinking’, ‘Cooking’, ‘Food Preparation’ as well as ‘Domestic Purpose’ – all are different expressions of the term ‘Activity’. Therefore, the term ‘Activity’ is identified as an implicit mother term of all explicit associated terms used in primary legislative texts. Likewise, all WEF Nexus Top Classes are types of implicit knowledge acquisitions.

Secondly, many definitions of legal terms used in the legal ontology for nexus are considered as implicit knowledge acquisition too as those definitions are implicitly mentioned in the primary legislative texts from where the terms are originally conferred. One of such example is the term ‘Expected to be ingested’, shown in Figure 4.

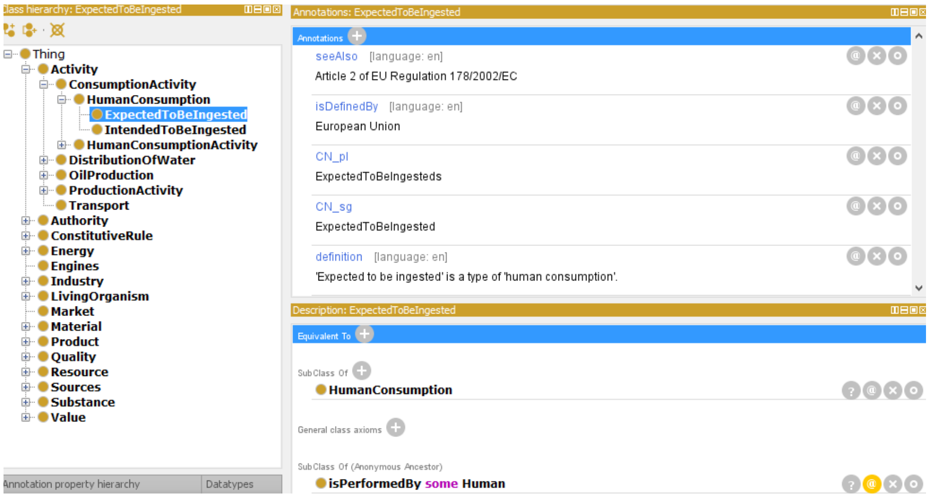



**Fig.4.** Implicit knowledge acquisition of the term ‘ExpectedToBeIngested’

Article 2 of EU Regulation 178/2002/EC explicitly mentions this term as follow -

“...intended to be, or reasonably ***expected to be ingested*** by humans...”

However, neither this legislation nor any other EU legislation defines this term explicitly. Therefore, it was required to define this term from the implicit contexts those are derived from this explicit legal knowledge. One of such, the most reasonable, implicit contexts might be that ‘expected to be ingested’ is a type of activity performed by humans in order to complete the performance of consumption. Hence, the term ‘expected to be ingested’ is considered as a type of ‘human consumption’ and consequently sub-class of it, shown in Figure 4.

### 27.2 Ontology Construction of Legal Ontology for Nexus

There are following major similarities as well as dissimilarities between general ontology construction and legal ontology for nexus –

- Ontology construction is generally domain, purpose and/or task oriented. Similarly legal ontology for nexus is designed with a purpose to be used for Akoma Ntoso based legal documents related with water, energy and food domains. So that it can contribute semantically in the legal reasoning process for nexus through a comprehensive legal knowledge framework as proposed in chapter one. In theory and practice of ontology, even though legal ontology for nexus is purpose oriented, it differs radically in its objective, scope and application domain from general ontology (related analytic discussion has been placed in chapter two and three).
- Unlike general ontology construction, legal ontology for nexus is a merged ontology with four isolated legislative text specific ontologies, as described in chapter

four. It means that, on the one hand, each of these ontologies, including merged legal ontology for nexus, is independent from any particular task to serve. Therefore, their scope of reuse-ability in the semantic web is as much as a legal definition has in the real world. For example, a lawyer can use a legal definition wherever its jurisdiction allows to be used. Likewise, each of these ontologies can be used and/or reused in the entire semantic web in connection with its related legal documents. On the other hand, as legislative sources of these ontologies are EU Directives and Regulation, these ontologies can also be used into local national semantic legal domain. Further discussion has been given in the later of this section.

However, from the evaluation point of view, there core features of legal ontology for nexus are epistemological adequacy, operation-ability and reuse-ability. Each of them is discussed below with examples.

### 27.2.1 Epistemological Adequacy of Legal Ontology for Nexus

Ensuring optimal utility of legal ontology in legal knowledge engineering requires legal epistemological adequacy. The relationship between legal ontology and legal epistemological adequacy is evaluated, as posed by McCarthy, Hayes and Reichgelt and widely used in eGanges project[343].

The common sense world about nexus uses a language to describe nexus oriented concepts, properties and their relationships which are quite different from that used in legislative texts and in legal documents. The three key differences are – (a) the information is less complete, (b) does not have legal validity and authenticity, and (c) semantically inappropriate to be used. Therefore, nexus needs to be expressed in such legal semantic manner which is legally valid, known and permitted in order to navigate the expected legal semantic networks of nexus which does not only contain its conceptual relationships and hierarchies but also contemplates its legal navigations in diverse areas of digitalized legal documents.

The epistemological adequacy of legal ontology for nexus denotes to the degree to which the nexus ontology resembles the legal semantic framework of nexus. Therefore, it is an evaluative measure of the legal dimension of nexus related concepts and relations exist in EU legislative body. Consequently, the legal ontology for nexus must not compromise its epistemological adequacy features such as clarity, intuitiveness, relevance, completeness and discriminative power. The analytic evaluation of all of these features of legal ontology for nexus are discussed below -

#### 27.2.1.1 Epistemological Clarity of Legal Ontology for Nexus

Three methods have been used to evaluate epistemological clarity of the legal ontology for nexus – annotation, restrictions and is-a relationship. First, it is found that

[343] Is a new generation smart, user-friendly expert system shell and used a meta-epistemological methodology in which legal ontology is located. For detail, see at https://en.wikipedia.org/wiki/EGanges

each and every entity, both concepts and properties, have a minimum number of annotation axioms. There are total 850 annotation axioms have been used in the legal ontology for nexus in order to provide a clear and unequivocal meaning of every entity it contains. The most used annotation axioms are – isDefinedBy, definition, seeAlso, comments, inCompatibleWith. As an example, annotation axioms of the entity ‘BioDiesel’ is shown in Figure 5.

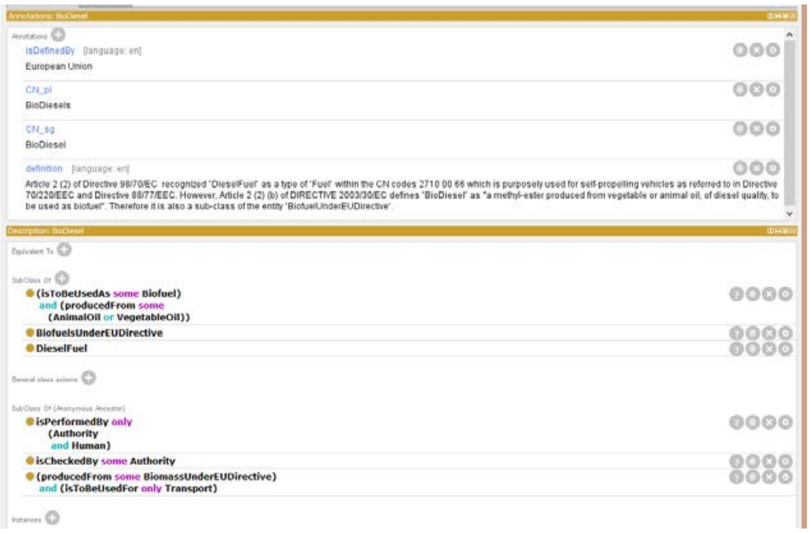



**Fig.5.** Epistemological clarity of the entity ‘BioDiesel’ through its annotation axioms

The second method is to examine restrictions used in this ontology in order to evaluate effectiveness of the communication of legal meaning, which is written in legislative texts, in the ontology. There are total 31 legal restrictions have been used. However, here the legal meaning of the term ‘BioDiesel’, is used as an example. Article 2 (2) (b) of Directive 2003/30/EC says that

> “.....(b) ‘biodiesel’: a methyl-ester produced from ***vegetable or animal oil***, of diesel quality, ***to be used as biofuel*****.....”**

Considering this legislative text, a number of legal restrictions have been created over the term ‘BioDiesel’, shown in Figure 5. One of such legal restriction is formalized, given in equation R21, which particularly represents that bio-diesel is to be used as biofuel and produced from vegetable or animal oil. That precisely proves the actual communication of legal meaning of the term ‘BioDiesel’ in the legal ontology for nexus.

$BioDiesel \sqsubseteq \exists\ isToBeUsedAs\ .\ (\ Biofuel\ )\ \sqcap\ \exists\, producedFrom\ .\ (\ AnimalOil\ \sqcup\ VegetableOil)$............ [R21]

The third method of evaluating epistemology clarity in the legal ontology for nexus is to examine is-a relationships in order to see whether this ontology effectively communicate the intended legal meaning of the defined concepts and their relations. As an example, is-a relationship of the term 'water intended for human communication' is taken from the legal ontology for nexus, shown in Figure 6.

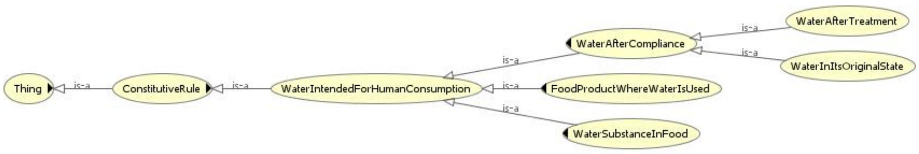



**Fig.6.** Epistemological clarity of the entity 'WaterIntendedForHumanConsumption'

It shows that the terms 'water after treatment', 'food product where water is used' and 'water substance in food' have is-a relationship with the term 'water intended for human communication'. This means that, for instance, all water after compliance is the water intended for human consumption, which is specifically mentioned in the Article 2 of Council Directive 98/83/EC. Therefore it proves the effective communication of the legal meaning into the legal ontology for nexus. In addition, Table 2 shows the summary of the evaluation of epistemological clarity of the legal ontology for nexus.

**Table 2.** Evaluation of epistemological clarity of legal ontology for nexus

| *Questions considered for evaluation* | *Evaluative result* |
|---|---|
| Do all concepts and relations in the legal ontology for nexus have a clear and unequivocal meaning? | Yes. There are 663 annotation assertion axioms used in order to express the clear and unequivocal legal and authentic meaning of each concept, property and their relation. |
| Does the legal ontology for nexus effectively communicate the intended legal meaning of the defined concepts and relations? | Yes. There are total 31 legal restrictions, besides sub-class and dis-joint axioms, have been used in the legal ontology for nexus in order to establish effective communication of the intended legal meaning of the defined concepts and relations. |
| Does the legal ontology for nexus correctly represent is-a relationships of concept and sub-concepts as they are explicitly and implicitly expressed in the legislative texts? | Yes. It does. One of such proof is given in Figure 4. |

#### 27.2.1.2 Epistemological Intuitiveness of Legal Ontology for Nexus

The following two methods have been used to examine whether the legal vocabulary those are engineered in the legal ontology for nexus matches the intuition of water, energy and food domains –

- Evaluation of concept and sub-concept relationships – in the case of legal ontology for nexus, the relationships between concepts and sub-concepts are generally implicit in the body of legislative texts. Therefore, it is crucial to evaluate whether those semantic relationships are counter-intuitive from the expert point of view. Let's consider, as an example, the term 'food under EU Regulation' and its subclass relationship with the term 'water after compliance', shown in Figure 7.

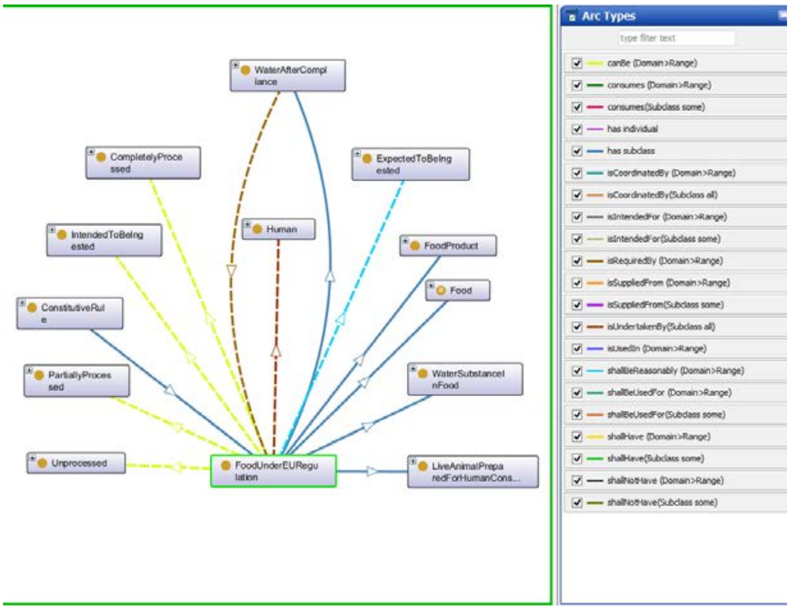



**Fig.7.** Epistemological intuitiveness of the term 'FoodUnderEURegulation'

This relationship particularly represents the legal relationship between these two terms as it is mentioned in Article 2 of the Food definition from Regulation (EC) no 178/2002. It shows that 'water after compliance' is 'food under EU Regulation'. The epistemological intuitiveness of this relations and their legal meaning is found correct in a number literature including government report and other EU legislation[344].

---

[344] Many of such examples can be found at http://www.water-energy-food.org/en/home.html , which is an initiative of Federal Government of Germany and funded by EU and contains a large number of water-energy-food nexus related documents.

- Matching between the legal restrictions that used in the legal ontology for nexus and their common sense based counter-parts – the common sense can be used a tool in order to verify the epistemological intuitiveness of relations and restrictions used in the legal ontology for nexus. In order to do so, one of the legal restrictions, given in R10, over the term 'water intended for human consumption' is used as an example here.

$$\text{WaterIntendedForHumanConsumption} \sqsubseteq \exists \text{shallBeUsedFor} . (\text{FoodProductionActivity}) \sqcap \exists \text{shallHave} . (\text{QualityOfWater}) \sqcap \exists \text{shallNotHave} . (\text{WasteWater}) \text{.............[R10]}$$

The above restriction shows following two fundamental conditions and one usage for the term 'water intended for human consumption' –

- One fundamental usage – 'water intended for human consumption' must be used for 'food production activity' such as food manufacturing, food preservation as well as food preparation etc.
- First fundamental condition – 'water intended for human consumption' must have 'quality of water' as it is mentioned in the respective law.
- Second fundamental condition – 'water intended for human consumption' must not be or have 'waste water'.

Even though above mentioned three points are taken from Article 2 of the Food definition from Regulation (EC) no 178/2002 and Council Directive 98/83/EC, these are undeniable fact and absolutely comprehended by common sense of any human being. That simply proves epistemological intuitiveness of legal ontology for nexus in consistent with general as well as expert's intuition. However Table 3 provides a brief summary of this evaluation -

**Table 3.** Evaluation of epistemological intuitiveness of legal ontology for nexus

| ***Questions considered for evaluation*** | ***Evaluative result*** |
|---|---|
| Does the legal ontology for nexus provide a vocabulary that matches the intuition of the experts, legal and non-legal, in the domain? | Yes. All concepts, properties and their relationships used in the legal ontology for nexus are found in the Water, Energy, and Food Security Resource Platform promoted by German Federal Government. |
| Does concepts, properties and their relationships used in the legal ontology for nexus are consistent with human's common sense based intuition? | Yes. One of such proof is given in the explanation of R11. |

#### 27.2.1.3 Epistemological Relevance of Legal Ontology for Nexus

To what extend the legal ontology for nexus represents the legal meaning of the nexus - is the main subject matter of evaluating epistemological relevance of the legal ontology of nexus. In the current state of art of European water, energy and food policy domain, neither there is law for nexus nor any agreed normative definition of it. That pulls up cognitive challenge in order to prove the epistemological relevance of the legal ontology for nexus. However, as legal ontology for nexus is a merged ontology combined with three independent ontologies of EU legal definition of water, biofuel and food attached with WEF top classes ontology, the legal meaning of nexus derived from combined semantic networks of those ontologies. As a result, there are many independent legal meaning of nexus exist in the legal ontology for nexus. One of such legal meaning of 'Not food under EU Regulation' and 'biofuel' nexus is drawn in Figure 8.

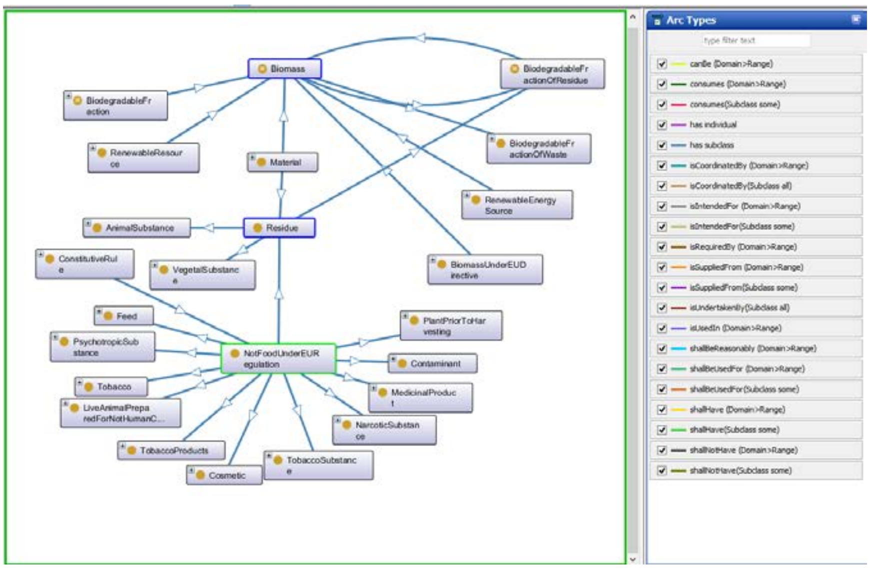



**Fig.8.** Epistemological relevance of Food and biofuel nexus in the legal ontology for nexus

In the Figure 8, on the one hand, it shows the term 'Residue' is a sub-class of 'Not food under EU Regulation', which precisely represents the legislative text of Article 2 of the Food definition from Regulation (EC) no 178/2002 as it says –

"......'***Food' shall not include***:........ (h) ***residues*** and contaminants.'........."

On the other hand, it also shows that the term 'Residue' is a subclass of the terms - 'Biodegradable fraction of residues', 'Material' and 'Biomass'. Therefore, in according to the Article 2(1)(a) of Directive 2003/30/EC, residue can be used for biofuel production, as it says –

> "......(a) ***'biofuels'*** means liquid or gaseous fuel for transport ***produced from biomass***......''

Applying following legal restriction –

*BifuelsUnderEUDirective* $\sqsubseteq \exists$ *producedFrom* **.** **(** *BiomassUnderEUDirective* ) $\sqcap \forall$ *isToBeUsedFor* . ( *Transport* )..........................[R16]

Through this example, it has been proved that by combining semantic relationships of two independent legislative texts, the epistemological relevance of 'Not food under EU Regulation' and 'biofuel' is adequate in the legal ontology for nexus. In addition, Table 4 provides the summary of this evaluation.

**Table 4.** Evaluation of epistemological relevance of legal ontology for nexus

| ***Questions considered for evaluation*** | ***Evaluative result*** |
|---|---|
| Are all concepts, properties and their relationships used in the legal ontology for nexus relevant for modeling legal meaning of nexus? | Yes. Indeed, there is no specific legislation for nexus in EU. However, by combing semantic relationships of three independent legal definitions of water, food and biofuel, the merged legal ontology for nexus provides sufficient epistemological relevance in order to model legal meaning of the nexus. |

### 27.2.1.4 Epistemological Completeness of Legal Ontology for Nexus

The evaluation of epistemological completeness of the legal ontology for nexus displays the limits of this ontology and what need to be done in order to make this ontology as epistemologically complete one. The resulting answer of this evaluation has both sides – completed as well as uncompleted. Both of these aspects are discussed below with legal example –

- Legal ontology for nexus is epistemologically completed – as it was mentioned earlier that there is lack of legislation for nexus in EU, the legal ontology for nexus is a merged ontology combined with three EU legal definitions of water, bio-fuel and food. Therefore, it advances the fundamental legal epistemological understanding of nexus in policy domain and can be useful to analysis various nexus aspects in the entire legal information system of FAOLEX, ECOLAX, WaterLax, WISH, EurLeX, legislation.gov.uk. From the point of view, as it was not available before but now, it proves to some extend the epistemological completeness of legal ontology for nexus. Many of nexus examples that deprived from the legal ontology for nexus are already discussed in chapter 4 and earlier of this chapter.

- Legal ontology for nexus is epistemologically uncompleted - The nexus as a growing policy discourse is very comprehensive as well as complex cross-cutting policy domain. There are many emerging information communication technologies have been using in this field but in isolation. For example, (a) GIS contains vast number of water related information, (b) many sensor systems can detect contamination level in water as well as food, (c) bio-technology can measure various water particles used in the food manufacturing. These all ICTs have been gathering a vast amount of water, energy and food related scientific and parametric data every day. As these information systems contain mainly parametric properties of water, energy and food related concepts, the usability of legal ontology for nexus in such environmental knowledge system will be limited. For example, quality of water is mentioned in Article 2 of both legislations - Council Directive 98/83/EC and Regulation (EC) no 178/2002. The former one mentions as follow -

> "..........competent national authorities are satisfied that ***<u>the quality of the water</u>*** cannot affect the wholesomeness of the foodstuff....."

Considering this legislative text, the legal ontology for nexus is constructed and shown in Figure 9.

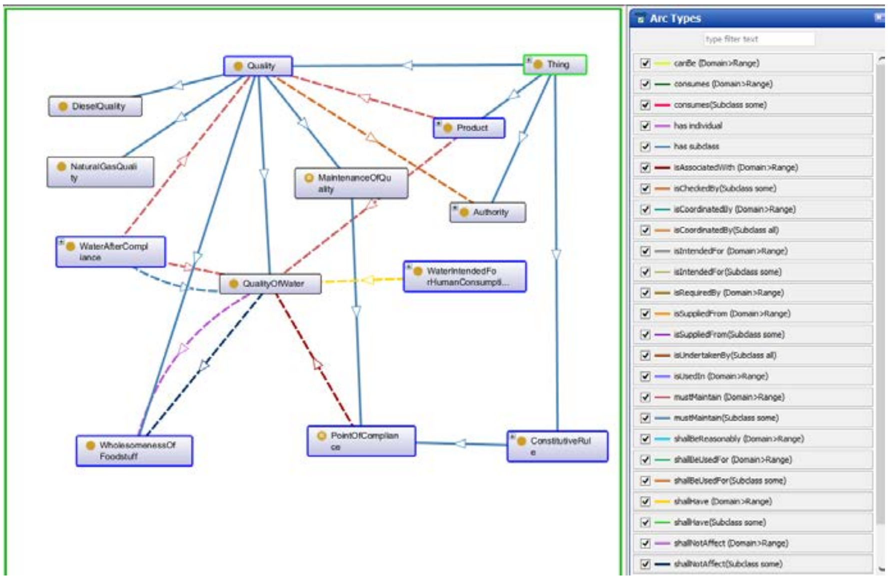



**Fig.9.** Epistemological completeness and incompleteness of the term 'quality of water'

It shows epistemological completeness of the term ‘quality of water’ in the legal ontology for nexus is well performed and constructed using a number of legal restrictions over it, shown in R3, R14, R15, R29 and R31.

$$Quality \sqsubseteq \exists\ isCheckedBy\ .\ (Authority) \text{ .......[R3]}$$

$$QualityOfWater\ \sqsubseteq \exists\ \ shallNotAffect\ .\ (\ \ WholesomenessOfFoodstuff\ ) \text{......[R14]}$$

$$WasteWater\ \sqsubseteq \exists\ \ shallNotBeUsedFor\ .\ \ (\ FoodProductionActivity\ \ \sqcup\ ConsumptionActivity) \text{.......[R15]}$$

$$PointOfCompliance \equiv MaintenanceOfQuality \text{......[R29]}$$

$$WaterAfterCompliance \sqsubseteq \exists\ \ mustMaintain\ .\ (\ \ QualityOfWater\ ) \text{.......[R31]}$$

However, the latter EU Regulation more specifically refers Article 6 of the former EU Directive, saying that -

“..........It includes ***water after the point of compliance*** as defined in ***Article 6 of Directive 98/83/EC*** and without prejudice to the requirements of Directives 80/778/EEC and 98/83/EC.....”

where the compliance of quality of water is discussed about and subsequently in the Annexes of the same legislation, it provided all necessary parametric values of the quality of water. Therefore, without legal ontological modeling of those parametric values of the quality of water, the usability of legal ontology for nexus will remain limited. For this reason, the legal ontology for nexus remains incomplete. However, Table 5 shows summary of evaluative results on epistemological completeness of legal ontology for nexus.

**Table 5.** Evaluation of epistemological completeness of legal ontology for nexus

| ***Questions considered for evaluation*** | ***Evaluative result*** |
|---|---|
| Does the legal ontology for nexus cover all legal concepts, properties and their relationships that may be relevant for any combination of legal tasks for nexus? | Partially yes. Because it covers all necessary top legal concepts, properties and their relations those are necessary and essential for establishing legal meaning of nexus except the parametric values of the quality of water. |
| Are there entities that cannot be modeled with the entities distinguished in the legal ontology for nexus? | No. because parametric values of the quality of water can be model under the term ‘quality of water’ without compromising its operation-ability. |

#### 27.2.1.5 Epistemological Discriminative Power of Legal Ontology for Nexus

There are following two aspects of the epistemological discriminative power of the legal ontology for nexus -

- Firstly, as fundamentally legal ontology for nexus is a merged ontology combining following ontologies – (a) WEF nexus top classes, (b) EU legal definition of water intended for human consumption, (c) EU legal definition of biofuels, and (d) EU legal definition of food, it possess, on the one hand, sufficient epistemological discriminative power, because each of these ontologies is distinct and independent with its respective legislative expressivity. On the other hand, temporal enforceability of each of these legal ontologies, especially (b), (c) and (d), might not affect the operation-ability of legal ontology for nexus, because the legal ontology for nexus is not imported ontology. Therefore, any change happens in the legal ontology of (a), (b), (c) and (d) will not affect the function-ability of legal ontology for nexus. As a result, the reusability of these ontologies is technically potential.
- Secondly as the legal ontology for nexus is a merged ontology and does not have semantic connectivity with other legal ontologies (b), (c) and (d), it seems that it itself, on the one hand, has zero level of epistemological discriminative power. However, on the other hand, as an example, considering the terms ‘food under EU Regulation’ and ‘not food under EU Regulation’ proves the epistemological discriminative power of the legal ontology for nexus, shown in Figure 10.

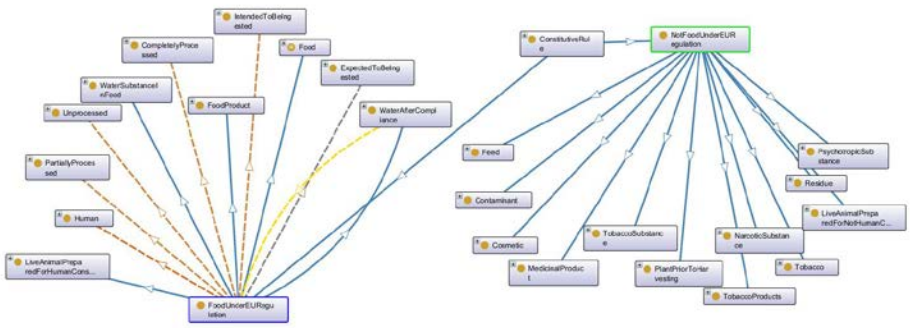



**Fig.10.** Discriminative power of legal ontology for nexus between what is ‘food’ and ‘not food’ in EU Regulation

Because Article 2 of Regulation (EC) no 178/2002 explicitly demonstrates that –

“.....***‘Food’*** includes drink, chewing gum and any substance, including water......
‘***Food’ shall not include***: (a) feed;...............”

In order to establish this particular epistemological discriminative power in the legal ontology for nexus, the sub-class restrictions have been used over the term ‘not food under EU Regulation' and following legal restrictions, besides a number of sub-class restrictions, have been used over the term 'food under EU Regulation' -

$$FoodUnderEURegulation \sqsubseteq \forall\ isAssociatedWith\ .\ (\ IntendedToBeIngested\ )\ \sqcup\ \forall\ shallBeReasonably\ .\ (\ ExpectedToBeIngested) .......[R26]$$

$$FoodUnderEURegulation \sqsubseteq \forall\ canBe\ .\ (\ CompletelyProcessed\ \sqcup\ PartiallyProcessed\ \sqcup\ Unprocessed\ ) ......[R27]$$

$$FoodUnderEURegulation\ \sqsubseteq \forall\ isUndertakenBy\ .\ (\ Human\ ) ......[R28]$$

However, Table 6 expresses the question based summary of this evaluation.

**Table 6.** Evaluation of epistemological discriminative power of legal ontology for nexus

| ***Questions considered for evaluation*** | ***Evaluative result*** |
|---|---|
| Does the legal ontology for nexus have enough discriminative power in that it provides distinctions at a sufficiently high granularity level? | Yes, due to two main reasons – (a) legal ontology for nexus is a merged ontology, but not an imported ontology. Therefore, all other legal ontologies used in order to merge and then to construct legal ontology for nexus are remained distinctive and independent, and (b) sub-class and legal restrictions have been designed and constructed in such a way that show expressability of epistemological discriminative power in the legal ontology for nexus, as shown in Figure 10. |

### 27.2.2 Operationality of Legal Ontology for Nexus

The operationality feature of legal ontology for nexus mainly deals with the effort that has been performed in order to implement all ontological concepts, properties and their relations in a representational language, e.g. OWL Full. In the case of legal ontology for nexus, protégé 5 editor has been used which is in compatible with OWL Full. The most important sub-criteria of the evaluation of operationality of the legal ontology for nexus are – encoding bias, coherence, and computationality. They are discussed below -

#### 27.2.2.1 Encoding Bias of Legal Ontology for Nexus

The evaluation of encoding bias of the legal ontology for nexus primarily deals with how this ontology is specified at the semantic knowledge level. The most important issues that are considered to be evaluated are its dependence as well as convenience over the notation or symbol-level choices by putting few questions forward such as whether legal ontology for nexus represents the legal meaning of nexus on the basis of purely restriction or on the basis of sub-class and/or domain and range relationships.

First of all, it is noteworthy to mention that as Protégé 5 editor has been used for building the legal ontology for nexus, usages of syntax or symbol were very limited. Subsequently, evaluation of encoding bias criterion has following two outcomes –

- No unnecessary incorporation of implementation decision in the legal ontology for nexus – as the legal ontologies of EU legal definitions of ‘water intended for human consumption’, ‘food’ and ‘’biofuel’ are entirely based on their respective legislative texts, the legal ontology for nexus does not contain any unnecessary terms, properties and relations. However, in some cases, it might give an impression that some terms are used in the ontology that does not correspond the legal meaning of the nexus. Two of such terms are ‘engine’, shown in Figure 11, and ‘emission requirement’ extracted from Article 2(2)(j) of Directive 2003/30/EC as it mentions that

> “.....(j) ‘pure vegetable oil’: oil produced from oil plants.......... when compatible with the type of ***engines*** involved and the corresponding ***emission requirements***.’...”

Considering the implementation of these two terms in the legal ontology for nexus for expressing semantic legal meaning of nexus might be unnecessary due to its epistemological irrelevance towards the legal meaning of nexus.


**Fig.11.** Use of the term ‘Engine’ in the legal ontology for nexus

However, on the contrary, it is also true that without establishing existential relations, shown in R26, between the terms ‘engines’ and ‘pure vegetable oil’ using the object property ‘compatible with’ may not be represented the legal meaning of the term ‘pure vegetable oil’, as it is given in the above mentioned legislative text, into the legal ontology for nexus.

$PureVegetableOil \sqsubseteq \exists compatibleWith . ( Engines ) \sqcap \exists mustCorrespondWith . ( EmissionRequirement) \sqcap \exists\ producedFrom . ( OilProduction )$.......[R26]

Therefore, even though it seems that the term ‘engine’ may create some level of encoding bias in the process of expressing legal meaning of nexus through the legal ontology for nexus, it is a legal requirement for constructing the legal meaning of the term ‘pure vegetable oil’, which is a sub-class of the term ‘biofuel under EU Directive’.

- Minimal encoding bias at the implementation of restrictions in the legal ontology for nexus – there are total 31 restrictions used in the legal ontology for nexus. Some of them have symbol-level choice. For example, considering following restrictions – R09, R10 and R11, all of these restrictions have been given to the term ‘water intended for human consumption’ extracted from Article 2 of Council Directive 98/83/EC.

*WaterIntendedForHumanConsumption* ⊑ *∃ isIntendedFor . ( HumanConsumptionActivity) ⊓ ∃ isSuppliedFrom . (DistributionOfWater) ⊓ ∀ isCoordinatedBy . (CompetentNationalAuthoritiesInWaterDomain)* .....[R09]

WaterIntendedForHumanConsumption ⊑ ∃ shallBeUsedFor . (FoodProductionActivity) ⊓ ∃ shallHave . ( QualityOfWater) ⊓ ∃ shallNotHave . (WasteWater)........[R10]

*WaterIntendedForHumanConsumption* ⊑ *∃ isUsedIn* **.** *(FoodProduct ⊔ FoodProductionActivity)*.......[R11]

The implementation of these restrictions involves a number of symbol-level choices. Therefore, there might have minimum level of encoding bias. Furthermore, Table 7 presents the summery of this evaluation -

**Table 7.** Evaluation of encoding bias of legal ontology for nexus

| ***Questions considered for evaluation*** | ***Evaluative result*** |
|---|---|
| Does the legal ontology for nexus rely on symbol-level choices? | Not entirely. Because as total 2 restrictions have been used in the legal ontology for nexus, there might have some symbol-level choices. |
| Is there unnecessary incorporation of implementation decision of legal meaning of nexus in the legal ontology for nexus? | No. Because all terms, properties and relations have been used in the legal ontology for nexus are extracted from plain legislative texts. |

### 27.2.2.2 Coherence of Legal Ontology for Nexus

The evaluation of coherence of the legal ontology of nexus is based on two types of inference checks – (a) reasoning check on the conceptualization of legal ontology for nexus, which is performed by human manually with cognitive analytic skills, and (b) inference check on the specification of the legal ontology for nexus, which is performed by artificial intelligence based reasoning tools. The evaluative results are discussed below -

- Reasoning checks on the conceptualization – as the legal knowledge acquisition for the legal ontology for nexus is performed manually with following very well structured methodology, for detail see chapter 3 and 4, inference checks on the conceptualization has been performed iteratively in every steps of this ontology construction. However, two examples of such manual inference checks are demonstrated here.

$QualityOfWater \sqsubseteq \exists\ shallNotAffect\ .\ (\ WholesomenessOfFoodstuff\ )$.........[R14]

First, the restriction over the term 'quality of water', shown in R14, which shows that the property 'shall not affect' is used to express existential relationship between the terms 'quality of water' and 'wholesomeness of foodstuff' as it is explicitly mentioned in Article 2 of Council Directive 98/83/EC saying that

"....***quality of the water*** **cannot affect** the ***wholesomeness of the foodstuff***...."

That proves legal reasoning checks over the conceptualization of the terms 'quality of water' and 'wholesomeness of foodstuff' and their relations are legally clear and correct.

$RenewableFuel \sqsubseteq \exists\ isOriginatedFrom\ .\ (\ RenewableEnergySource) \sqcap \forall\ isToBeUsedFor\ .\ \ (\ Transport\ )$.....[R19]

The other example is the reasoning check of the conceptualization of the term 'renewable fuel' and its relationship with other terms and properties, shown in R20. In this restriction, it shows that the term 'renewable fuel' has existential relationship with the term 'renewable energy source' with the property 'is originated from' and universal relationship with the term 'transport' using object property 'is to be used for'. This restriction has been extracted from Article 2 (1) (c) of Directive 2003/30/EC, see following extract –

"*.....**renewable fuels**' means renewable fuels, other than biofuels, which **originate from** **renewable energy sources** as defined in Directive 2001/77/EC (2) and **used for transport** purposes;.....*"

Both of these examples prove that there is coherence on the conceptualization in the legal ontology for nexus.

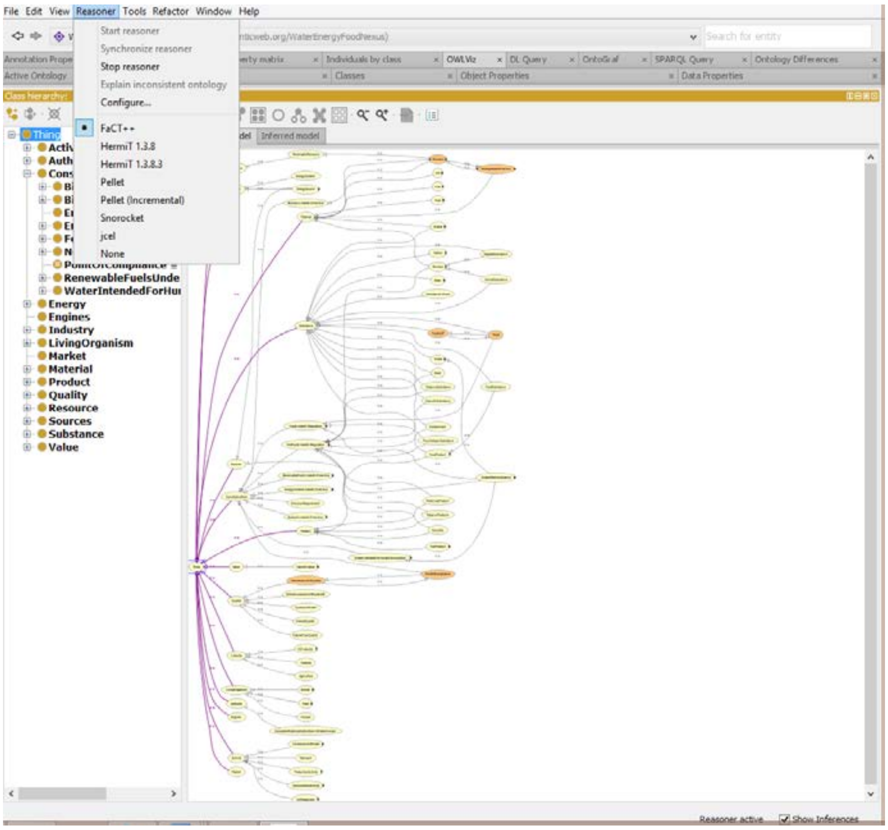



**Fig.12.** Inference check by reasoner on the specification in the legal ontology for nexus

- Inference check on the specification – total 7 built-in reasoners those are available in protégé 5 editor have been used in order to check inferences in the legal ontology for nexus. These reasoners are – FaCT++, HermiT 1.3.8 and 1.2.8.3, Pellet, Pellet (incremental), snorocket and jcel, shown in Figure 12. None of these reasoners found error in inferences, see at the right corner of the Figure 12 and it does not show any error sign. In addition Table 8 shows the summary of the evaluation -

**Table 8.** Evaluation of coherence of legal ontology for nexus

| *Questions considered for evaluation* | *Evaluative result* |
|---|---|
| Is the legal ontology for nexus coherently defined in that it is internally consistent? | Yes, the legal ontology for nexus is internally consistent. Because the manual as well as automated reasoners show that there is no error in the inferences among the interactions of total 176 concepts and sub-concepts, 36 object properties and 1 |

| | |
|---|---|
| | data-property including 31 restrictions. |
| Does the legal ontology for nexus infer a sentence from a definition that is inconsistent with another definition? | No. Every concept, property, and their relations have their own unique legal and authentic definition which does not have any conflict with other concept and relation definition. |

#### 27.2.2.3 Computationality of Legal Ontology for Nexus

The evaluation of computationality of the legal ontology for nexus has been performed by analyzing following two aspects –

- Computationality of the legislative texts – there are few referential parts of each selected legislative text that were not modeled in the legal ontology for nexus. Two of such examples are taken discussed here. First example is drawn from the second paragraph of Article 2 of Regulation (EC) no 178/2002. It says that –

  "....._**'Food'**_ includes.......... _**water**_ after the point of compliance as defined in _**Article 6 of Directive 98/83/EC**_ and without prejudice to the requirements of _**Directives 80/778/EEC and 98/83/EC**_........."

  In this legislative text, water is considered as food but only when water is in compliance with other EU Directives. Therefore, mere ontological modeling of water-food nexus by saying that 'water is a sub-class of food' does not actually representation all aspects of legislative texts and hence computationality of such ontology for nexus is incomplete. The other examples is taken from Article 2(2)(f) of Directive 2003/30/EC, which specifies as follow –

  ".....2. At least the products listed below shall be considered biofuels:........ (f) 'bio-ETBE (ethyl-tertio-butyl-ether)': ETBE produced on the basis of bioethanol. The percentage by volume of bio-ETBE that _**is calculated as biofuel is 47 %**_..........."

  The above mentioned legislative explicitly mentions that bio-ETBE can only be considered as biofuel when it contains a specific amount of ETBE that is 47%. Therefore, only putting value restriction of '47%' over a data property 'is calculated as biofuel', shown in Figure 13, does not provide complete computation-ability of the legal ontology for nexus.


**Fig.13.** Value restriction over the data property 'is calculated as biofuel'

- Computationality of legal meaning of nexus – even though there is limited computationality of legislative texts in the legal ontology for nexus, as discussed above, the computationality of the legal meaning of nexus works very efficiently. Let's consider the computationality of the term 'water intended for human consumption', shown in Figure 14.

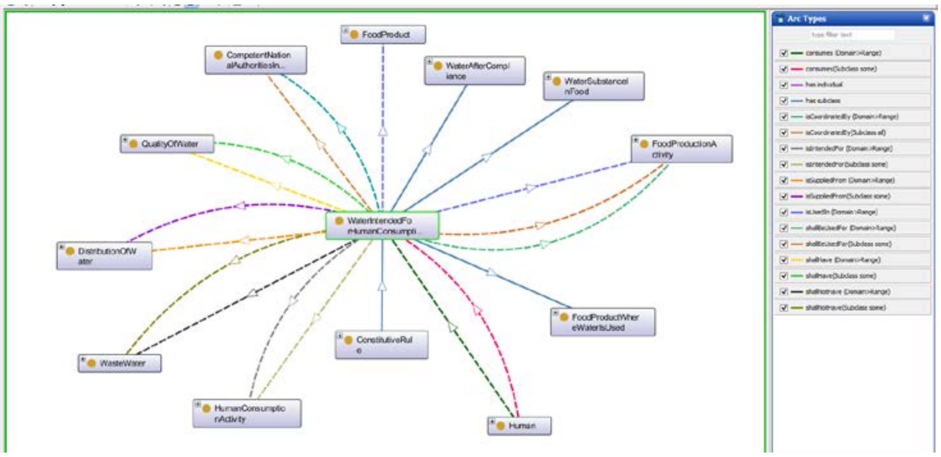



**Fig.14.** Computationality of the term 'water intended for human consumption '

It explicitly shows that both 'domain-ranges relationship' as well as 'sub-class restriction' over the terms 'water intended for human consumption' and 'food production activity' have effective computationality. Both relationships prove the same legal meaning of water and food production nexus representing that 'food production activity' shall use the water intended for human consumption. likewise, in the Figure 14, maximum of terms have double relationships with the term 'water intended for human consumption' – domain-range and sub-class restriction relationship, but indeed both of these relationships compute same legal meaning. That proves the effective computationality of the legal ontology for nexus. however, table 9 shows the summary of this evaluation.

**Table 9.** Evaluation of computation-ability of legal ontology for nexus

| *Questions considered for evaluation* | *Evaluative result* |
|---|---|
| Does the legal ontology for nexus provide a suitable basis for computational representation? | Yes except the ontological modeling of legal references given in the respective legislative texts, examples are given above. |
| Is this representation computationality adequate? | Yes. Even when 'domain-range' relationship and 'sub-class' restriction work together over a single term, computationality of legal ontology for nexus work effectively and in adequate manner. |

### 27.2.3 Reusability of Legal Ontology for Nexus

The evaluation of reusability of the legal ontology for nexus refers the examination that confirm its potentiality of being extended and reused in order to conceptualize new legal tasks, methods and sub-domains. It has been performed in two following aspects -

#### 27.2.3.1 Domain Reusability of Legal Ontology for Nexus

The primary sets of legal ontologies, those are merged in order to build legal ontology for nexus, are independent and their legal epistemological adequacies are extracted from respective EU Directives and Regulation. Therefore, their domain reusability is open and unrestricted. For example, legal ontology of 'EU legal definition of water intended for human consumption' can be independently used for retrieving water related information from WISE paltform. Likewise, other legal ontologies can be used for respective legal knowledge acquisition, legal knowledge system design, legal knowledge system documentation, automated legal reasoning as well as for legal knowledge exchange. The summary of this evaluation is shown in Table 10.

**Table 10.** Evaluation of domian reuseability of legal ontology for nexus

| *Questions considered for evaluation* | *Evaluative result* |
|---|---|
| Is the legal ontology for nexus dependent on certain type of legal sub-domains? | No. As legal ontology for nexus is a merged ontology, not an imported ontology, it is independent. Other legal ontologies of EU legal definition of water intended for human consumption, food and biofuel are independent too and entirely based on corresponding legislative texts. |

| | |
|---|---|
| To what extend is the legal ontology for nexus reusable for various legal subdomains? | At greater extend in the European environmental law domains and legal knowledge system. |

#### 27.2.3.2 Task and Method Reusability of Legal Ontology for Nexus

The legal ontology for nexus is based on legal definitional knowledge. As a result, one of its prime tasks is to represent semantic legal meaning of nexus independently, which can be further useful for various tasks in connection with legal documents and legal knowledge system. Therefore, it is designed to be capable of supporting classical assessment like straight forward matching of a problem case with necessary and sufficient conditions in definitions. In addition, as all legal ontologies, those are merged in the legal ontology for nexus, of EU legal definitions are also based on legal definitional knowledge; they are task and method independent and capable for any types of ontological reusability. Table 11 shows the summary of this evaluation -

**Table 11.** Evaluation of task and method reuseability of legal ontology for nexus

| ***Questions considered for evaluation*** | ***Evaluative result*** |
|---|---|
| Is the legal ontology for nexus dependent on certain tasks and methods? | No. Even though legal ontology for nexus is designed for representing semantic legal definitional knowledge of nexus, it is independent for any other types of ontological reuses. |
| To what extend is the legal ontology for nexus reusable for various methods and tasks? | At greater extend, because the legal ontology for nexus is a merged ontology, but not an imported ontology. |

## 28 Consistency Check Between T-Boxes and A-Boxes of Legal Ontology for Nexus using DL Query

As legal ontology for nexus is based on such legislative texts where there is no instance or individual given, a number of instances or individuals have been created in order to test the consistencies between its T-Boxes and A-Boxes using DL Query. The results of some DL Query tests over some important set of nexus related questions are given below –

**Query test 1. Nexus between Biofuel and Not-food.** The test is implemented by a number of questions. The first question is – “***Q1:Which biofuel is produced from distillers grains?”*** The class expression of DL Query for the Q1 is constructed as below –

```
Biofuel and producedFrom value distillers_grains ...(1)
```

The query result is ‘syngas’, shown in Figure 15, which is an individual of biofuel.

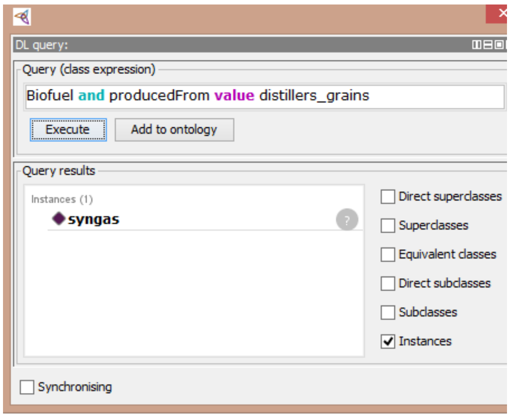



**Fig.15.** Nexus between biofuel and non-food in legal ontology for nexus **(a)**

Then the second question is – ***“Q2. Is distillers grains not food under EU Regulation but biomass as well as residue?”*** In order to get the answer, all instances of the concept ‘not food under EU Regulation’, ‘biomass’ and ‘residue’ are called by DL

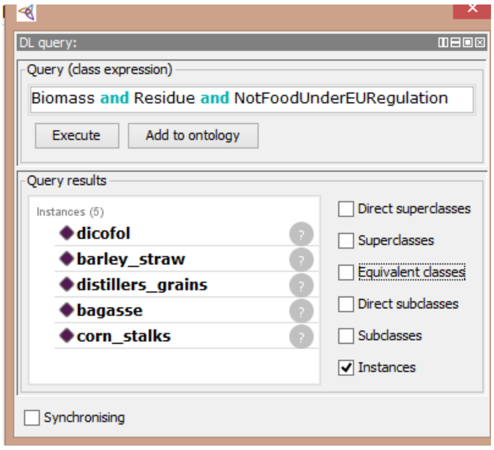



**Fig.16.** Nexus between biofuel and non-food in legal ontology for nexus **(b)**

query, the result is shown in Figure 16, where it is mentioned that distillers-grains is a type of not food under EU Regulation but it is type of biomass and residue. By using Q1 and Q2, the QL Query result proves the nexus between biofuel and not-food.

**Query test 2. Nexus between Water and Food.** For observing the ontological legal relationship between water and food, the third question considered for query is – **“Q3.**

**Which water after compliance does Ms. Agenzia Dogane consume?”** The class expression of this question in QL Query is –

```
WaterAfterCompliance and isConsumedBy value agen-
zia_dogane  ...(2)
```

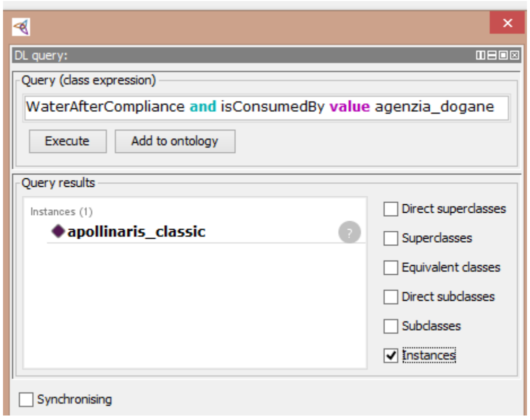



**Fig.17.** Nexus between Water and Food in legal ontology for nexus (a)

The query result is apollinaris classic, which is an instance of distribution of water in bottle, shown in Figure 17. Now the fourth question is ***“Q4. Is apollinaris classic also an instance of food product?”***

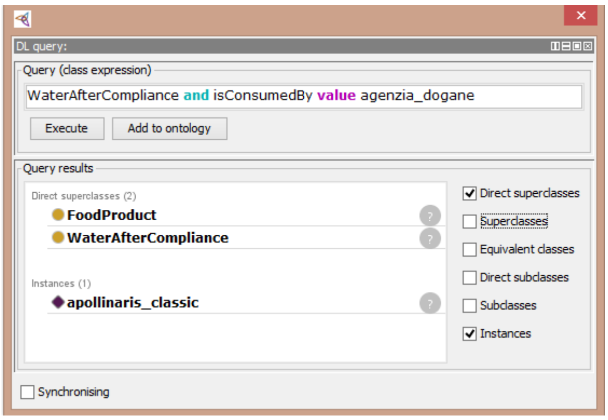



**Fig.18.** Nexus between Water and Food in legal ontology for nexus (b)

In order to get the answer, the same DL query class expression (2) is used but, this time, for finding the direct super-classes of the instance ‘apollinaris classic’. The answer is – yes apollinaris classic is also a type of food product. Hence, it establishes that nexus between water and food is clear in the legal ontology for nexus and consistent with respective legislative texts.

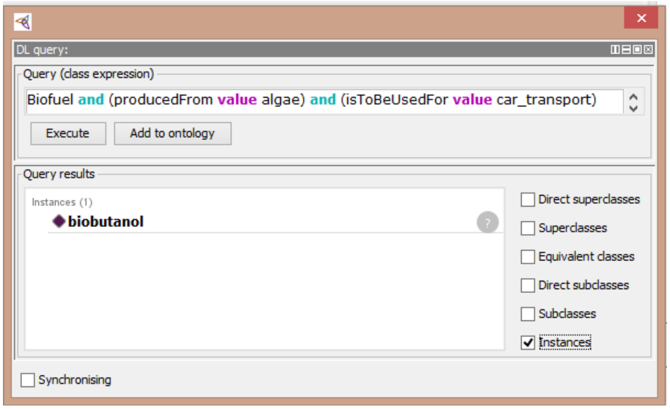



**Fig.19.** Nexus between Biofuel and Water in legal ontology for nexus (a)

**Query test 3. Nexus between Water and biofuel.** For establishing nexus between water and biofuel, the fifth question is – **"Q5. Which biofuel is produced from algae and is used for car transport?"** The class expression in DL query is –

```
Biofuel and (producedFrom value algae) and (isToBeUsedFor
value car_transport)...(3)
```

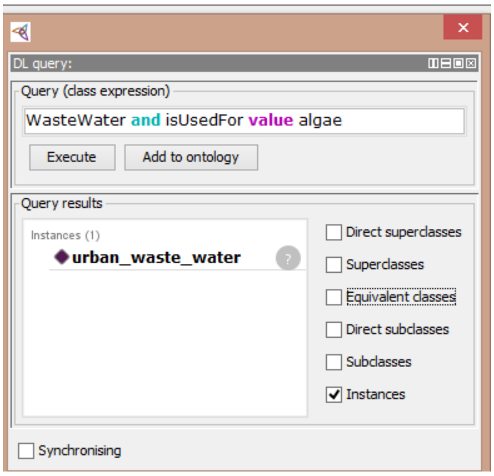



**Fig.20.** Nexus between Biofuel and Water in legal ontology for nexus (b)

In this expression, algae and car-transport are instances of residue and transport respectively. The answer, shown in Figure 19, is biobutanol, which is an instance of biofuel. That answer is completely consistent with EU definition of biofuels. However, the next question is – **"Q6. Which waste water is used for algae?"** the class expression for this question in DL query is –

```
WasteWater and isUsedFor value algae ...(4)
```

The answer is unban waste water, shown in Figure 20, which is an instance of waste water. The answers of Q5 and Q6, thus, show the nexus between biofuel and water. In addition, it also shows further relation between not-food and waste water indicating that algae is an instance of residue and therefore it is not food by law and waste water can be used for algae.

Above three DL query tests successfully evaluate following aspects of legal ontology for nexus –

(a) T-Boxes and A-Boxes in the legal ontology for nexus are consistent.

(b) Three fundamental dimensions of nexus, as described in Chapter 1, is established and proven in the legal ontology for nexus. They are – energy-food nexus, food-water energy and water-energy nexus.

## 29 Application of Legal Ontology for Nexus to the Documents

In the nutshell, the legal knowledge of nexus is embedded in the legal ontology for nexus as it is merged with three legal ontologies that represent there EU legal definitions of water interned for human consumption, food and biofuels those are written in separate as well as independent legal documents. Nevertheless, now the next step is to link and/or apply it to the nexus related documents, especially to the legal document [258,259], in order to facilitate legal reasoning of nexus, along with serving other purposes such as legal knowledge acquisition etc., over any legal knowledge system[345]. Considering this direction, this section primarily discuss about digital legal documentation, legal ontology and their relationships[346] with examples of existing nexus related legal information systems such as FAOLEX, ECOLAX, WaterLax, WISH, EurLeX, legislation.gov.uk. Furthermore, it rationalizes why legal ontology for nexus can add values to this type legal information and knowledge system.

[345] See Cervone L. Palmirani M. Peroni S. Vitali F. Barabucci, G. Multi-layer markup and ontological structures in akoma ntoso. In Proceeding of the International Workshop on AI approaches to the complexity of legal systems II (AICOL-II)., Rotterdam, The Netherlands, 2009.

[346] Jérôme David, Jérôme Euzenat, François Scharffe, and Cássia Trojahn dos Santos. The alignment api 4.0. Semantic Web – Interoperability, Usability, Applicability, 2(1):3–10, 2011.

## 29.1 Legal Document and Legal Ontology

Any legal information system used for managing and digitalizing legal documents[347], through editing, storing, signing, publishing as well as use to perform automated legal reasoning, has to deal with the meaning of internal entities and their interoperability [260,261,262], e.g. entities that exist inside of a legal document and literally those entities represent the flow of legal knowledge embedded into that document and link with other related legal knowledge that is embedded into other legal documents. For example, Article 2 of Regulation (EC) no 178/2002 mentions that –

"..............'***Food***' includes..................... ***water*** after the ***point of compliance***............."

This legislative text proves the water-food nexus as it explicitly demonstrates that all water after the point of compliance is food. However, this particular legislation does not define the meaning of water. Therefore, it is required to look for the meaning of the water in Article 2 of Council Directive 98/83/EC, where it says –

"....'***water intended for human consumption***' shall mean............. all ***water*** either in its ***original state*** or ***after treatment***.................. all ***water*** used in any ***food-production***........."

Through this example, there is a number of important issues to be consider – (a) as the legal knowledge that former legal document contains has a legal link with latter legal document, it must be interoperable with the latter legal document, (b) as Article 2 of former legal document expresses the legal definition of food and declares its legal relationship with the term 'water' which is a legal term of latter legal document, it must be communicate to the rest of the same document as well as to the latter legal document in order to establish the legal semantic relationship between 'food' and 'water' nexus. Both of these conditions are needed to be implemented in order to promote automated legal reasoning of nexus between these two isolated legal documents. In order to do so, all the needed legal ontological information must be stored in such way that is connected with respective legal documents, semantically interoperable among the documents, understandable by the machine as well as computable by the system. In this scenario, legal ontology for nexus can play an important interoperable role among all legal and Para-legal documents of water, energy and food domains. However, as formats and methodologies for digitalizing legal documents of water, energy and food domains are becoming widespread and standardized; it is noteworthy to understand exiting legal information systems of water, energy and food domains, especially how legal documents are digitalized in their legal information

[347] One of such works described in Palmirani, M., Benigni, F.: Norma-system: A legal information system for managing time. In: Proceedings of the V Legislative XML Workshop, 2007, 205-224

systems and their scopes for incorporating legal ontology for nexus into their internal architecture[348].

### 29.1.1 Akoma Ntoso, Legal Document and Legal Ontology

One of the most prominent formats for digitalizing legal documents is Akoma Ntoso[349], an open XML standard for parliamentary, legislative and judicial documents. Akoma Ntoso become an useful format for drafting legislation and legal data storage in general for every moments of the legal document life-cycle. This standard makes a clear distinction between legal texts, structure, metadata and ontological information engineered for using on the top of such metadata. Each of these layer works with specific technical solutions. The text layer provides extract representation of the original legislative texts in conjunction with representing entire legal document. The structure layer delivers hierarchical organization of different parts of the legal documents. The metadata layer provides inherent information about the legal document as well as it is enriched with ontological information in order to serve semantic data as a legal-linked data and semantic tool as to perform automated legal reasoning on them[115][134][144].

The metadata layer of Akoma Ntoso based legal document is the place where legal ontology for nexus can play its role as legal-linked data for nexus as well as to as a semantic tool in order to execute legal reasoning of nexus over the legal open documents as well as legal open linked data [262].

In addition, it is noteworthy to mention that one of the most important features of the Akoma Ntoso metadata layer is that it has the capability to store multiple interpretations of the same legal texts, even if some of the legal interpretations are conflicting with each other. This particular feature makes Akoma Ntoso based legal documents rich with interpretative legal knowledge of any particular legal document. This also provides following, not limited to, technical advantages to the legal ontology for nexus –

[348] The necessity of ontology merging and alignment is discussed in Jaehong Kim, Minsu Jang, Young-Guk Ha, Joo-Chan Sohn, and Sang Jo Lee. Moa: Owl ontology merging and alignment tool for the semantic web. In Proceedings of the 18th international conference on Innovations in Applied Artificial Intelligence, IEA/AIE'2005, pages 722–731, London, UK, UK, 2005. Springer-Verlag. Legal ontology for nexus also can be used for managing complexities of nexus domains, see Palmirani, M., Ceci, M.: Ontology Framework for Judgement Modelling. In: AI Approaches to the Complexity of Legal Systems. Models and Ethical Challenges for Legal Systems, Legal language and Legal Ontologies, Argumentation and Software Agents, LNCS vol. 7639, Springer, Berlin, 2012, 116-130.

[349] The XML schemas of Akoma Ntoso make explicit the structure and semantic components of the digital documents so as to support the creation of high value information services that deliver the power of ICTs and increase efficiency and accountability in parliamentary, legislative and judiciary contexts. For more detail, see http://www.akomantoso.org/

- Potential extendibility[350] – other legal ontology engineers can also contribute their versions of legal ontology for nexus to the same legal and para-legal documents where this legal ontology for nexus will be used.
- Furthermore this particular legal ontology for nexus can be extended with adding legal parametric values of different terms without changing its existing ontological construction. For example, the term 'quality of water' can be extended with the parametric values given in the Annexes of Council Directive 98/83/EC. That might enhance its usability as well as reusability at greater extend.

Furthermore, in order to use Akoma Ntoso based legal documents of nexus domains as a knowledge base for legal reasoning tool for nexus, all explicit and implicit resources inside the legislative texts of a legal document must be precisely marked, identified and classified. As classification of these resources is non-trivial task[351], it requires legal shared vocabulary or legal linked-data for nexus. This is another good reason in favor of having such legal ontology for nexus. This interoperability feature of the legal ontology for nexus can also enhance query system for nexus in both – national, regional and foreign nexus related datasets like WISE, FaoLex etc.

### 29.2 Few Legal Information Systems Related with Nexus and In Where Legal Ontology For Nexus Can Add Value

More particularly, the legal ontology for nexus can add such values, as discussed above, to the following existing legal information systems related with nexus domain -

**FAOLEX.** is the world's largest legal information system containing electronic collection of international, regional as well as national laws and regulations on agriculture, food and renewable resources, implemented by FAO legal office. It provides direct access to the indexing information as well as abstracts of all available legislative documents that contained in the database.

**ECOLEX.** is an internet based legal information service system on environmental laws and polices jointly coordinated by UNEP, IUCN and FAO. Its databases include environmental regulations related with multilateral and bilateral treaties, national legislations, EU legal instruments, judicial decision, soft and hard law and policy literature of water, food, renewable energy resources and other related documents. The database of FAOLEX has been progressively integrating into ECOLEX.

[350] See Jérôme Euzenat and Pavel Shvaiko. Ontology matching. Springer-Verlag, Heidelberg (DE), 2007.

[351] See Sylvie Despress and Sylvie Szulman. Merging of legal micro-ontologies from europen directives. Artif. Intell. Law, 15(2):187–200, June 2007 and Aldo Gangemi, Maria-Teresa Sagri, and Daniela Tiscornia. A constructive framework for legal ontologies. In Law and the Semantic Web, pages 97–124, 2003.

**WaterLex Legal Database.** is a dynamic online platform that contains laws and regulations related with water-governance managed and ensured by WaterLex Database Scientific Committee (WDSC), which comprises with a number of academic institutions like School of Law, New York University, Asia-Pacific Centre for Environmental Law of National University of Singapore. This legal database also contains all database exist in FAO, IUCN and ECOLEX. This project is supported by Swiss Agency for Development and Cooperation and Swedish International Development Cooperation Agency and designed with a crowd-souring approach that enables academic, practitioners and law makers the possibility to feed related documents into the database.

**WISE (Water Information System for Europe).** is partnership between EU DG Environment, Joint Research Center, Eurostat and European Environment Agency, known as 'the Group of Four'. It collects electric versions of all office national, local and regional reports covered by EU water legislations; subsequently it provides environment monitoring and water resources modeling including forecasting services. Additionally Eurostat, as a part of WISE, collects and disseminates water related statistics and enhance the development of water related GIS as a part of WISE.

**Eur-Lex and N-Lex.** Provides XML based EU laws, EU Official Journal, treaties as well as EU case-laws. It also contains international agreements, EFTA documents and other official public documents. It also helps to follow the procedures of EU legislation making process. In addition, N-Lex provides multi-lingual access to the EU national laws supported by Eur-Lex existing platform and technical structure. This legal information system contain a vast XML-based collection of nexus related regional, national and international laws and other related official documents.

**Legislation.gov.uk.** is known as XML based official home for revised and enacted UK legislations from 1267 to the present time. This also uses a light ontology based on Functional Requirements for Bibliographic Records (FRBR) that helps to categorize following distinctions –legislation and/or a legal document is defined as a work, the expression of such work is based on different versions of the legislation, different publishing formats express manifestations while item is considered when a copy of such legal document is made. Furthermore, it carries a vast number XML based legal documents related with nexus.

Considering these nexus domains related legal information systems, it is not yet evident that they use their legal information system for performing automated legal reasoning. On the one hand, from the Akoma Ntoso standard point of view, FAOLEX, ECOLEX, WaterLex and WISH are still working at the text and structural layers. However, it is evident that each of these legal information systems have been continuously making afford in order to transform their technical capacity to handle metadata layer of legal documentation. On the other hand, Eur-Lex, N-Lex and Legislation.gov.uk, already have such technical structure in order to handle metadata layers of legal documents and a vast collection of XML based legal documents related with nexus and therefore legal ontology for nexus can play an important role for detecting nexus into their existing legal information systems. However, none of these legal information systems has technical capability to deal with LegalRuleML standard, which will be technically required in order to use legal ontology for nexus for automated legal reasoning of nexus on any legal information systems.

### 29.3 Annex 2 of EU Notice no 2012/C 325/02[352] and the Legal Ontology for Nexus

The importance of establishing interoperability among legal documents though using metadata and ontology for describing internal properties that a legal document contains is mentioned in Annex 2 of EU notice 2012/C 325/02, which specifically says that

"*..... (2) Properties describing each legislative act*

*While a structured URI can already identify acts using a set of defined components, the attribution of additional metadata established in the framework of a shared syntax will set the basis to promote interchange and enhance interoperability between legal information systems. By identifying the metadata describing the essential characteristics of a resource, Member States will be able to reuse relevant information processed by others for their own needs, without having to put into place additional information systems........................"*[353]

and

"*...........Ontology is an 'explicit, formal specification of a shared conceptualisation' and represents a formal description of a set of concepts and the relationships in a given domain. By describing the properties of legislation and their relationships between different concepts, a shared understanding is made possible and ambiguities between terms can be avoided. Being a formal specification, it is directly machine-processable............."*[354]

[352] EU Council's conclusions inviting the introduction of the European Legislation Identifier (ELI)(2012/C 325/02) as a form of Notices from European union Institutions, Bodies, Offices and Agencies, published in EU Official Journal on 26.10.2012
[353] Ibid
[354] Ibid

This above legislative text precisely emphasis the potential of legal ontology[355] for nexus as a semantic carrier of legal knowledge of nexus and also for establishing legal pattern based knowledge system[356] for nexus.

# Conclusion, Critical Issues and Future Work

Following the discussion of Chapter 1, nexus perspective backed by process philosophy is likely to shape the institutional arrangements for implementing water, energy and food domains related policies and laws collectively in coming years. Strategic thinking, in order to merge bottom-up approach and forward-thinking, over the nexus issues needs to be guided by hybrid reasoning where conflicting legal, technical, social rules can be resolved. Sustainable development, as mentioned in UN Resolution 70/1 of 2015, and EU digital city initiatives require using innovation and technology for detecting nexus in real time and space as well as to reduce the knowledge gaps that exist in the nexus domains. In order to do so, a legal knowledge framework for nexus is proposed where legal ontology for nexus is intended to play intermediate role, but not limited to, between digitalized legal documentation, e.g. using Akoma Ntoso standard, and hybrid or legal reasoning tool, e.g. using LegalRuleML standard, for nexus. Nevertheless, legal ontology for nexus can also be independently useful to promote interexchange and enhance interoperability between existing legal information systems related with nexus domains, e.g. FAOLEX, ECOLEX etc. In order to construct legal ontology for nexus, chapter 1 also investigated EU legislations and cases laws related with water, food and energy domains and found a legal shared meaning for nexus in combined form of Article 2 of EU Directive 98/83/EC, which defines water intended for human consumption, EU Regulation 178/2002, which defines food, and EU Directive 2003/30/EC, which defines biofuel. Subsequently, the legislative texts of these said EU legal definitions are used for engineering legal definitional knowledge that is formalized in the legal ontology for nexus.

As engineering legal knowledge for modeling ontology as a research domain has been growing faster for last two decades, it was a challenging demand under considered study to find out right perspective and methodology for construing legal ontology for nexus and the evaluative criteria for it, which turned as a need for this research. This particular need has been fulfilled by examining current start of art of legal ontology and successfully presented in chapter 2. This examination has been performed at two stages. Firstly two sets of evaluative criteria have been developed for twofold purpos-

[355] See Sartor, G., Palmirani, M., Francesconi, E., Biasiotti, M. A. (eds): Legislative XML for the Semantic Web: Principles, Models, Standards for Document Management. In: Law, Governance and Technology Series, Vol. 4, Springer 2011.

[356] See Aldo Gangemi. Introducing pattern-based design for legal ontologies. In barabucci, editor, Proceedings of the 2009 conference on Law, Ontologies and the Semantic Web: Channelling the Legal Information Flood, pages 53–71, Amsterdam, The Netherlands, The Netherlands, 2009. IOS Press.

es – (a) to set standard criteria for construing legal ontology for nexus, and (b) to evaluate current legal ontology modeling perspectives and methodologies in order to find the correct one used for this research purpose. These two sets of criteria are based on knowledge acquisition, which is mainly consisted with explicit and implicit knowledge acquisitions, and ontology construction, which is mainly consisted with legal epistemological adequacy, operationality and reusability, aspects of legal ontology for nexus. Secondly, evaluation of existing methodologies of constructing legal ontology has been performed using the criteria set earlier of this chapter. On the one hand, after examining eight different perspectives of legal ontology, e.g. cognitive science, legal theory, legal service science perspectives etc., the study found that legal documentation perspective supports legal ontology for nexus to be used as intermediate between digitalized legal documentation and their corresponding reasoning tool as well as to facilitate interexchange and interoperability between and within the legal information systems. On the other hand, after examining fourteen methodologies used for constructing legal ontology, the study found there is no single methodology that fulfills the standard criteria developed for legal ontology for nexus. Therefore, the findings in chapter 2 led the necessity to develop a new and modular based methodology for legal ontology for nexus which is presented with details in chapter 3. Following that newly developed methodology, the legal ontology for nexus has been construed with total 176 concepts and sub-concepts, 37 object-properties and 1 data-property corresponding with 32 restrictions. It also contains 850 annotation axioms and 313 logical axioms. The automated reasoners found no error in the legal ontology for nexus, the detail of which is explained in chapter 4 and its evaluation is demonstrated in chapter 5.

However, throughout this legal knowledge engineering works, following critical issues have been encountered –

**Multiple terms of the same concept.** For example, 'QualityOfWater', 'WaterAfterCompliance', 'WaterAfterTretment','FoodUnderEURegulation' – these all terms are different expressions of one concept – 'WaterIntendedForHumanConsumption'.

**Same term with different semantic usages.** For example, semantic usage of the term 'Biomass' given in *Article 2 of EU Regulation 178/2002/EC* has different semantic uses in *Article 2 of EU Directive 2003/30/EC.* In the former legislation, it is used as 'NotFoodUnderEURegulation' but, in the latter legislation, it is used as a source of 'BiofuelsUnderEUDirective'.

**Interdepended enumeration.** For example, the enumerations of *Article 2 of EU Directive 2003/30/EC* and *EU Regulation 178/2002/EC* are interdepended by a major term 'Biomass' with same meaning but different semantic usages and legislative sources.

**Implicit constitutive terms.** For example, 'WaterUsedInBiomass' is not defined neither in Article 2 of *EU Regulation 178/2002/EC* nor in *EU Directive 2003/30/EC,* nor in *EU Directive 98/83/EC.* But without establishing legal meaning of this term, it is not legally possible to construct water and biofuels nexus under the existing setting of these legal definitions.

**Multiple sources of legal exceptions with different legislative values.** For example, *Article 2* of *EU Directive 2003/30/EC* indicates that 'BiofuelsUnderEUDirective' is when it is used for transportation purposes and made out of 'Biomass', whereas *Article 2 of EU Regulation 178/2002/EC* establishes that 'Biomass' is 'NotFoodUnderEURegulation'. Hence the sources of exceptions on 'Biomass' are multiple and from different hierarchies of legislation as Directive and Regulation has different legislative value.

**Ontological limitation of modeling constitutive rules.** In this ontology, term and property extracted from the legislative texts have been used in order to provide some kind of restrictions over the constitutive rule, shown in restriction R27. That is not sufficient and/or enough in order to compute or model properly the constitutive rules, because of following reasons –

- Constitutive rule works like a legal loop with two circuits. If one circuit generates activities, the other legally justifies it and vice versa (*see section 20.1, 21.1 and 22.1 of chapter four*).
- The source of legislative texts for modeling constitutive rule is multiple and often involve with various level of legislative hierarchy (*see section 19.3 of chapter four*).
- From the nexus perspective, it requires to handle complex mathematical calculation. For example, in order to model the constitutive rule 'WaterIntendedForHumanConsumption', it must correspond with water quality compliance given in the Annexes of *EU Directive 98/83/EC,* which often involve with the mathematical values of certain parameters. These values fluctuate with the application of legal rules coming from different legislative texts.
- Legal validity of constitutive rules often involve with the validity of sources and hierarchies of legal rules, which is difficult to model.

However, in the current structure of OWL 2 full, it is not possible to construct such interactive rules. Hence further technical investigation is required. This motivates to look for other technological solution like LegalRuleML for modeling constitutive rules. In addition, in future, the scope of reusability of legal ontology for nexus can be enhanced by adding parametric values of water quality as it is described in detail in the annexes of EU Directive 98/83/EC. Then it would be also useful in order to facilities nexus detection, from legal point of view, through geographic information systems, stateliest and sensor technologies in real space and time.

## References.


1. Beisheim, M.: The Water, Energy and Food Security Nexus: How to Govern Complex Risks to Sustainable Supply? SWP Comments 32. Berlin, German Institute for International and Security Affairs (SWP) (2013)
2. Bonn2011 Nexus Conference: Messages from the Bonn 2011 Conference: The Water, Energy and Food Security Nexus – Solutions for a Green Economy, http://www.water-energy-food.org/en/conference.html (2012)
3. Glassman, D., Wucker, M., Isaacman, T. and Champilou, C.: The Water-Energy Nexus: Adding Water to the Energy Agenda. In: World Policy Papers. New York/Zurich, USA/Switzerland, World Policy Institute (WPI)/EBG Capital (2011)
4. Sperling, F. and Bahri, A.: Powering Africa's Green Growth: The importance of Water-Energy Nexus. In: Presentation at the 5th Africa Water Week, Dakar, Senegal (2014)
5. UNECE (United Nations Economic Commission for Europe): Alazani/Ganikh River Basin Water-Food-Energy-Ecosystems Nexus assessment. In: Unpublished first draft report for comments by the concerned authorities. Prepared by the (KTH, Stockholm) under the supervision of the UNECE Water Convention Secretariat (2014)
6. Wang, J., Rothausen, S., Conway, D., Zhang L., Xiong, W., Holman, I. and Li, Y.: China's water–energy nexus: Greenhouse-gas emissions from groundwater use for agriculture. Environmental Research Letters, 7014035 (2012)
7. WWAP (World Water Assessment Programme): The United Nations World Water Development Report 2014: Water and Energy. Paris, UNESCO (2014)
8. WWF (World Wide Fund For Nature): Living Planet Report 2012: Biodiversity, Biocapacity and Better Choices. Gland, Switzerland, WWF international (2012)
9. Zekri, S., Karimi, A. and Madani, K.: Groundwater Policing for a Sustainable Food Supply in Oman. In: Paper delivered to the 41st International Association of Hydrologists (IAH) Congress: Groundwater: Challenges and Strategies. Moroccan Chapter. 15-19, Marrakech (2014)
10. Jiménez Cisneros, B.E., Oki, T., Arnell, N.W., Benito, G., Cogley, J.G., Döll, P., Jiang, T. and Mwakalila, S.S.: Freshwater resources. Intergovernmental Panel on Climate Change (IPCC), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the IPCC, pp. 229-269. Cambridge University Press, Cambridge/New York, UK/USA (2014)
11. World Economic Forum Water Initiative, Water Security: The Water-Food-Energy-Climate Nexus (2011)

12. Naylor, R. L.: Managing food production systems for resilience, in F. S. Chapin, G. P. Kofinas, and C. Folke (Eds), Principles of Natural Resource Stewardship: Resilience-Based Management in a Changing World, Springer, New York (2008)
13. Gerten D., Heinke H., Hoff H., Biemans H., Fader M., Waha K.: Global water availability and requirements for future food production, Journal of Hydrometeorology, 12, pp. 885-899 (2011)
14. Grey D., Sadoff C.W.: Sink or swim? Water security for growth and development, Water Policy, 9, pp. 545-571 (2007)
15. Boyle Works, The Works of Robert Boyle, Hunter, M., and Davis, E. B. (eds.), 14 vols., London: Pickering and Chatto (1999–2000)
16. Bazillian, M., and others: Considering the energy, water and food nexus: towards an integrated modeling approach. Energy Policy, vol. 39, pp. 7896-7906 (2012)
17. Carrillo, A.M.R. and C. Frei.: Water: a key resource in energy production. Energy Policy, vol. 37, No. 11, pp. 4303–4312 (2009)
18. Hulbert, M.: Chindia: Asia's energy challenge. Public Policy Research, vol. Nov-Dec, pp. 152-156 (2010)
19. Bickhard, M.: Process and Emergence: Normative Function and Representation, Axiomathes, 14(3): pp. 135–169 (2004)
20. Campbell, R.: A process-based model for an interactive ontology, Synthese, 166 (3): pp. 453–477 (2009)
    ––– The emergence of action, New Ideas in Psychology, 28(3): pp. 283–295 (2010)
    ––– The Concept of Truth, Basingstoke: Palgrave MacMillan (2011)
21. Whitehead, A. N.: An Enquiry Concerning the Principles of Natural Knowledge, Cambridge: Cambridge University Press; reprinted New York: Kraus Reprints, 1982 (1919)
    ––– The Concept of Nature, Cambridge: Cambridge University Press (1920)
    ––– The Principle or Relativity, Cambridge: Cambridge University Press (1972)
    ––– Science and the Modern World, New York: Macmillan (1925)
    ––– Religion in the Making, New York: Macmillan (1926)
    ––– Process and Reality: An Essay in Cosmology, New York: Macmillan. Critical edition by D. R. Griffin and D. W. Sherbourne, New York: Macmillan (1929)
    ––– Symbolism: Its Meaning and Effect, New York: Macmillan; reprinted New York: G. P. Putnam's Sons (1927)
    ––– The Function of Reason, Boston: Beacon Press (1929)
    ––– Adventures of Ideas, New York: Macmillan (1933)
    ––– Nature and Life, Cambridge: Cambridge University Press (1934)
    ––– Modes of Thought, New York: Macmillan (1938)
    ––– Essays in Science and Philosophy, New York: Philosophical Library (1948)
22. Nichols, S., Stich, S., Leslie, A. and Klein, D.: Varieties of Off-Line Simulation. In P. Carruthers and P. Smith (eds.). Theories of Theories of Mind, pp. 39–74. Cambridge University Press, Cambridge, UK (1996)
23. Sellars, W.: Empiricism and the philosophy of mind. In Science, Perception and Reality. London and New York, Routledge & Kegan Paul, 1963, pp. 127–96 (1956)
24. Weber, M. (ed.): After Whitehead: Rescher on Process Metaphysics, Frankfurt: Ontos Verlag (2004)
25. Jensen, Michael C., and William H. Meckling. The Nature of Man. Journal of Applied Corporate Finance 7, no. 2 (summer 1994): pp. 4–19. Reprinted in Michael C. Jensen, Foundations of Organizational Strategy, Harvard University Press (1998)

26. Jensen, Michael C. Self-interest, Altruism, Incentives, and Agency Theory. Journal of Applied Corporate Finance 7, no. 2 (summer 1994): pp. 40–45. Reprinted in Michael C. Jensen, Foundations of Organizational Strategy, Harvard University Press (1998)
27. Frank H. Easterbrook, Arbitration, Contract, and Public Policy, in Arbitration 1991: The Changing Face of Arbitration in Theory and Practice, Gladys W. Gruenberg eds. BNA Books (1992)
28. Bainbridge, Stephen M., The Board of Directors as Nexus of Contracts: A Critique of Gulati, Klein & Zolt's 'Connected Contracts' Model: UCLA, School of Law Research Paper No. 02-05. Available at SSRN: http://ssrn.com/abstract=299743 or http://dx.doi.org/10.2139/ssrn.299743 (2002)
29. Gunnar Eliasson, The Theory of the Firm and the Theory of Economic Growth: An Essay on the Economics of Institutions, Competition, and the Capacity of the Political System to Cope with Unexpected Change. In: Evolutionary and Neo-Schumpeterian Approaches to Economics (ed) Lars Magnusson, pp. 173. Kluwer Publishers, Boston (1993)
30. Thomas W. Dunfee and Thomas J. Donaldson, Untangling the Corruption Knot: Global Bribery Viewed through the Lens of Integrative Social Contract Theory. In: The Blackwell Guide to Business Ethics, ed. Norman Bowie, pp. 64. Blackwell Publishers, Oxford (2002)
31. Oscar A. Gómez S., Des Gasper, Yoichi Mine: Good practices in addressing human security through Human Development Reports. Report prepared for the Human Development Report Office, UNDP (2013)
32. UNDP Human Development Report 1994, New Dimensions of Human Security, New York, UNDP (1994)
33. Richard Jolly and Deepayan Basu Ray, The Human Security Framework and National Human Development Reports: A Review of Experiences and Current Debates, NHDR Occasional Paper 5, New York: Human Development Report Office, UNDP (2006)
34. Dar O. A., Khan M. S. Millennium development goals and the water target: Details, definitions and debate. Tropical Medicine & International Health, 16: pp. 540–544, doi:10.1111/j.1365-3156.2011.02736.x. (2011)
35. McGraw, George S. Defining and Defending the Right to Water and its Minimum Core: Legal Construction and the Role of National Jurisprudence, Loyola University Chicago International Law Review vol. 8, No. 2, pp. 127-204 (2011)
36. World Bank: Climate Change and the World Bank Group – Phase I: An Evaluation of World Bank Win-Win Energy Policy Reforms. World Bank and IEG (Independent Evaluation Group) Report (2009)
37. Everett, Robert; Boyle, Godfrey; Peake, Stephen and Ramage, Janet eds.: Energy Systems and Sustainability: Power for a Sustainable Future (2nd ed.). Oxford: Oxford Univerity Press (2012)
38. Maxwell, Daniel G.: Measuring food insecurity: the frequency and severity of coping strategies. Food Policy 21 (3): pp. 291–303, doi:10.1016/0306-9192(96)00005-X (1996)
39. Food and Agriculture Organization: The Right to Food in International Law, Critical Issues in Realising the Right to Food in South Africa, prepared by Margret Vidar, Socio-Economic Rights Project of the Community Law Centre, University of the Western Cape (2003)
40. Henry Mintzberg: Crafting Strategy, Harvard Business Review, 65(4), pp. 66-75, (1987)
41. Liedtka, J.: Linking strategic thinking with strategic planning, Strategy and Leadership, October, (1), pp. 120-129 (1998)
42. Fiona Graetz: Strategic thinking versus strategic planning: towards understanding the complementarities, Management Decision, vol. 40 Iss: 5, pp. 456 – 462 (2002)

43. Batty, M.; et al.: Smart Cities of the Future. European Journal of Physics Special Topics 214: pp. 481–518. doi:10.1140/epjst/e2012-01703-3 (2002)
44. Solanas, A.; Patsakis, C.; Conti, M.; Vlachos, I.; Ramos, V.; Falcone, F.; Postolache, O.; Perez-Martinez, P.; Pietro, R.; Perrea, D.; Martinez-Balleste, A.: Smart health: A context-aware health paradigm within smart cities. IEEE Communications Magazine 52 (8): pp. 74. doi:10.1109/MCOM.2014.6871673 (2014)
45. Fusco, Girad L., Lombardi, P., Nijkamp, P.: Creative Urban Design and Development (special issue). In: International Journal of Services Technology and Management, vol. 13, No. 2/3/3, pp. 111-115 (2009)
46. Komninos, N.: The Architecture of Intelligent Cities, Intelligent Environments 06, Institution of Engineering and Technology, vol. 1, pp. 13-20 (2006)
47. Komninos, N. and Schaffers, H. (eds): Smart Cities and the Future Internet in Europe, Journal of the Knowledge Economy, vol. 3, No 3 (2012)
48. Angelidou, M.: Smart city policies: A spatial approach. Cities, 41, pp. 3-11. doi: 10.1016/j.cities.2014.06.007 (2014)
49. Dept Business: Smart cities – background paper. UK Government Department for Business, Innovation and Skills (2013)
50. Blewitt, John: Understanding Sustainable Development (Second ed.). Routledge (2015)
51. Rogers, P., K.F. Jalal, and J.A. Boyd: An Introduction to Sustainable Development. Routledge, ISBN 1844075214 (2007)
52. Donella H. Meadows, et al. Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind, New American Library, ISBN 0-451-13695-0 (1977)
53. Donella H. Meadows, Jorgen Randers and Dennis L. Meadows Limits to Growth-The 30 year Update, ISBN 1-931498-51-2 (2004)
54. Donella H. Meadows: Thinking in Systems - A primer (Earthscan) ISBN 978-1-84407-726-7 (2008)
55. Atkinson, G., Dietz, S. & Neumayer, E.: Handbook of Sustainable Development. Cheltenham: Edward Elgar Publishing, ISBN 978-1-84376-577-6 (2007)
56. Costanza, R., Graumlich, L.J. & Steffen, W. (eds): Sustainability or Collapse? An Integrated History and Future of People on Earth. Cambridge, MA.: MIT Press, ISBN 978-0-262-03366-4 (2007)
57. Liam Magee, Andy Scerri, Paul James, James A. Thom, Lin Padgham, Sarah Hickmott, Hepu Deng, Felicity Cahill: Reframing social sustainability reporting: Towards an engaged approach. Environment, Development and Sustainability 15 (1): pp. 225–43 (2013)
58. Blackburn, W.R.: The Sustainability Handbook. London: Earthscan, ISBN 978-1-84407-495-2 (2007)
59. Komiyama, Hiroshi; Kraines, Steven Benjamin: Vision 2050: Roadmap for a Sustainable Earth. Springer, Berlin, ISBN 4-431-09430-X (2008)
60. Rogers, P., K.F. Jalal, and J.A. Boyd: An Introduction to Sustainable Development. Routledge (2007)
61. Cox, Robert: Global Restructuring: Making Sense of the Changing International Political Economy. In Richard Stubbs and Geoffrey Underhill, eds. Political Economy and the Changing Global Order, pp. 45-59. St. Martin's Press, New York (1994)
62. Scholte, Jan Aart: The Globalization of World Politics. In J. Baylis and S. Smith, eds. The Globalization of World Politics: An Introduction to International Relations, pp. 13-30. OUP, Oxford (1997)
63. Fischer, Stanley: Globalization and Its Challenges. American Economic Review, vol. 93-#2, pp. 1-30 (2003)

64. Held, David and Anthony McGrew, editors: The Global Transformations Reader. Oxford: Blackwell (2000)
65. Perraton, Jonathan, David Goldblatt, David Held, and Anthony McGrew: The Globalisation of Economic Activity. New Political Economy, vol. 2-#2, pp. 257-277 (1997)
66. Held, David: Regulating Globalization. In D. Held and A. McGrew, eds. The Global Transformations Reader, pp. 420-430. Polity, Cambridge (2000)
67. Marin, Dalia; Verdier, Theirry: Globalization and the empowerment of talent. Journal of International Economics 86 (2): pp. 209–223, doi:10.1016/j.jinteco.2011.10.005 (2012)
68. Johnson, D. L.; Ambrose, S. H.; Bassett, T. J.; Bowen, M. L.; Crummey, D. E.; Isaacson, J. S.; Johnson, D. N.; Lamb, P.; Saul, M.; Winter-Nelson, A. E.: Meanings of Environmental Terms. Journal of Environmental Quality 26 (3): pp. 581–589. doi:10.2134/jeq1997.00472425002600030002x (1997)
69. McCornick, P. G., Awulachew, S. B., & Abebe, M.: Water–food–energy–environment synergies and tradeoffs: Major issues and case studies. Water Policy, 10: Supplement 1, pp. 23–36 (2008)
70. Swanson, D. A., Barg, S. Tyler, S. Venema, H. D., Tomar, S., Bhadwal, S., Nair, S., Roy, D., & Drexhage, J.: Seven tools for creating adaptive policies. Technological Forecasting & Social Change 77, pp. 924–939 (2010)
71. Thirlwell G. M., Madramootoo, C. A. & Heathcote, I. W.: Energy–water nexus: Energy use in the municipal, industrial, and agricultural water sectors. Developed for the Canada–U.S. Water Conference, Washington D.C. October 2, 2007. Guelph, Ontario, Canada: Graduate Studies, University of Guelph; Montreal: Brace Centre for Water Resources Management, McGill University; Montreal: Faculty of Agricultural and Environmental Sciences, McGill University (2007)
72. Waughray, D. (Ed.): Water security—The water–food–energy–climate nexus. Washington, D.C.: Island Press (2011)
73. Hussey, K and J. Pittock.: The Energy–Water Nexus: Managing the Links between Energy and Water for a Sustainable Future. Ecology and Society, vol. 17(1): 31 (2012)
74. OECD: Water, Energy and Agriculture: Meeting the Nexus Challenge, OECD, Paris (2011)
75. World Bank: The Water-Energy-Food Nexus, A new approach in support of food security and sustainable agriculture, Food and Agriculture Organization of the United Nations Rome (2014)
76. EC (European Commission): World Energy Technology Outlook- 2050 - WETO H2. EUR 22038. Luxembourg: Office for Official Publications of the European Communities (2007)
77. Pimentel, D.: Energy Inputs in Food Crop Production in Developing and Developed Nations. Energies 2, pp. 1-24 (2009)
78. Dobbs R et al: Resource Revolution: Meeting the World's Energy, Materials, Food, and Water Needs. Seoul: McKinsey Global Institute (2011)
79. Jain, H.K.: The Green Revolution: History, Impact and Future (1st ed.). Houston, TX: Studium Press, ISBN 1-933699-63-9 (2010)
80. Chapman, Graham P.: The Green Revolution. The Companion to Development Studies, pp. 155–9. Arnold, London (2002)
81. Ponting, Clive: A New Green History of the World: The Environment and the Collapse of Great Civilizations, pp. 244, ISBN 978-0-14-303898-6. Penguin Books, New York (2007)
82. Olivier De Schutter, Gaëtan Vanloqueren. The New Green Revolution: How Twenty-First-Century Science Can Feed the World Solutions 2(4): pp. 33-44 (2011)
83. Cordell, D., J.O. Drangert, S. White: The story of phosphorus: Global food security and food for thought. Global Environmental Change 19(2), pp. 292-305 (2010)

84. World Economic Forum WEF: Global risks 2011. 6th Edition. World Economic Forum, Cologne/Geneva (2011)
85. Mitchell, D.: A Note on Rising Food Prices. World Bank Policy Research Working Paper no. 4682. World Bank, Washington, DC. Schneider, S.H., S. Semenov, A. Patwardhan, I. Burton, C.H.D. Magadza, M. Oppenheimer, A.B. Pittock, A. Rahman, J.B. Smith, A. Suarez, F. Yamin, 2007. Assessing key vulnerabilities and the risk from climate change. Climate Change 2007: Impacts, Adaptation and Vulnerability. In Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, C.E. Hanson (eds.), Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, pp. 779-810. Cambridge University Press, Cambridge, UK (2008)
86. Klare M T: The Race for What's Left: The Global Scramble for the World's Last Resources. New York: Metropolitan Books (2012)
87. Bazillian M et al: Considering the energy, water and food nexus: towards an integrated modeling approach: Energy Policy 39, pp. 7896-7906 (2012)
88. Cuellar, A.D. and M.E. Webber: Wasted Food, Wasted Energy: The Embedded Energy in Food Waste in the United States. Environmental Science Technology, vol. 44: pp. 6464–6469 (2010)
89. Stillwell, A.S., King, C.W., Webber, M.E., Duncan, I.J., and A. Hardberger: The Energy-Water Nexus in Texas. Ecology and Society, vol. 16: 1 (2011)
90. Lang, T. and D. Barling: Food security and food sustainability: reformulating the debate. The Geographical Journal, vol. 178: pp. 313-326 (2012)
91. Murphy, C.F. and D.T. Allen: Energy-water nexus for mass cultivation of algae. Environmental Science and Technology, 45 (13): pp. 5861-5868 (2011)
92. Link Environmental Security, Water Security and Food Security. International Journal of Water Resources Development, vol. 17: pp. 539-554
93. Rosegrant, M.W. and S.A. Cline: Global food security: challenges and policies. Science, vol. 302 (5652): pp. 1917-1919 (2003)
94. Mukherji, A.: The energy-irrigation nexus and its impact on groundwater markets in eastern Indo-Gangetic basin: Evidence from West Bengal, India. Energy Policy, vol. 35: pp. 6413-6430 (2007)
95. Eichelberger, L.P.: Living in utility scarcity: Energy and water insecurity in Northwest Alaska. American Journal of Public Health, vol. 100 (6): pp. 1010-1018 (2010)
96. Li. X., Feng, K., Siu, Y.L., and K. Hubacek: Energy Water Nexus of Wind Power in China: The Balancing Act Between CO2 Emissions and Water Consumption. Energy Policy, vol. 45: pp. 440-448 (2012)
97. Khan, M.A., Hanjrab, M.A. and J. Mub. Pathways to reduce the environmental footprints of water and energy inputs in food production. Food Policy, vol. 34(2): pp. 141-149
98. Gleick, P.H.: Water and Energy, in Annual Reviews, Annual Review of Energy and the Environment 19: pp. 267-99 (1994)
99. Mohtar, R.H. and Daher, B.: Water, Energy, and Food: The Ultimate Nexus Encyclopedia of Agricultural, Food, and Biological Engineering, Second Edition (2012)
100. FAO: State of Food Insecurity. Food and Agriculture Organization. Rome (2009)
101. Bizikova, L., Roy, D., Swanson, D.A., Venema, H.V.and McCandless, M.: The Water-Energy-Food Security Nexus: Towards a Practical Planning and Decision Support Framework for Landscape Investment and Risk Management International Institute for Sustainable Development (IISD). Winnipeg, Canada (2013)
102. FAO: The Water-Energy-Food Nexus. Concept Note. FAO. Rome (2014)

103. Bonte, M., P. J. Stuyfzand, A. Hulsmann, and P. Van Beelen: Underground thermal energy storage: environmental risks and policy developments in The Netherlands and European Union. Ecology and Society 16(1): pp. 22 (2011)
104. Hussey, K., and J. Pittock: The Energy–Water Nexus: Managing the Links between Energy and Water for a Sustainable Future. Ecology and Society 17(1): pp. 31 (2012)
105. Carter, N.: Energy's water demand: trends, vulnerabilities, and management. Congressional Research Service, Washington, D.C., USA (2010)
106. Gerbens-Leenes, W., A. Hoekstra, and T. van der Meer: The water footprint of energy consumption: an assessment of water requirements of primary energy carriers. ISESCO Science and Technology Vision 4(5): pp. 38-42 (2008)
107. Ryngaert, Cedric. Jurisdiction in International Law. Oxford: Oxford University Press (2008)
108. Akehurst, Michael. Jurisdiction in International Law. British Yearbook of International Law 46: pp. 145–257 (1975)
109. Mann, Frederick A. The Doctrine of Jurisdiction in International Law. Recueil des Cours 111: pp. 1–162 (1964)
110. Turral, H., Burke, J. and J-M. Faurès: Climate Change, Water and Food Security. FAO Water Reports 36. Food and Agriculture Organization, Rome (2008)
111. McClean, David; Beevers, Kisch: The Conflict of Laws (Seventh ed.). London: Sweet & Maxwell (2009)
112. Clarkson, C.M.V.; Hill, Jonathan: The Conflict of Laws (Third ed.). Oxford University Press (2006)
113. Calliess, Gralf-Peter: The Rome Regulations: Commentary on the European Rules of the Conflict of Laws. Kluwer (2010)
114. Briggs, Adrian: The Conflict of Laws (Second ed.). Oxford: Oxford University Press (2008)
115. Palmirani M, Vitali F. 2013 July 23. Release CSD05 - Akoma Ntoso 3.0 Schema. http://www.akomantoso.org/release-notes/akoma-ntoso-3.0-schema/schema-for-AKOMA-NTOSO-3.0. Accessed 2013 Oct 25
116. Palmirani M, Governatori G, Rotolo A, Tabet S, Boley H, Paschke A.: LegalRuleML: XML-based rules and norms. In: The 5th internaltion RuleMLsymposium on rules, 2011 Nov 3-5, Florida, USA. RuleML America, pp. 298-312 (2011)
117. Hu, Han; Wen, Yonggang; Chua, Tat-Seng; Li, Xuelong: Towards scalable systems for big data analytics: a technology tutorial, IEEE Access 2: pp. 652–687, doi:10.1109/ACCESS.2014.2332453 (2014)
118. Bowman, M., Debray, S. K., and Peterson, L. L.: Reasoning about naming systems. ACM Trans. Program. Lang. Syst. 15, 5 (Nov. 1993), pp. 795-825. DOI= http://doi.acm.org/10.1145/161468.16147 (1993)
119. Ding, W. and Marchionini, G.: A Study on Video Browsing Strategies. Technical Report. University of Maryland at College Park (1997)
120. Fröhlich, B. and Plate, J.: The cubic mouse: a new device for three-dimensional input. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (The Hague, The Netherlands, April 01 - 06, 2000). CHI '00. ACM, New York, NY, pp. 526-531. DOI= http://doi.acm.org/10.1145/332040.332491 (2000)
121. Tavel, P.: Modeling and Simulation Design. AK Peters Ltd., Natick, MA (2007)
122. Berners-Lee, T.: Tim Berners-Lee on the next web: Retrieved 4/5/2014 from TED, http://www.ted.com/talks/tim_ (2009)

123. Shadbolt, Nigel, Berners-Lee, Tim, Hendler, Jim, Hart, Claire, Benjamins, Richard: The next wave of the web. In: Proceedings of the 2006 International Conference on the World Wide Web, pp. 750. http://doi.acm.org/10.1145/1135777.1135889 (2006)
124. Palmer, S. B.: The Early History of HTML. Available at: http://infomesh.net/html/history/early/. Retrieved 2013-04-30 (2009)
125. Sartor, G., Palmirani, M., Francesconi, E., Biasiotti, M. A. (eds): Legislative XML for the Semantic Web: Principles, Models, Standards for Document Management. In: Law, Governance and Technology Series, vol. 4. Springer (2011)
126. Hendler, James A., Shadbolt, Nigel, Hall, Wendy, Berners-Lee, Tim, Weitzner, Daniel J.: Web science: an interdisciplinary approach to understanding the web. In Communications of the ACM, 51 (7) pp. 60-69. http://doi.acm.org/10.1145/1364782.1364798 (2008)
127. Bizer, Christian, Heath, Tom, Idehen, Kingsley, Berners-Lee, Tim: Linked data on the web (LDOW2008). In: Proceedings of the 2008 International Conference on the World Wide Web, pp. 1265-1266, http://doi.acm.org/10.1145/1367497.1367760 (2008)
128. Bizer, Christian, Heath, Tom, Berners-Lee, Tim, Hausenblas, Michael: 4th linked data on the web workshop (LDOW2011). In: Proceedings of the 2011 International Conference on the World Wide Web, pp. 303-304. http://dx.doi.org/10.1145/1963192.1963323 (2011)
129. Casellas, N.: Legal Ontology Engineering Methodologies, Modelling Trends, and the Ontology of Professional Judicial Knowledge. In: Law, Governance and Technology Series, vol. 3 (2011)
130. Palmirani, M., Ceci, M.: Ontology Framework for Judgement Modelling. In: AI Approaches to the Complexity of Legal Systems. Models and Ethical Challenges for Legal Systems, Legal language and Legal Ontologies, Argumentation and Software Agents, LNCS vol. 7639, pp. 116-130. Springer, Berlin (2012)
131. Casanovas, P., Poblet, M., Casellas, N., Contreras, N., Benjamins, R., Blasquez, M.: Supporting newly-appointed judges: A legal knowledge management case study. In: Journal of Knowledge Management, pp. 7-27 (2005)
132. Artz, D., Gil, Y.: A Survey of Trust in Computer Science and the Semantic Web. In: Journal of Web Semantics: Science, Services and Agents on the World Wide Web. Available at: http://www.isi.edu/~gil/papers/jws-trust-07.pdf (2007)
133. Wahlforss, E., Ljung, A.: People, Profiles & Trust: On interpersonal trust in web-mediated social spaces. Alexander ljung & Eric Wahlforss, Berlin. Available at: http://trustmojo.com/media/People-Profiles-And-Trust.pdf (2008)
134. Barabucci, G., Cervone, L., Palmirani, M., Peroni, S., Vitali, F.: Multi-layer markup and ontological structures in Akoma Ntoso. In: AI Approaches to the Complexity of Legal Systems: Complex Systems, the Semantic Web, Ontologies, Argumentation, and Dialogue, pp. 133-149. Springer, Berlin Heidelberg (2010)
135. Mommers, L.: Ontologies in the Legal Domain. In: Poli, R., Seibt, J. (eds): Theory and Applications of Ontology: Philosophical Perspectives, pp. 265-276. Springer, Berlin (2010)
136. Palmirani, M., Governatori, G., Rotolo, A., Tabet, S., Boley H., Paschke, A.: LegalRuleML: XML-Based Rules and Norms. In: RuleML, pp. 298-312 (2011)
137. Palmirani, M., Ognibene, T., Cervone, L.: Legal rules, text, and ontologies over time. In: Proceedings of the RuleML@ ECAI 6th International Rule Challenge (2012)
138. Lam, H.-P., Governatori, G.: The making of SPINdle. In: Rule Interchange and Applications, pp. 315-322. Springer, Berlin Heidelberg (2009)
139. Cuninghame, K.: Guidelines for Legislative Libraries. De Gruyter Saur, Munich (2009)
140. Goldfarb, C.: XML Handbook. Prentice Hall, Upper Saddle River, NJ (1998)

141. Decker, S., Melnik, S., van Harmelen, F., Fensel, D., Klein, M., Broekstra, J., Erdmann, M., Horrocks, I.: The Semantic Web: The Roles of XML and RDF. In: IEEE Internet Computing 4, pp. 63-74 (2000)
142. Nejdl, W., Wolpers, M., Capelle, C.: The RDF Schema Specification revisited. In: Workshop Modellierung 2000, St. Goar, Germany (2000)
143. Lam, H.-P., Governatori, G.: The making of SPINdle. In: Rule Interchange and Applications, pp. 315-322. Springer, Berlin Heidelberg (2009)
144. Vitali, F.: Akoma Ntoso Release Notes. Available at: http://www.akomantoso.org (1997)
145. XEML environmental ontology. 2009 Sep 9. Welcome to the wiki for XEML environmental ontology. http://xeo.codeplex.com/. Accessed 2013 Oct 24.
146. e-SAVE: Ontologies for energy efficiency. Luxembourg: e-SAVE, pp. 11-13 (2012)
147. Arauz PL, Redondo PJM. EcoLexicon: contextualizing an environmental ontology. In Proceedings of the Terminology and Knowledge Engineering (TKE) Conference 2010. Dublin: Dublin City University (2010)
148. [Envo] Environmental ontology. About EnvO. http://environmentontology.org/home/about-envo. Accessed 2013 Oct 28.
149. Environment ontology. 2012 Nov 19. Biome. http://bioportal.bioontology.org/ontologies/ENVO?p=classes. Accessed 2013 Oct 27.
150. Cisney VW. 2013 Jun 28. Differential Ontology. In Internet Encyclopedia of Philosophy. http://www.iep.utm.edu/diff-ont/. Accessed 2013 Oct 25.
151. Herrmann, C. S.: Symbolical reasoning about numerical data: A hybrid approach. In: Applied Intelligence 7, pp. 339-354 (1997)
152. Forgy, C. L.: Rete: A fast algorithm for the many pattern/many object pattern match problem. In: Artificial Intelligence, Volume 19, pp. 17-37 (1982)
153. Sottara, D., Mello, P., Proctor, M.: A configurable Rete-OO engine for reasoning with different types of imperfect information. In: Knowledge and Data Engineering, IEEE Transactions on, 22(11), pp. 1535-1548 (2010)
154. Palmirani M, Cervone L, Bujor O, Chiappetta M.: RAWE: a web editor for rule markup in LegalRuleML. In CEUR workshop proceedings (2013)
155. Palmirani, M., Contissa, G., Rubino, R.: Fill the Gap in the legal Knowledge Modelling. In: Proceedings of RuleML 2009, LNCS 5858, pp. 305-314. Springer, Berlin (2009)
156. Kelsen H.: Reine Rechtslehre, 2d. ed., Wien (1960)
157. Bench-Capon T. and Coenen F.: Isomorphism and legal knowledge based systems. Artificial Intelligence and Law, 1(1): pp. 65–86 (1992)
158. Sullivan T.: Evaluating environmental decision support system. New York: Brookhaven Science Associates for the US Department of Energy, pp. 02-43 (2002)
159. Frysinger SP, Gmbh C.: Environmental decision support systems: a human factors perspective (2010)
160. Poch M, Comas J, Rodríguez-Roda I, Sánchez-Marre M, Cortes U.: Designing and building real environmental decision support system. In Enviromental Modelling and Software (2003)
161. Sánchez-Marre M, Gibert K, Sojda RS, Steyer JP, Struss P, Rodríguez-Roda I, Comas J, Brilhante V, Roehl EA.: Intelligent environmental decision support systems. In Envrionmental Modelling, Software and Decision Support Research paper 190: pp. 119-144 (2008)
162. Rahman M. 2013. Legal knowledge framework for identifying water, energy, food and climate nexus, ceur-ws.org/Vol-1105/paper3.pdf, Accessed (2014)

163. Antoniou, G., E. Franconi, and F. van Harmelen: Introduction to Semantic Web ontology languages. In Reasoning web, ed. N. Eisinger and J. Maluszynski. Lecture notes in computer science, vol. 3564, pp. 1–21. Springer, Berlin Heidelberg (2005)
164. A´lvarez, R., M. Ayuso, and M. Be´cue: Statistical study of judicial practices. In Law and the Semantic Web. Legal ontologies, methodologies, legal information retrieval, and applications, ed. V. R. Benjamins, P. Casanovas, J. Breuker, and A. Gangemi. Lecture notes in artificial intelligence, vol. 3369, pp. 25–35. Springer, Berlin/Heidelberg (2005)
165. Benjamins, V. R., P. Casanovas, J. Breuke, and A. Gangemi: Law and the SemanticWeb: An introduction. In Law and the Semantic Web. Legal ontologies, methodologies, legal information retrieval, and applications [Outcome of the Workshop on Legal Ontologies and Web-Based Legal Information Management, June 28, 2003, Edinburgh, UK & International Seminar on Law and the Semantic Web, November 20–21, 2003, Barcelona, Spain], ed. V. R. Benjamins, P. Casanovas, J. Breuker, and A. Gangemi. Lecture notes in computer science, vol. 3369, pp. 1–17. Springer, Berlin/Heidelberg (2005)
166. Bench-Capon, T., and P. Visser: Deep models, ontologies and legal knowledge based systems. In Proceedings of JURIX'96, Legal Knowledge Based Systems (Foundations of Legal Knowledge Systems), ed. R. van Kralingen, H. van den Herik, J. Prins, M. Sergot, and J. Zeleznikow, pp. 3–14. Tilburg University Press, Tilburg (1996)
167. Breuker, J., A. Valente, and R. Winkels: Use and reuse of legal ontologies in knowledge engineering and information management. In Law and the Semantic Web. Legal ontologies, methodologies, legal information retrieval, and applications, ed. V. R. Benjamins, P. Casanovas, J. Breuker, and A. Gangemi. Lecture notes in computer science, vol. 3369, pp. 35–64. Springer, Berlin/Heidelberg (2005)
168. De Rosnay, M. D.: Cognitive interfaces for legal expressions description – application to copyrighted works online sharing and transactions. In Proceedings of the 16th Annual Conference on Legal Knowledge and Information Systems (JURIX'03), Utrecht, ed. D. Bourcier, pp. 121–130. IOS Press, Amsterdam (2003)
169. Schneider, L., and J. Cunningham: Ontological foundations of natural language communication in multiagent systems. In Knowledge-Based Intelligent Information and Engineering Systems, 7th International Conference, KES 2003, September 3–5, 2003, Proceedings, Part I. Oxford, UK, ed. V. Palade, R. J. Howlett, and L. C. Jain. Lecture notes in computer science, vol. 2773, pp. 1403–1410. Springer (2003)
170. Shaheed, J., A. Yip, and J. Cunningham: A top-level language-biased legal ontology. In LOAIT, Workshop on Legal Ontologies and Artificial Intelligence Techniques at ICAIL 2005, ed. J. Lehmann, M. A. Biasiotti, E. Francesconi, and M. T. Sagri. IAAIL workshop series, Vol. 4. Bologna: Wolf Legal Publishers (2005)
171. Mommers, L.: Applied legal epistemology. Building a knowledge-based ontology of the legal domain. Ph.D. thesis, Leiden University (2002)
172. Breuker, J., and R. Hoekstra: Epistemology and ontology in core ontologies: FOLaw and LRI-Core, two core ontologies for law. In Proceedings of Workshop on Core Ontologies in Ontology Engineering in the 14th International Conference (EKAW'04), ed. A. Gangemi and S. Borgo, Whittlebury Hall, CEUR (2004)
173. Gangemi, A.: Design patterns for legal ontology construction. In Proceedings of the Workshop on Legal Ontologies and Artificial Intelligence Techniques (LOAIT 2007) at the International Conference on AI and Law (ICAIL'07), June 4, Stanford, ed. P. Casanovas, M. A. Biasiotti, and E. Francesconi, M. Teresa, T. Sagri, pp. 65–85 (2007)
174. Visser, P. R. S., and T. J. M. Bench-Capon: A comparison of four ontologies for the design of legal knowledge systems. Artificial Intelligence and Law 6: pp. 27–57 (1998)

175. Bench-Capon, T. J. M. & Visser, P. R. S.: Ontologies in legal information systems; the need for explicit specifications of domain conceptualisations, Proceedings of the Sixth International Conference on Artificial Intelligence and Law, pp. 132–141. ICAIL ’97, Melbourne, Australia (1997)
176. Chandrasekaran, B. & Josephson, J. R.: The ontology of tasks and methods, Working Notes of the AAAI Spring symposium on Ontological Engineering, pp. 9–16. Stanford University, CA, USA (1997)
177. Musen, M. A.: An overview of knowledge acquisition. In Second generation expert systems. ed. J.-M. David, J.-P. Krivine, and R. Simmons, pp. 405–427. Springer-Verlag, New York, Berlin (1993)
178. Lenat, D.,M. Prakash, and M. Shepherd: Cyc: Using common sense knowledge to overcome brittleness and knowledge acquisition bottlenecks. AI Magazine 6(4): pp. 65–85 (1985)
179. Milton, N.: Knowledge acquisition in practice. A step-by-step guide. Decision engineering. Springer, London (2007)
180. Hoekstra, R., J. Breuker, M. D. Bello, and A. Boer: The LKIF core ontology of basic legal concepts. In Proceedings of the Workshop on Legal Ontologies and Artificial Intelligence Techniques (LOAIT 2007) at the International Conference on AI and Law (ICAIL’07), Stanford, June 4, ed. P. Casanovas, M. A. Biasiotti, E. Francesconi, and M. T. Sagri, pp. 43–63 (2007)
181. Visser, P. R.: Implicit assumptions in legal knowledge systems. In Proceedings of the 13th BILETA Conference: The Changing Jurisdiction, Trinity College, Dublin March, 27th–28th, Dublin. BILETA, British and Irish Legal Education Technology Association (1998)
182. Searle, J.R.: How to Derive Ought from Is. Philosophical Review 73, pp. 43-58 (1964)
- Speech Acts: An Essay in the Philosophy of Language. Cambridge, Cambridge University Press (1969)
- Intentionality: An Essay in the Philosophy of Mind. Cambridge, Cambridge University Press (1983)
- Intentionalistic Explanations in the Social Sciences. Philosophy of the Social Sciences 21, pp. 332-44 (1991)
- The Construction of Social Reality. New York, The Free Press (1995)
- Mind, Language and Society. London, Weidenfeld & Nicolson (1999)
- Reply to Barry Smith. American Journal of Economics and Sociology 62, pp. 299-309 (2003)
- What Is an Institution? Journal of Institutional Economics 1, pp. 1-22 (2005)
183. Mommers, L.: On the ontological status and representation of legal concepts. In Proceedings of the Eleventh Conference of Legal Knowledge-Based Systems (JURIX’98), ed. J. Hage, T. Bench-Capon, A. Koers, C. de Vey Mestdagh, and C. Grütters, pp. 45–58. Gerard Noodt Instituut, Nijmegen (1998)
184. Schreiber, G.: Pragmatics of the Knowledge Level, Ph.D. Thesis, University of Amsterdam, The Netherlands (1992)
185. Heijst, G. Van & Schreiber, G.: CUE: Ontology-based knowledge acquisition, in L. Steels, A. Th. Schreiber, and W. Van de Velde (eds.), A Future for Knowledge Acquisition, Proceedings of the 8th European Knowledge Acquisition Workshop EKAW ’94, vol. 867 of Lecture Notes in Artificial Intelligence, pp. 178–199. Springer-Verlag, Berlin/Heidelberg, Germany (1994)
186. Gruber, T. R.: A translation approach to portable ontology specifications, Knowledge Acquisition, No. 5, pp. 199–220 (1993)

187. Bench-Capon, T. J. M.: Knowledge Representation; An Approach to Artificial Intelligence, APIC series, No. 32, Academic Press, London, United Kingdom (1990)
188. Falkenberg, E. D.: Informatiesystemen – aan de kinderschoenen ontstegen?, University of Nijmegen, Nijmegen, The Netherlands (in Dutch) (1989)
189. Liebwald, D.: Semantic spaces and multilingualism in the law: The challenge of legal knowledge management. In Proceedings of the Workshop on Legal Ontologies and Artificial Intelligence Techniques (LOAIT 2007) at the International Conference on AI and Law (ICAIL'07), Stanford, June 4, ed. P. Casanovas, M. A. Biasiotti, and E. Francesconi, M. T. Sagri, pp. 131–146 (2007)
190. Tijerino.A, Ikeda, M., Kitahashi, T., and Mizoguchi, R.: A Methodology for Building Expert Systems Based on Task Ontology and Reuse of Knowledge, Journal of Japanese Society for Artificial Intelligence, vol.8, No.4, pp. 476-487 (in Japanese) (1993)
191. Uschold, M., and M. Grüninger: Ontologies: Principles, methods, and applications. Knowledge Engineering Review 11(2): pp. 93–155 (1996)
192. Gangemi, A., G. Steve, and F. Giacomellli: ONIONS: An ontological methodology for taxonomic knowledge integration. In Proceedings of the ECAI-96 Workshop on Ontological Engineering, Budapest (1996)
193. Visser, P. R. S., and T. J. M. Bench-Capon: On the reusability of ontologies in knowledge system design. In Proceedings of the Seventh International Workshop on Database and Expert Systems Applications (DEXA '96), Zurich, September 9–10, ed. R. Wagner and H. Thoma, pp. 256–261. IEEE-CS Press, Washington (1996)
194. Mizoguchi, R., J. Vanwelkenhuysen, and M. Ikeda: Task ontology for reuse of problem solving knowledge. In Towards very large knowledge bases: Knowledge building and knowledge sharing (KBKS'95), ed. N. Mars, pp. 45–59. IOS Press, Amsterdam (1995)
195. Mizoguchi, R., Y. Tijerino, and M. Ikeda: Task analysis interview based on task ontology. Expert Systems with Applications 9(1): pp. 15–25 (1995)
196. Mommers, L.: Applications of a knowledge-based ontology of the legal domain in collaborative workspaces. In Proceedings of the International Conference on Artificial Intelligence and Law (ICAIL), pp. 70–108. ACM, New York (2003)
197. Mulder, R. D., K. van Noortwijk, and L. Combrink-Kuiters: Chapter Jurimetrics please!. In A history of legal informatics, ed. Paliwala, A. 2010. A history of legal informatics. LEFIS series, vol. 9, LEFIS, Zaragoza: Prensas Universitarias de Zaragoza (2010)
198. Gruber, T. R.: Toward principles for the design of ontologies used for knowledge sharing. Technical Report KSL 93-04, Knowledge Systems Laboratory, Stanford University (1993)
199. Gruber, T.: Where the social web meets the Semantic Web. In The Semantic Web – ISWC 2006, Proceedings of the 5th International Semantic Web Conference, ISWC 2006, Athens, November 5–9 (Keynote Abstract), ed. I. F. Cruz, S. Decker, D. Allemang, C. Preist, D. Schwabe, P.Mika, M. Uschold, and L. Aroyo. Lecture notes in computer science, vol. 4273, pp. 994. Springer, Berlin/Heidelberg (2006)
200. Sartor, G., P. Casanovas, M. Biasiotti, and M. Fern´andez-Barrera: Approaches to legal ontologies. Theories, domains and methodologies. Number 1 in law, governance and technology series. Springer, New York/Heidelberg (2011)
201. Marcus, S. L.: Knowledge acquisition. In The MIT encyclopedia of the cognitive sciences, ed. R. A. Wilson and F. C. Keil, pp. 428–430. MIT Press, Cambridge (1999)
202. Hoekstra, R., J. Breuker, M. D. Bello, and A. Boer: LKIF core: Principled ontology development for the legal domain. In Law, ontologies and the Semantic Web. Channelling the legal information flood, ed. J. Breuker, P. Casanovas, M. C. A. Klein, and E. Francesconi. Frontiers in artificial intelligence and applications, vol. 188, pp. 21–52. IOS Press, Amsterdam (2009)

203. Hertz, J., Palmer, R.G., Krogh. A.S.: Introduction to the theory of neural computation, Perseus Books, ISBN 0-201-51560-1 (1990)
204. Minsky, M.: Form and content in computer science (1970 acm turing lecture). Journal of the ACM 17(2): pp. 197–215 (1970)
205. Bing, J.: Chapter Let there be LITE: A brief history of legal information retrieval. In A History of legal informatics, ed. Paliwala, A. LEFIS series, vol. 9, LEFIS, Prensas Universitarias de Zaragoza, Zaragoza (2010)
206. Leith, P.: The rise and fall of the legal expert system. In A History of legal informatics, ed. Paliwala, A. 2010. A history of legal informatics. LEFIS series, vol. 9, LEFIS, Prensas Universitarias de Zaragoza, Zaragoza (2010)
207. Breuker, J., R. Hoekstra, A. Boer, K. van den Berg, R. Rubino, G. Sartor, M. Palmirani, A. Wyner, and T. Bench-Capon: OWL ontology of basic legal concepts (LKIF-core). Deliverable 1.4 D.1.4, ESTRELLA project (IST-2004-027655) (2007)
208. Gordon, T. F.: From jhering to alexy. using artificial intelligence models in jurisprudence. In Legal knowledge based systems (JURIX'94) the foundation for legal knowledge systems: The relation with legal theory, ed. H. Prakken, A. Muntjewerff, and A. Soeteman, pp. 19–31, ISBN 9054581905. Koninklijke Vermande, Lelystad (1994)
209. Biasiotti, M., E. Francesconi, M. Palmirani, G. Sartor, and F. Vitali: Legal informatics and management of legislative documents. In GC working papers, ed. G. Sartor, vol. 2, Global Centre for ICT in Parliament. Rome, Italy (2008)
210. Sartor, G., Palmirani, M., Francesconi, E., Biasiotti, M. A. (eds): Legislative XML for the Semantic Web: Principles, Models, Standards for Document Management. In: Law, Governance and Technology Series, vol. 4. Springer (2011)
211. Brewka, G., Eiter, T. and Fink, M.: Nonmonotonic multi-context systems: A flexible approach for integrating heterogeneous knowledge sources. In: Logic programming, knowledge representation, and nonmonotonic reasoning, pp. 233-258. Springer, Berlin Heidelberg (2011)
212. Ajani, G., Boella G., Lesmo L., Mazzei A., Radicioni D. P., Rossi P.: Legal Taxonomy Syllabus: Handling Multilevel Legal Ontologies. In: Proceedings of Langtech (2008)
213. Bi´ebow, B., and S. Szulman: TERMINAE: A linguistics-based tool for building of a domain ontology. In Proceedings of the 11th European Workshop (EKAW'99), ed. D. Fensel and R. Studer, Lecture notes in artificial intelligence, vol. 1621, 49–66. Springer, Berlin/Heidelberg (1999)
214. Venturi, G.: Legal language and legal knowledge management applications. In Semantic processing of legal texts: Where the language of law meets the law of language, ed. E. Francesconi, S. Montemagni, W. Peters, and D. Tiscornia. Lecture notes in computer science. vol. 6036, 3–26. Springer, Berlin/Heidelberg (2010)
215. Lenci, A., S. Montemagni, V. Pirrelli, and G. Venturi: Nlp-based ontology learning from legal texts. A case study. In LOAIT, ed. P. Casanovas, M. A. Biasiotti, E. Francesconi, and M.-T. Sagri. CEUR Workshop Proceedings, vol. 321, pp. 113–129. CEUR-WS.org (2007)
216. Hafner, C. D. and Lauritsen, M.: Extending the Power of Automated Legal Drafting Technology. In Lodder, A.R. and L. Mommers, eds., Legal Knowledge and Information Systems: Jurix 2007, pp. 59-68. IOS Press (2007)
217. C. Hafner and D. Berman: The Role of Context in Case-based Legal Reasoning: teleological, temporal and procedural. Artificial Intelligence and Law, vol. 10, pp. 19-64 (2002)
218. McCarty, L. T.: Some requirements for a computer-based legal consultant. In AAAI-80 Proceedings, pp. 298–300. Kaufmann, Los Altos (1980)

219. McCarty, L. T.: A language for legal discourse i. basic features. In ICAIL '89: Proceedings of the 2nd International Conference on Artificial Intelligence and Law, pp. 180–189. ACM Press, New York (1989)
220. McCarty, L. T.: On the role of prototypes in appellate legal argument (abstract). In Proceedings of the International Conference in Artificial Intelligence and Law (ICAIL'91), pp. 185–190. ACM, Oxford (1991)
221. Stamper, R.: May. The LEGOL project: A survey. Technical Report 0081, IBM United Kingdom Scientific Center (1976)
222. Moles, R. N.: Ronald Stamper and norm based systems. Legal Theory Lecture published at Networked Knowledge web site. Retrieved October 22, 2008, from http://netk.net.au/LegalTheory.asp (2008)
223. Jones, S., P. Mason, and R. Stamper: LEGOL 2.0: A relational specification language for complex rules. Information Systems 4(4): pp. 293–305 (1979)
224. Stamper, R.: Social norms in requirements analysis: An outline of measur. In Requirements engineering: Social and technical issues, ed.M. Jirotka and J. A. Goguen, pp. 107–139. Academic Press Professional, Inc., San Diego (1994)
225. Stamper, R. K.: The LEGOL 1 prototype system and language. The Computer Journal 20(2): pp. 102–108 (1977)
226. Mariani, P., D. Tiscornia, and F. Turchi: The formalization of retrieval and advisory systems. In Proceedings of the Legal Knowledge Based Systems JURIX 92: Information Technology and Law, ed.C.Grütters, J. Breuker, H. van der Herik, A. Schmidt, and C. de Vey Mestdagh, pp. 71–80. Koninklijke Vermande, Lelystad (1992)
227. van Kralingen, R. W.: Frame-based conceptual models of statute law. Kluwer Law International, Hague (1995)
228. van Kralingen, R. W.: A conceptual frame-based ontology for the law. In Proceedings of the First International Workshop on Legal Ontologies, LEGONT'97, pp. 15–22. Ed. P. Visser and R. Winkels, Melbourne (1997)
229. van Kralingen, R. W., E. Oskamp, and E. Reurings: Norm frames in the representation of laws. In Legal knowledge based systems JURIX 93: Intelligent Tools for Drafting Legislation, Computer-Supported Comparison of Law, ed. J. Svensson, J.Wassink, and B. van Buggenhout, pp. 11–22. Koninklijke Vermande, Lelystad (1993)
230. van Kralingen, R. W., P. R. Visser, T. J. Bench-Capon, and H. J. V. D. Herik: A principled approach to developing legal knowledge systems. International Journal of Human-Computer Studies 51(6): pp. 1127–1154 (1999)
231. Visser, P., and T. Bench-Capon: The formal specification of a legal ontology. In Proceedings of JURIX'96, Legal knowledge based systems (Foundations of legal knowledge systems), ed. R. van Kralingen, H. van den Herik, J. Prins, M. Sergot, and J. Zeleznikow, 15–24. Tilburg University Press, Tilburg (1996)
232. Visser, P., and T. Bench-Capon: A comparison of two legal ontologies. In Proceedings of the First International Workshop on Legal Ontologies, LEGONT'97, ed. P. Visser and R.Winkels, pp. 37–45. University of Melbourne, Melbourne (1997)
233. Visser, P., and T. Bench-Capon: Ontologies in the design of legal information systems; towards a library of legal domain ontologies. In Proceedings of the Conference on Applied Ontology, pp. 76–85. Buffalo University (1998)
234. Visser, P. R.: Implicit assumptions in legal knowledge systems. In Proceedings of the 13th BILETA Conference: The Changing Jurisdiction, Trinity College, Dublin March, 27th–28th, Dublin. BILETA, British and Irish Legal Education Technology Association (1998)

235. Visser, P. R. S.: Framer: Source code of a legal knowledge system that performs assessment and planning. Reports on Technical Research in Law vol. 2, No. 1. University of Leiden, Leiden (1995)
236. Visser, P. R. S., and T. J. M. Bench-Capon: On the reusability of ontologies in knowledge system design. In Proceedings of the Seventh International Workshop on Database and Expert Systems Applications (DEXA '96), Zurich, September 9–10, ed. R. Wagner and H. Thoma, pp. 256–261. IEEE-CS Press, Washington (1996)
237. Valente, A., and J. Breuker: A functional ontology of law. In Towards a global expert system in law. ed. G. Bargellini and S. Binazzi. Cedam Publishers, Padua (1994)
238. Verheij, B., and J. Hage: States of affairs, events, and rules: An abstractmodel of the law. In JURIX'97, ed. A. Oskamp, R. V. De Mulder, C. van Noortwijk, C. A. F. M. Gr¨utters, K. Ashley and T. Gordon, 3–20. The Foundation for Legal Knowledge Systems, Nijmegen (1997)
239. Liu, K., and L. Sun: Capturing temporality and intentionality in information systems. In Proceedings of the Fifth International Workshop on the Language-Action Perspective on Communication Modelling (LAP 2000), Aachen, September 14–16, 2000, ed. M. Schoop and C. Quix, pp. 77–93 (2000)
240. Winkels, R., A. Boer, and R. Hoekstra: CLIME: Lessons learned in legal information serving. In Proceedings of the 15th European Conference on Artificial Intelligence (ECAI 2002), Lyon, pp. 230–234. IOS Press, Amsterdam (2002)
241. Winkels, R., A. W. Boer, J. A. Breuker, and D. J. Bosscher: Assessment based legal information serving and cooperative dialogue in CLIME. In Proceedings of the Eleventh Conference of Legal Knowledge-based Systems (JURIX'98), ed. J. Hage, T. Bench-Capon, A. Koers, C. de Vey Mestdagh, and C. Grütters, pp. 131–146. Gerard Noodt Instituut (GNI), Nijmegen (1998)
242. Boer, A., R. Winkels, and R. Hoekstra: The CLIME ontology. In Proceedings of the Second International Workshop on Legal Ontologies (LEGONT) in JURIX 2001, ed. R. Winkels, pp. 37–47. IOS Press, Amsterdam (2001)
243. Mommers, L.: A knowledge-based ontology of the legal domain. In Proceedings of the Second International Workshop on Legal Ontologies (LEGONT) in JURIX 2001, Amsterdam, ed. R. Winkels, 1–7 (2001)
244. Breuker, J., and R. Hoekstra: Epistemology and ontology in core ontologies: FOLaw and LRI-Core, two core ontologies for law. In Proceedings of Workshop on Core Ontologies in Ontology Engineering in the 14th International Conference (EKAW'04), ed. A. Gangemi and S. Borgo, Whittlebury Hall, CEUR (2004)
245. Breuker, J.: Constructing a legal core ontology: LRI-Core. In Proceedings of the Workshop on Ontologies and their Applications, pp. 115–126. Sao Luis, Maranhao – Brazil (2004)
246. Miller, G. A.: WordNet: A lexical database for English. Communications of the ACM 38(11): pp. 39–41 (1995)
247. Lame, G.: Knowledge acquisition from texts towards an ontology of French law. In Proceedings of the Workshop on Ontologies and Text in the 12th European Workshop on Knowledge Acquisition, Modeling and Management (EKAW '00), Juan-Les-Pins, ed. N. Aussenac-Gilles and S. Szulman (Application) (2000)
248. Lame, G.: Constructing an ir-oriented legal ontology. In Proceedings of the Second International Workshop on Legal Ontologies (LEGONT) in JURIX 2001, Amsterdam, ed. R.Winkels, pp. 31–36 (2001)
249. Lame, G.: Construction d'ontologie a partie de textes. Une ontologie du droit dediée à la recherche d'information sur le Web. Ph.D. thesis, L'école des Mines de Paris (2002)

250. Hoekstra, R., J. Breuker, M. D. Bello, and A. Boer: The LKIF core ontology of basic legal concepts. In Proceedings of the Workshop on Legal Ontologies and Artificial Intelligence Techniques (LOAIT 2007) at the International Conference on AI and Law (ICAIL'07), Stanford, June 4, ed. P. Casanovas, M. A. Biasiotti, E. Francesconi, and M. T. Sagri, pp. 43–63 (2007)
251. Hoekstra, R., J. Breuker, M. D. Bello, and A. Boer: LKIF core: Principled ontology development for the legal domain. In Law, ontologies and the Semantic Web. Channelling the legal information flood, ed. J. Breuker, P. Casanovas, M. C. A. Klein, and E. Francesconi. Frontiers in artificial intelligence and applications, vol. 188, pp. 21–52. IOS Press, Amsterdam (2009)
252. Derived from www.aims.fao.org/vest-registry/vocabularies/agrovoc-multilingual-agricultural-thesaurus
253. Derived from http://www.semantic-web.at/sesame-s-services-semantic-smart-metering
254. Derived from http://his.cuahsi.org/ontologyfiles.html
255. Neuhaus, H. and Compton, M.: The semantic sensor network ontology: a generic language to describe sensor assets. Derived from http://www.w3.org/2005/Incubator/ssn/wiki/images/2/2e/SemanticSensorNetworkOntology.pdf (2005)
256. Derived from https://sweet.jpl.nasa.gov
257. Pascual, A.F.R., Blazquez, L.M.V., Perez, A.D.M.G., Poveda, M.A.B., and Baonza, M.C.S.D.F.: Towntology and hydrOntology: relationship between urban and hydrographic features in the geographic information domain. In Ontologies for urban development: studies in computational intelligence. Springer, Berlin (2007)
258. Joost Breuker Abdullatif, Joost Breuker, Abdullatif Elhag, Emil Petkov, and Radboud Winkels. Ontologies for legal information serving and knowledge management. In In Legal Knowledge and Information Systems, Jurix 2002: The Fifteenth Annual Conference. IOS, pages 73–82. IOS Press (2002)
259. Joost Breuker and Rinke Hoekstra. Epistemology and ontology in core ontologies: FOLaw and LRI-Core, two core ontologies for law, 2004. Amedeo Cappelli, Valentina Bartalesi Lenzi, Rachele Sprugnoli, and Carlo Biagioli. Modelization of domain concepts extracted from the italian privacy legislation. In Proceedings of Seventh International Workshop on Computational Semantics, IWCS-7, pages 305 – 308 (2007)
260. Gianmaria Ajani, Leonardo Lesmo, Guido Boella, Alessandro Mazzei, and Piercarlo Rossi. Terminological and ontological analysis of european directives: multilinguism in law. In Proceedings of the 11th international conference on Artificial intelligence and law, ICAIL '07, pages 43–48. ACM, New York, NY, USA (2007)
261. A W F Boer, R J Hoekstra, E De Maat, F Vitali, Monica Palmirani, and B Ratai. Metalex (open xml interchange format for legal and legislative resources). Management Center, Akon (2010)
262. Cervone L. Palmirani M. Peroni S. Vitali F. Barabucci, G. Multi-layer markup and ontological structures in akoma ntoso. In Proceeding of the International Workshop on AI approaches to the complexity of legal systems II (AICOL-II). Rotterdam, The Netherlands (2009)

## Annexes

### Annex 1. Restrictions used in the legal ontology for nexus

***Restriction 1 :*** *Authority* $\sqsubseteq \exists$ *maintains . (Market* $\sqcup$ *Resource* $\sqcup$ *Sources)*
***Restriction 2 :*** *Authority* $\sqsubseteq \exists$ *isMaintainedBy . (ConstitutiveRule)*
***Restriction 3 :*** *Quality* $\sqsubseteq \exists$ *isCheckedBy . (Authority)*
***Restriction 4 :*** *Product* $\sqsubseteq \exists$ *mustMaintain . ( Quality )*
***Restriction 5 :*** *Activity* $\sqsubseteq \exists$ *isPerformedBy .* ***(*** *Human )*
***Restriction 6 :*** *Substance* $\sqsubseteq \exists$ *isUsedFor .* ***(*** *Product )*
***Restriction 7 :*** *ConsumptionActivity* $\sqsubseteq \exists$ *isPerformedBy* ***. (*** *Human )*
***Restriction 8 :*** *ProductionActivity* $\sqsubseteq \exists$ *isPerformedBy* ***. (*** *Human )*
***Restriction 9 :*** *WaterIntendedForHumanConsumption* $\sqsubseteq \exists$ *isIntendedFor . ( HumanConsumptionActivity)* $\sqcap \exists$ *isSuppliedFrom . (DistributionOfWater)* $\sqcap \forall$ *isCoordinatedBy . (CompetentNationalAuthoritiesInWaterDomain)*
***Restriction 10 :*** WaterIntendedForHumanConsumption $\sqsubseteq \exists$ shallBeUsedFor . (FoodProductionActivity) $\sqcap \exists$ shallHave . ( QualityOfWater) $\sqcap \exists$ shallNotHave . (WasteWater)
***Restriction 11 :*** *WaterIntendedForHumanConsumption* $\sqsubseteq \exists$ *isUsedIn* ***.*** *(FoodProduct* $\sqcup$ *FoodProductionActivity)*
***Restriction 12 :*** *Human* $\sqsubseteq \exists$ *consumes .* ***(*** *WaterIntendedForHumanConsumption )*
***Restriction 13 :*** *FoodProduct* $\sqsubseteq \forall$ *isConsumedBy . ( Human )*
***Restriction 14 :*** *QualityOfWater* $\sqsubseteq \exists$ *shallNotAffect . ( WholesomenessOfFoodstuff )*

***Restriction 15 :*** *WasteWater* $\sqsubseteq \exists$ *shallNotBeUsedFor* **.** *( FoodProductionActivity* $\sqcup$ *ConsumptionActivity)*
***Restriction 16 :*** *BifuelsUnderEUDirective* $\sqsubseteq \exists$ *producedFrom* **. (** *BiomassUnderEUDirective )* $\sqcap \forall$ *isToBeUsedFor . ( Transport )*
***Restriction 17 :*** *Biomass ≡ BiodegradableFraction ≡ BiodegradableFractionOfResidue*
***Restriction 18 :*** *BiodegradableFractionOfResidue* $\sqsubseteq \exists$ *comesFrom* **.** *(Agriculture* $\sqcup$ *Biodegradabl FractionOfWaste* $\sqcup$ *Forestry)*
***Restriction 19 :*** *RenewableFuel* $\sqsubseteq \exists$ *isOriginatedFrom* **. (** *RenewableEnergySource)* $\sqcap \forall$ *isToBeUsedFor . ( Transport )*
***Restriction 20 :*** *SyntheticBiofuel* $\sqsubseteq \exists$ *isMixturesOf* **.** *( SyntheticHydrocarbon )*
***Restriction 21 :*** *BioDiesel* $\sqsubseteq \exists$ *isToBeUsedAs* **. (** *Biofuel )* $\sqcap \exists$ *producedFrom . ( AnimalOil* $\sqcup$ *VegetableOil)*
***Restriction 22 :*** *BioETBE* $\sqsubseteq \forall$ *isProducedOnTheBasisOf . ( Bioethanol)* $\sqcap$ ***value*** *isCalculatedAsBiofuel . (36%)*
***Restriction 23 :*** *BioMTBE* $\sqsubseteq \forall$ *isProducedOnTheBasisOf . ( BioMethanol )* $\sqcap$ ***value*** *isCalculatedAsBiofuel . ( 47% )*
***Restriction 24 :*** *BioGas* $\sqsubseteq \exists$ *canBePurifiedTo . (NaturalGas* $\sqcup$ *WoodGas))* $\sqcap \exists$ *isToBeUsedAs . ( Biofuel)*
***Restriction 25 :*** *PureVegetableOil* $\sqsubseteq \exists$ *compatibleWith . ( Engines )* $\sqcap \exists$ *mustCorrespondWith .* **(** *EmissionRequirement)* $\sqcap \exists$ *producedFrom* **. (** *OilProduction )*
***Restriction 26 :*** *FoodUnderEURegulation* $\sqsubseteq \forall$ *isAssociatedWith* **. (** *IntendedToBeIngested )* $\sqcup \forall$ *shallBeReasonably . ( ExpectedToBeIngested)*
***Restriction 27 :*** *FoodUnderEURegulation* $\sqsubseteq \forall$ *canBe* **.** *( CompletelyProcessedFoodProduct* $\sqcup$ *PartiallyProcessedFoodProduct* $\sqcup$ *UnprocessedFoodProduct )*
***Restriction 28 :*** *FoodUnderEURegulation* $\sqsubseteq \forall$ *isUndertakenBy* **. (** *Human )*
***Restriction 29 :*** *PointOfCompliance ≡ MaintenanceOfQuality*
***Restriction 30 :*** *Food ≡ FoodStuff*
***Restriction 31 :*** *WaterAfterCompliance* $\sqsubseteq \exists$ *mustMaintain* **. (** *QualityOfWater )*

**Annex 2. Links of all modules and documentations of legal ontology for nexus.**

A) Owl files of legal ontology for nexus are available at https://github.com/mizanur3/WEFNexus
B) Documentations of legal ontology for nexus are available at http://codexml.cirsfid.unibo.it/post-doctoralresearchers/mizanur-rahman/