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Engineering in Transition

Approaches, strategies and technologies
for implementing system innovation towards sustainability.

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Esame finale anno 2015

To my family.
Especially, to my sons
in whose hand is our future.

***Whatever you do**, **put your** whole*
***heart** and soul into it*
Colossesi 3, 23

Preface

"Be the change that you wish to see in the world."

Mahatma Gandhi

This PhD thesis is about change or else *transitions* to a sustainable society. Transitions are like discovery journeys, the destination is certainly important, but so is the path done through exploration, learning, discovery and change. In this journey I have not traveled alone, but have been accompanied, supported, guided and diverted by many colleagues, friends and family.

Firstly, I would like to thank ENEA, the Italian Italian National Agency for New Technologies, Energy and Sustainable Economic Development which funded my research. The PhD was carried out in the Department of Civil, Chemical, Environmental, and Materials Engineering (DICAM) of the University of Bologna. Certainly, I was very lucky in finding a stimulating scientific environment. In particular at the School of Engineering and Architecture located in via Terracini, Bologna, I found a perfect interdisciplinary scientific 'niche' to develop the first ideas on transition. Therefore, I would acknowledge especially my supervisor professor Alessandra Bonoli for the confidence and the encouragement in pursuing my research. Likewise, this work would not have been possible without the support of other colleagues such as professors, researchers and PhD students DICAM, CIEG professor and Technical Staff of the University of Bologna, such as AUTC and NuTeR. I gratefully acknowledge all of them for having made it possible the creation of the Transition Team at the University of Bologna. Additionally, ARIC and professor Dario Braga played an important role in the journey towards Unibo sustainable transition resulting in Alma Low Carbon.

Besides these institutes and their outstanding staff, I also have the pleasure to be part of the programme Pioneers into Practice (PiP) of Climate KIC promoted by the EIT (European Institute of Innovation and Technology). Definitely, PiP programme promotes the experimentation of low-carbon transformative innovations. PiP provides transition practitioners with a guidance of competences

developed through a mentoring programme. Particularly, as a pioneer I was supported by leading European experts on transition and systems thinking and by a Regional Innovation Center (RIC), in my case Emilia-Romagna RIC. The core of the PiP programme was the placement, a working period during which I could develop hands-on experience of low-carbon innovations within the host organizations. This inspiring experience was carried out at the University of Kassel (Germany) with the support of Hessen RIC of Climate KIC. The experience was relevant because it provided opportunities for analyzing through the lens of transition thinking a novel and significant domain for transition as university is. Therefore I would like to thank the Pioneers into Practice colleagues of Competence Centre of Climate Change Mitigation and Adaption (CliMA) of University of Kassel, Fernando Mateo Cecilia, pioneer of Valencia region of Spain. Unibo, Suzanne van den Bosch, PiP mentor and Filippo Saguatti and Pamela Regazzi of ASTER Emilia Romagna RIC of Climate-KIC.

Furthermore, an important role in this journey was played by the Transition Towns Movement. Especially, in the Bologna area I found inspiring companions which supported and gave a shape to transition practices and initiatives. I want to thank Cristiano Bottone and Massimo Giorgini my mentors in the first step of practicing the transition journey. In the same way, San Lazzaro in Transizione (SLIT) was an extraordinary platform for experimenting transition together with an open and welcoming Transition group very inspiring for my research and experimentation.

Finally, I want to extend my gratitude to family, friends and colleagues for their support and interest, especially my husband Pietro and sons Gabriele, Giovanni and Giacomo who helped me to always have in mind the importance of caring about our common future.

Francesca Cappellaro

Bologna, March 2015

Extended abstract (Italian)

La dissertazione intende approfondire il tema della transizione, come approccio emergente all'innovazione sostenibile di sistema. In particolare il percorso di ricerca punta a valutare il ruolo dell'Ingegneria nel processo di transizione verso la sostenibilità, sia da un punto di vista tecnico/tecnologico che da un punto di vista disciplinare e infine etico. L'Ingegneria è infatti sia una disciplina che una professione ed ha come obiettivo l'applicazione di conoscenze e risultati delle scienze matematiche fisiche e naturali alla risoluzione di problemi che concorrono alla soddisfazione dei bisogni umani nella società. L'avvio della dissertazione ha visto l'analisi degli attuali bisogni che emergono a livello mondiale. Dall'analisi emerge una situazione di crisi globale (economica, sociale e ambientale) e crescenti pericoli e minacce per l'umanità. Al contempo emerge anche una connessione (nexus) tra le diverse criticità che gravano sul nostro pianeta. Appare quindi chiara la necessità di individuare un approccio innovativo per un cambiamento radicale a livello di tutto il sistema. **La domanda di ricerca consiste dunque nell'identificazione e sperimentazione di un approccio efficace, di strategie e di tecnologie per affrontare le sfide che la crisi globale pone al fine di favorire l'innovazione di sistema verso la sostenibilità.** In questo panorama, la dissertazione ha individuato la Transizione Sostenibile come approccio emergente che si pone a livello di sistema e che abbraccia una vasta gamma di campi di ricerca tra cui l'Ingegneria della Transizione (Transition Engineering). Obiettivo di questa tesi è stato quello di applicare l'approccio della transizione, sperimentando strategie e tecnologie di Transition Engineering a livello di sistema universitario. La sperimentazione della tesi è avvenuta attraverso l'esecuzione di diversi esperimenti di transizione condotti all'interno della Scuola di Ingegneria e Architettura di via Terracini da cui è nata l'iniziativa Terracini in Transizione. Queste iniziative hanno permesso di esplorare un nuovo ruolo delle discipline ingegneristiche a livello di sistema socio-tecnico. In particolare è stato possibile ideare nuove modalità di pianificazione e progettazione sostenibile di soluzioni innovative e al contempo attivare processi partecipativi di crescita della consapevolezza.

In particolare, la progettazione degli esperimenti di transizione ha visto l'impiego strategico di tecnologie di transizione con la finalità di incrementare la sostenibilità e la resilienza dei plessi universitari. La transizione ha permesso l'adozione di strategie innovative a supporto della pianificazione e controllo dei percorsi di sostenibilità. Infine ha visto il coinvolgimento attivo degli attori coinvolti nella realizzazione di questi processi di transizione. In questo modo la Scuola di Ingegneria e Architettura può trasformarsi in un living-lab della sostenibilità. Il fine ultimo è quello di estendere il percorso di transizione a tutta la comunità intera con l'obiettivo di accelerare il percorso di trasformazione verso una società più sostenibile.

Materiali e metodi

Come per la storia, anche per la sostenibilità vi sono stati importanti passaggi evolutivi che hanno guidato il cambiamento verso stili di vita e modalità di produrre e consumare più sostenibili. La dissertazione ha analizzato e sistematizzato l'evoluzione degli approcci all'innovazione sostenibile. Tali approcci sono stati investigati sia da un punto di vista teorico che attraverso alcuni esempi e casi studio. In tal modo è stato possibile strutturare i campi di applicazione delle diverse tipologie di innovazione sostenibile e la loro utilità ed efficacia in diversi contesti. Da un approccio protettivo, in cui l'uomo si è trovato a sviluppare nuove tecnologie e nuove modalità di organizzarsi per difendersi da pericoli e minacce ambientali, si è passati ad un'era in cui le attività antropiche stanno determinando importanti ricadute sull'ambiente. Al fine di mitigare gli impatti ambientali prodotti dall'uomo si è adottato primariamente un approccio correttivo improntato a mitigare gli impatti già prodotti (approccio end-of-pipe). Questo tipo di approccio non ha portato a una totale soluzione del problema ma solo a una sua mitigazione; è quindi nata la necessità di un approccio preventivo volto a evitare la produzione degli impatti fin dalla fase di progettazione (approccio life-cycle, ecodesign). Recenti studi e dati ambientali (IPCC, IEA, ONU, FAO) hanno riportato come gli effetti di problemi ambientali, quali ad esempio il cambiamento climatico, stiano avendo importanti conseguenze sulle attività umane e sulla qualità degli ecosistemi (si veda lo studio di Cambridge Institute of Sustainability Leadership, Cambridge Judge Business School, European Climate Foundation). Emerge perciò la necessità di adottare un approccio proattivo che preveda al contempo la prevenzione, la mitigazione ma anche l'adattamento agli impatti. Eventi calamitosi, che si stanno verificando in maniera sempre più frequente richiedono di aumentare la protezione e la preparazione ad affrontare questi eventi. Ciò deve avvenire sia attraverso l'impiego sia di tecnologie appropriate e innovative (es. smart o net-zero), ma anche col coinvolgimento attivo delle persone. Si evince infatti che le numerose innovazioni tecnologiche, di prodotto e di processo non sono sufficienti affinché la transizione verso un mondo sostenibile avvenga alla velocità richiesta per fronteggiare le sfide future. Appare quindi chiara la complessità, ma al contempo l'urgenza, di adottare un approccio *olistico* per l'innovazione sostenibile. La dissertazione ha investigato tra i vari tipi di innovazione, l'approccio sistemico. Tale approccio è in grado di risolvere problemi complessi e facilitare l'individuazione di connessioni e feedback tra i vari componenti del sistema. L'innovazione sistemica, oltre a considerare singoli problemi e settori, si pone a un livello più ampio, a livello di sistema. In questo panorama, la Transizione Sostenibile (ST) si è rivelata un approccio emergente per l'innovazione di sistema, che si pone non solo da un punto di vista tecnico ma socio-tecnico (F.W. Geels, J. Schot, R. Kemp e J. Rotmans). Il termine transizione significa processo di trasformazione, cambiamento. Le teorie delle Transizioni Sostenibili (TST) studiano i processi di trasformazione fondamentale di sistemi socio-tecnici, multi-dimensionali e a lungo termine, attraverso i quali si stabiliscono i passaggi verso modalità più sostenibili di produzione e consumo. Tra le diverse teorie di transizione la dissertazione ha approfondito in particolare la Multi-Level Perspective (MLP) che si rivela un utile strumento di analisi di processi di innovazione. Essa descrive come avviene il cambiamento distinguendolo su tre diversi livelli: livello delle nicchie, livello del regime socio-tecnico, livello generale del contesto socio-tecnico. La MLP esamina la dinamica del cambiamento andando a evidenziare il ruolo determinante delle nicchie come lo spazio dove si crea innovazione in ambiente protetto senza essere sottoposto alle pressioni esterne. In questo contesto, lo Strategic Niche Management (SNM) approfondisce il ruolo strategico delle nicchie e quali le azioni per rafforzarle. Un'altra teoria analizzata dalla dissertazione è il Transition Management (TM) che descrive gli strumenti per avviare processi di transizione. Il TM attraverso un approccio ciclico identifica le azioni da intraprendere a vari livelli: strategico, tattico, operativo e di controllo. In particolare rimarca l'importanza degli esperimenti di transizione come esperimenti su piccola scala che hanno un elevato potenziale per contribuire alla transizione. La conclusione di questa ricerca evidenzia il ruolo strategico delle nicchie nel percorso di transizione e la cruciale relazione tra nicchie ed esperimenti: le nicchie rendono attuabile la sperimentazione, ma allo stesso tempo la sperimentazione crea le nicchie o le rinforza. Da questo quadro metodologico, scaturisce la scelta del metodo con cui valutare l'efficacia dell'approccio di transizione. Il metodo scelto è il Transition Management (TM). Da un punto di vista tecnico la dissertazione individua l'Ingegneria della Transizione come disciplina con un ruolo proattivo nella pianificazione e progettazione di soluzioni innovative, low carbon e resilienti a livello di sistema socio-tecnico. Da questo quadro, è emersa l'importanza di sperimentare la transizione a livello di sistema e la sperimentazione consta nell'applicazione della transizione in ambito universitario attraverso la conduzione di diversi esperimenti di transizione. Il fine ultimo è trasformare i campus in nicchie strategiche di transizione che siano a loro volta motori di cambiamento verso una società sostenibile.

Risultati e discussione

La parte sperimentale della dissertazione è consistita nel testare casi di successo di pratiche di transizione sostenibile in contesti differenti. La transizione è stata per prima sperimentata in Olanda dove numerosi sono i programmi e i progetti applicati in diversi contesti (transizione energetica e transizione urbana). A livello europeo il programma Pioneers into Practice della Climate-KIC promuove l'approccio della transizione attraverso progetti innovativi (http://www.climatekicemiliaromagna.it/). Numerosi sono le esperienze di Urban Transition e la tesi ha analizzato con l'approccio della transizione due casi studio: il PAES (Piano d'azione per l'energia sostenibile) della città di Bologna e le iniziative del movimento delle Transition Towns sempre nell'area di Bologna. I risultati di questi casi studio sono stati utili per individuare l'approccio efficace per avviare un'iniziativa di transizione. Il cuore della dissertazione è infatti costituito dalla sperimentazione di un percorso di transizione sostenibile in ambito universitario. Le università possono infatti contribuire a dimostrare la teoria e la pratica della sostenibilità attraverso azioni volte a comprendere e a ridurre gli impatti delle proprie attività. Lo studio ha permesso di identificare le barriere e le opportunità che si manifestano negli attuali percorsi di campus sostenibili. Nonostante le numerose comunità universitarie che in Italia e all'estero hanno avviato processi importanti verso la sostenibilità, si evincono ancora lacune e difficoltà nel raggiungimento della sostenibilità nei vari ambiti quali attività di ricerca, didattica e azioni concrete di gestione dei campus e di governance. La dissertazione dimostra come attraverso un processo di Transition Management, mutuando su scala di campus le esperienze sempre più diffuse di pratiche di transizione sia possibile facilitare il cambiamento verso la sostenibilità e al contempo avviare nuove opportunità e utili feedback per i campus universitari. In particolare, la dissertazione descrive i passi che hanno caratterizzato l'implementazione di un percorso di transizione presso la sede di via Terracini della Scuola di Ingegneria e Architettura dell'Università di Bologna. La sede di via Terracini è un plesso abbastanza recente, dove sono state già realizzati e sono attualmente in corso misure e interventi con ricadute positive dal punto di vista della sostenibilità. Queste misure sono parte integrante del Piano della Sostenibilità ambientale dell'Ateneo. Dal 2009, infatti Unibo ha avviato percorsi di sostenibilità a livello di ateneo e le misure e gli interventi sono descritti nel Piano della sostenibilità ambientale. Le attività sperimentali sviluppate in questa dissertazione hanno contribuito alla redazione nuovo Piano della Sostenibilità di Unibo (2013-2016), in particolare alle misure dedicate al Plesso di Terracini. Il risultato è stata la nascita dell'iniziativa Terracini in Transizione con la vision di trasformare la Scuola di Ingegneria e Architettura in un living-lab della sostenibilità. Seguendo l'approccio del TM, l'attività sperimentale è consistita nella creazione del Transition Team che è il core team che guida il processo TM. Questo Team trasversale e interdisciplinare è il motore dell'implementazione di iniziative di sostenibilità e resilienza del Plesso di via Terracini. Il Team vede la partecipazione di ricercatori, docenti, personale tecnico, amministrativo e studenti. Uno degli aspetti più significativi di questa iniziativa è il coinvolgimento degli studenti in laboratori esperienziali all'interno di alcuni corsi di insegnamento di Ingegneria. Tali laboratori hanno permesso di far sperimentare agli studenti l'efficacia dell'approccio della transizione, con particolari applicazioni legate alle tematiche della sostenibilità ambientale e dell'Ingegneria della Transizione. Numerosi sono i temi di ricerca risultati dall'iniziativa di Terracini in Transizione e diverse le applicazioni nel campo dell'Ingegneria della Transizione. I progetti avviati si possono raggruppare nelle seguenti aree principali: sostenibilità e risparmio energetico, risparmio idrico e valorizzazione della risorse, gestione dei rifiuti, autocostruzione di uno spazio per gli studenti adottando materiali e tecniche a basso impatto ambientale, applicazione dei concetti di resilienza e di transition technologies al campus universitario. La progettazione degli esperimenti di transizione ha permesso di rafforzare le misure di sostenibilità implementate nel plesso universitario. Al contempo gli esperimenti si sono rivelati un'opportunità e un utile feedback per la didattica, aiutando a mettere in pratica le attività di ricerca. E' stato così possibile ottenere una sinergia tra didattica, ricerca e attività di gestione, «sfruttando» le competenze interne e i processi di apprendimento a beneficio del sistema universitario. Tali benefici sono stati confermati da numerosi riscontri: dal nuovo piano della sostenibilità di Ateneo alla adesione di Unibo all'International Sustainability Campus Network (ISCN), fino al recente risultato della classifica 2014 del ranking internazionale UI Greenmetric World University che valuta l'approccio green nella gestione dei campus (link: http://greenmetric.ui.ac.id/ranking/year/2014). Scopo del ranking è quello di verificare la sostenibilità attraverso quattro prospettive: Setting & Infrastructure, Energy and Climate Change, Waste, Water, Transportation, Education. Nell'edizione 2014, Unibo è risalita di ben 86 posizioni, passando dalla 182esimo posto nel 2014 al 96esimo classificando la prima università green in Italia. Tali segnali confermano che grazie all'approccio della transizione è possibile trasformare le università in «living-lab della sostenibilità». Vi sono poi numerose iniziative sorte in correlazione a Terracini in Transizione e ciò a dimostrazione che i risultati del percorso sono andati al di là della singola applicazione. Seguendo l'approccio del Transition Management, si è andato infatti a costituire un Transition Network di soggetti e iniziative che concorrono al percorso di transizione. Tra questi si segnalano la nascita all'interno di Unibo dell'Integrated Research Team (IRT) Alma Low Carbon, un team di ricerca interdisciplinare sui temi della transizione che coinvolge oltre 100 ricercatori. Inoltre la nascita del Network Italiano degli Atenei Sostenibili e la collaborazione con altre università partner del Programma Europeo Climate-KIC nella predisposizione del progetto Sustainable Campus Launching Customers (www.sustainablecampus.eu). Si segnalano inoltre la collaborazione col Comune di Bologna nei progetti di sostenibilità e resilienza della città e il coinvolgimento di associazioni come Transition Towns e Ingegneri Senza Frontiere nelle iniziative di sostenibilità dell'Ateneo. A conclusione della dissertazione si sottolinea il successo dell'approccio di transizione come strumento di avvio e accelerazione dei percorsi di sostenibilità. In particolare emerge il ruolo cruciale degli esperimenti di transizione e il contributo dell'Ingegneria della Transizione come parte integrante di un percorso interdisciplinare a livello socio-tecnico. Al contempo si identifica la possibilità di trasferire questa esperienza anche in altri contesti come quelli industriali o di governance territoriale per facilitare il cambiamento verso una società sostenibile.

Abstract (English)

With the aim of providing people with sustainable options, engineers are ethically required to hold paramount the safety, health and welfare of the public and answer society's need for sustainable development. Currently, global crisis and correlated sustainability challenges are calling for a fundamental change in culture, structures, and practices. Sustainability Transitions (ST) have been recognized as promising frameworks for radical system innovation towards sustainability. In order to enhance the effectiveness of transformative processes, both the adoption of a transdisciplinary approach and the experimentation of practices have been recognized crucial. The evolution of approaches towards ST provides a series of inspiring cases which allow to identify advances in making sustainability transitions happen. In this framework, the thesis has recognized the role of Transition Engineering (TE). TE adopts a transdisciplinary approach of engineering to face the sustainability challenges and address the risks of un-sustainability. With this purpose, a definition of Transition Technologies is provided as a valid instruments to contribute to ST. In the empirical section, several transition initiatives are analysed especially at urban level. As a consequence, the model of living-lab of sustainability is crucially emerged. Living-labs are environments where innovative technologies and services are co-created with users active participation. In this framework, university plays a key role as learning organization. The core of the thesis has concerned the experimental application of transition approach within the School of Engineering and Architecture of University of Bologna at Terracini Campus. The final vision is to realize a living-lab of sustainability. Particularly, a transition team has been established and several transition experiments have been conducted. The final result is not only the improvement of sustainability and resilience of the Terracini Campus, but the demonstration that university as learning institution can generate solutions and strategies to tackle the dynamic, complex factors fueling the global crisis.

Key words: science of sustainability, resilience, system innovation, transition, living-lab, transition experiments, sustainable campus

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List of abbreviations

AOD Arena of Develoment

EcoAP Eco-Innovation Action Plan

EIO EcoInnovation Observatory

EAUC Environmental Association for Universities and Colleges

GRI Global Reporting Initiative

HEI Higher Education Institution

ISCN International Sustainable Campus Network

LCA Life Cycle Assessment

MLP Multi-Level Perspective

NSPE National Society Professional Engineers

OECD Organisation for Economic Co-operation and Development

SD Sustainable Development

SEAP Sustainable Energy Action Plan

SNM Strategic Niche Management

ST Sustainability Transitions

STARS Sustainability Tracking, Assessment & Rating System

TE Transition Engineering

TIS Technological Innovation Systems

TM Transition Management

TST Theories of Sustainability Transitions

UHIE Urban Heat Island Effect

Table of Contents

1 Introduction

I say to you today, my friends, so even though we face the difficulties of today and tomorrow,
I still have a dream.
Martin Luther King

According to the Code of Ethics for Engineers (NSPE, 2014), engineers are "ethically required to hold paramount the safety, health and welfare of the public and answer society's need for sustainable development". Currently, global crisis and its correlated sustainability challenges are calling for a fundamental change in culture, structures, and practices. In effect, the global crisis trends urgently require the implementation of new ways to reach sustainable development goals. Above all, climate change effects, intensification of resources use, limits of water and energy sources, growing waste generation as well as the general state of the environment, of the economy and of the world population are calling for a radical change, to be more precise a transition. Due to the complexity of the global crisis, a nexus approach is needed in order to redress the direction of the business-as-usual trajectories. Actually, it has been recognized that efforts to address only one part of a systemic problem by neglecting other inherently inter-linked aspects, may not lead to desirable and sustainable outcomes. Furthermore, due to the increase of negative effects produced by global issues as climate change is, not only mitigation actions are needed. But, it is necessary to improve our resilience, i.e. our capacity to absorb disturbances and to adapt to stress and change. Therefore, developing sustainable and resilience-building systems has become a strict and increasing necessity for our future. Science has a great responsibility in this respect to provide a better understanding of the multiple challenges humanity is facing and to explore solutions for sustainable development. Therefore, the urgency of innovations towards sustainability has become fundamental in order to tackle the dynamic, complex factors fuelling the global crisis of our days. A definition of Sustainable innovation, according to the European Eco-Innovation Action Plan EcoAP (2012), states: : "*Eco-innovation is any form of innovation resulting in or aiming at significant and demonstrable progress towards the goal of sustainable development through: reducing impacts on the environment,* *enhancing resilience to environmental pressures and achieving a more efficient and responsible use of natural resources.*" At the beginning of this research thesis in 2012, the Eco-Innovation Observatory (EIO) published the Annual Report "Europe in Transition: Paving the Way to a Green Economy through Eco-innovation". The report stated that in spite of a number of sustainable innovation approaches and increasing eco-innovation initiatives, the effectiveness of innovation towards sustainability is not yet strong enough (EIO, 2013). In fact, sustainability challenges require new approaches and new knowledge frameworks. In particular, an emerging research framework is transdisciplinarity which is based on the idea of "switching from science *for society* to science *with society".* Lang et al. (2012) state that *transdisciplinarity is aiming at the solution or transition of societal problems and concurrently of related scientific problems by differentiating and integrating knowledge from various scientific and societal bodies of knowledge*. Accordingly, sustainable innovation should be an instrument for the reunion of science with society.

The purpose of this thesis is to identify advances in the approach of sustainable innovation. In particular, the role for engineering discipline is deeply explored in the sustainable innovation process.

The **first objective** of the thesis is to explore the evolution of sustainable innovation approaches (Chapter 3) and to analyze a series of inspiring cases useful to distinguish the most effective approach (Chapter 4). The first important insight is that the urgency of a systemic transformation requires a transformative change in the entire system of practices and provisions. There is the need to identify the roots of systemic problems and to adopt a systemic approach for enhancing eco-innovation in order to shift towards sustainability in a coordinated way. Eco-innovation should go beyond stand-alone innovations and combine product, process, organizational, marketing, and social eco-innovation towards a transformative system eco-innovation. According to OECD (2012), transformative system eco-innovation aims at building up a shared understanding of how and why systems work in order to integrate all the system components and to move the entire system towards sustainability. The second insight concern the dimension of innovations which is not only technology-driven, but needs to involve social and structural aspects. System approach is based on the concept of *socio-technical system*, consisting of actors and networks (individuals, firms, and other organizations, collective actors) and institutions (societal and technical norms, regulations, standards of good practice), as well as material artifacts and knowledge (Geels, 2004; Markard, 2011; Weber, 2003). A third important insight is that system approach recognizes that a broad variety of system elements are strongly interrelated and dependent on each other. This feature is also renowned as *co-evolutionary* approach. In order to highlight the co-evolutionary approach of socio-technical systems, the thesis analyzes two case studies of sustainable innovation: the former is a case of sustainable innovation regarding an industry sector as automotive is (Bonoli and Cappellaro, 2013a). The latter concerns a sustainable innovation practicing at urban level and it consists in the introduction of a water fountain in a small town of Italy (Cappellaro et al., 2013). In particular, the water fountain case study implements business models innovation since the adoption of an alternative modes of water provision.

The **second objective** of this thesis is related to the analysis of frameworks and practices of system innovation (Chapter 5 and 6). Over the past 15 years, a number of conceptual frameworks has been developed for the study of system innovation. Especially, sustainability transitions have been recognized as *a research field for long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption* (Markard, Raven and Truffer, 2012). The thesis studies different Theories of Sustainability Transitions (TST). In this research, several TST frameworks have the scope to analyze the transition dynamics; in other words they explain how the transitions originate, work and take place. Important theories are Technological Innovation Systems, TIS, Multi-Level Perspective (MLP) and Strategic Niche Management, SNM. The first insight is the importance of the concept of *niche*. In the ST perspective, niches are small-scale protected space that could be a beginning of radical innovation. The characteristics of niches enable experimenting and learning about novel or deviant culture, practices and structures. At the same time, niches are also shaped by learning experiences that become aggregated and embedded in new or deviant constellations of culture, practices, structures. A second insight is therefore that experimenting and learning are central instruments of TST. Transition experiments provide an alternative to classical innovation projects which are focused in obtaining short-term solutions. Definitely, the implementation of transition experiments contributes to support the process of sustainability transitions. On the other hand, other Transition Sustainability Theories aim to examine the management of the transformative change, viz. what influences the speed and the direction of change. In this field, a most notable process is provided by the Transition Management, TM (Kern and Smith, 2008; Loorbach, 2010; Rotmans et al., 2001). TM is characterized by a prescriptive cyclical framework of co-evolving activities with the capacity to shape a participatory process. The third insight is that TM provides instruments that can contribute in effective way to steer the sustainability transition process. Important TM instruments are Transition Team, Transition Arena, Transition Experiments and Transition Network. Additionally, TM also recognizes the importance of experimenting. Following this insight, the thesis investigates methods and recognizable examples of successful transition practices and initiatives in order to demonstrate which mechanisms, strategies and tools allow to trigger an effective transition process. Especially, it has been observed that most of transitions experiences are put into practice at urban level. Consequently, two cases of urban transition have been investigated under the lens of transition: the top-down initiatives of Sustainable Energy Action Plan (SEAP) of the City of Bologna and of the bottom-up movement of Transition Towns. An important insight is related to the importance of combining top-down and bottom-up approach. With this purpose, the *living-lab* concept has been recognized as a model to implement effective transition practices. In particular, living-labs are environments where innovative technologies and services are co-created with the users active participation. At the same time, transition practices have demonstrated they are catalysts of living-lab of sustainability in a mutual learning processes involving actors. As a consequence, the insight is a new role for the research embracing transdisciplinarity.

The **third objective** of the thesis is related to distinguish the role of engineering both in the transitions theories and practices (Chapter 7). Yarime (2012) originally proposed that *transdisciplinarity can be considered the engineering task of the twenty-first century*. With this purpose, Transition Engineering TE was first defined by Krumdieck and Dantas (2008) as an emerging discipline to face the sustainability challenges and address the risks of un-sustainability. The first insight is to outline synergies among Transition Engineering and TST. According to Krumdieck (2013), TE can provide a portfolio of tools and methods that allow to put into practice successful transition processes. Especially, this research investigates several correspondences between Transition Engineering and Transition Management. The second insight is that Transition Engineering can play an important role in the transition practices especially regarding the role of technologies. The focus has been not only on the specific aspects of technology, rather on the role that technology plays in conjunction with other instruments of the transition process. With this purpose, the concept of Transition Technology (TT) has been here introduced and defined. The final vision is that TT could contribute to transition practices especially in the co-creation of living-labs of sustainability As final insight, the thesis demonstrates that TE can become part of the Sustainability Transitions research fields.

The **final objective** is to combine the theories and practices of Sustainability Transitions (ST) in order to prove the potential of this emerging approach for system innovation towards sustainability. According to the Sustainability Transitions Research Network (STRN, 2010:4), emerging future lines of ST need to focus on expanding the application domains of transitions into new problems such as education, health care, welfare state, etc. The thesis has chosen education as promising domain for ST research (Chapter 8). Therefore, education is an important driver in order to achieve sustainable production and consumption patterns. In addition, universities are a model for a formal and organized education. The first insight is that several universities have begun the commitment to sustainability and a number of initiatives are aimed to integrate it into their university policy, organization and activities. In spite of the large number of outstanding higher education initiatives, several barriers still affect a truly holistic adoption of sustainability. This research is focused on describing the nature, risks and challenges associated to the university commitment to sustainability. With this purpose, barriers and exemplary initiatives which can affect the transition towards sustainability are identified. According to Sharp (2002), a crucial challenge for university system can be to *achieve mission alignment between teaching, research and campus operations, harnessing the vast collective learning process that is currently underway within its walls, to benefit its own systems*. Additionally, Lozano et al. (2014) identified several key elements characterizing Higher Education Institutions, HEIs, such as curricula, education, research, operations, community outreach, on-campus experiences, assessment and reporting. In order to establish a systemic integration among these elements, ST could play a crucial role. The thesis aims to provide an understanding on how to strengthen a real transformation of university system towards sustainability, proposing the implementation of a transition process within the entire system of university. The final vision is the transformation of the whole university system into a living laboratory of sustainability. The core of the thesis has concerned the experimental application of transition approach within the University of Bologna (Chapter 9 and 10). Unibo is therefore recognised as the oldest university in continuous operation and it has been selected for experimenting transition because it is a complex organization with a variety of projects, programs and initiatives related to sustainability. On the other hand, several weaknesses still inhibit a real transformation of this university in a place of sustainability. Thus, the necessity of re-orienting Unibo trajectories for a long term perspective on sustainability has become a crucial issue. With this purpose, a TM process has been implemented within the School of Engineering and Architecture of University of Bologna at Terracini Campus. It has been assumed that Terracini Campus can be considered as a transition niche and correlated effects are examined in order to drive the transitions process.

Finally, the choice of investigating sustainability initiatives at university level and the introduction of a new role of engineering discipline can reveal a broadening in the application domains of the Theories of Sustainability Transitions. As a consequence, new considerations and contributions can be added in the field of the science of sustainability.

2 Global Crisis and Sustainability Challenge

When written in Chinese, the word 'crisis' is composed of two characters.
One represents danger and the other represents opportunity.
John F. Kennedy

2.1 The concept of sustainability

Sustainability has been defined in many ways and frequently the terms "sustainability" and "sustainable development" have been used interchangeably. In fact, "sustainability" refers to the goal and "sustainable development" to the path or framework to achieve it. The most frequently quoted definition of sustainable development (SD) is from Our Common Future, also known as the Brundtland Report (World Commission on Environment and Development,1987):

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"

The Commission further defined two key concepts of sustainable development: (1) needs, specifically the essential needs of those living in poverty; and (2) limitations, specifically those imposed by technology and social structures on the environment's ability to meet present and future needs. In essence, sustainability is our capacity to continue to live life on our planet, the ability to endure.

Since Brundtland Report (1987), strategic reports, international conferences and summits have been realized. Sustainability was the main theme of what is often called the Earth Summit held in Rio de Janeiro in 1992. After 20 years, in 2012, the Rio+20 vision of sustainable development has adopted a holistic concept for sustainability introducing four dimensions of society (see Figure1):

- Economic development (including the end of extreme poverty),
- Social inclusion,
- Environmental sustainability,
- Good governance including peace and security.

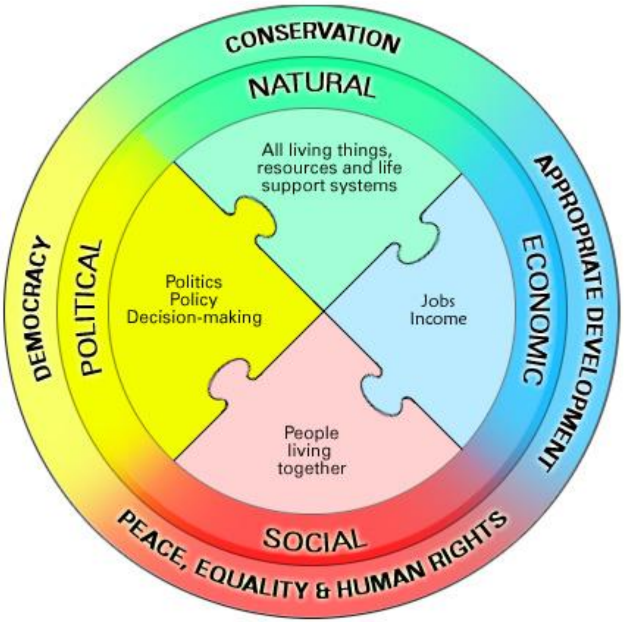


Figure 1: Four dimensions of sustainability (UNESCO, 2015)

Societies aim to achieve all four dimensions. Failures in one area, such as environmental sustainability or social inclusion, can undermine progress in others, such as the eradication of poverty. Poor governance and insecurity can all too easily undermine progress on economic, social, and environmental objectives. Sustainability is therefore an ultimate goal or destination. But how much are we sustainable now? In the following paragraphs an overview of the state of sustainable development is globally analysed.

2.2 State of Sustainable Development

Since 2000, when the Millennium Declaration was adopted, sustainability has been part of the eight Millennium Development Goals (MDGs). MDGs have been promoted by the United Nations (UN) and signed by 191 Heads of State from around the world. At the end of 2015, the fifteen-year period will be completed (Figure 2).

Figure 2: The eight Millennium Development Goals (MDGs) (UN, 2015)

Since 2000, important results have been achieved. The infant mortality rate was reduced by 41%, with less than 14,000 child deaths every day in comparison to 1990, 56 million more children go to school every year, and the number of people living below the poverty line of $ 1.25 a day has halved. This rate dropped to 22 per cent by 2010, reducing the number of people living in extreme poverty by 700 million. Access to safe drinking water has been greatly expanded. In 2012, 89 per cent of the world's population had access to an improved source, up from 76 per cent in 1990. Over 2.3 billion people gained access to an improved source of drinking water between 1990 and 2012. Targeted investments in fighting malaria, AIDS and tuberculosis have saved millions. More children than ever are attending primary school. By 2012, all developing regions have achieved, or were close to achieving, gender equality in primary education. The political participation of women has continued to increase in January 2014, 46 countries boasted of having more than 30 per cent female members of parliament in at least one chamber.

Although huge progress has been made towards achieving the Millennium Development Goals (MDGs), much more effort is needed. Major trends that threaten environmental sustainability continue and we are facing a global crisis affected by different and interconnected issues. Millions of hectares of forest are lost every year, many species are being driven closer to extinction and renewable water resources are becoming scarcer. The extinction of plant and animal species will potentially affect the development of new drugs; it will reduce ecosystem adaptability and lead to the loss of genetic resources. In the following paragraphs, an overview of the different aspects of global crises are described.

2.3 Environmental crisis

In spite of immense technological development and progress, our economies and societies still fundamentally depend on ecosystems to provide us with a hospitable climate, clean water, food, fibers and numerous other goods and services. It is time to fully realize that our societies and economies are integral parts of the biosphere, and to start accounting for and governing natural capital.

2.3.1 Loss of biodiversity

According to WWF (2014), the Living Planet Index (LPI), which measures trends in thousands of vertebrate species populations, shows a decline of 52 per cent between 1970 and 2010 (Figure 3).

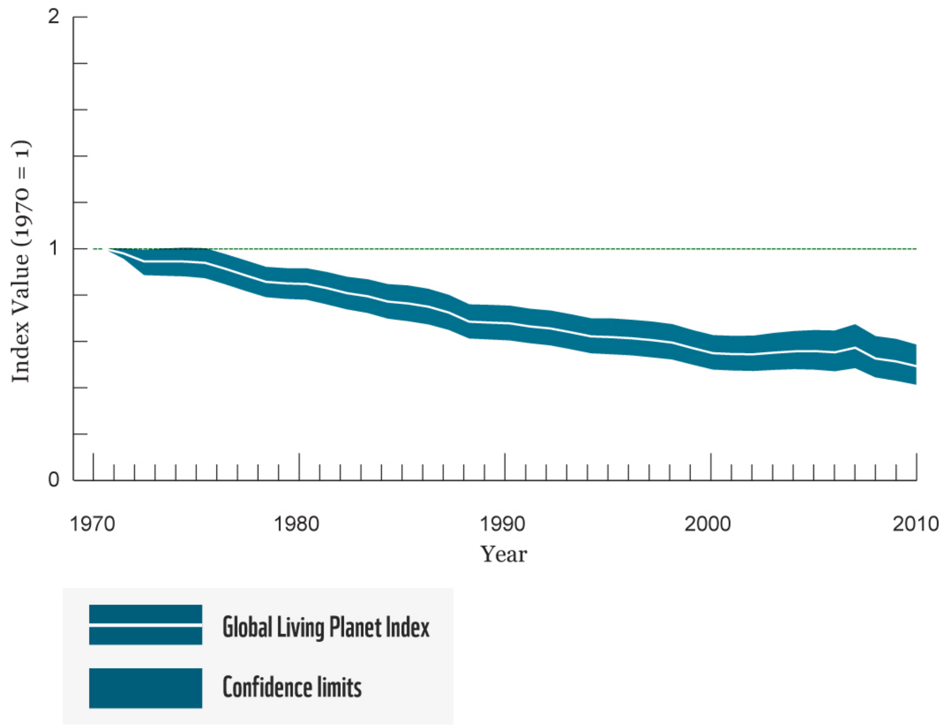


Figure 3: Living Planet Index (WWF, 2014)

Terrestrial LPI	Terrestrial species declined by 39 per cent between 1970 and 2010, a trend that shows no sign of slowing down (see Figure).
Freshwater LPI	The LPI for freshwater species shows an average decline of 76 per cent. The main threats to freshwater species are habitat loss and fragmentation, pollution and invasive species. Changes to water levels and freshwater system connectivity – for example through irrigation and hydropower dams – have a major impact on freshwater habitats.
Marine LPI	Marine species declined by 39 per cent between 1970 and 2010. The period from 1970 through to the mid-1980s experienced the steepest decline, after which there was some stability, before another recent period of decline. The steepest declines can be seen in the tropics and the Southern Ocean – species in decline include marine turtles, many sharks, and large migratory seabirds like the wandering albatross

Table 1: Different types of Living Planet Index

The number of mammals, birds, reptiles, amphibians and fish across the globe is, on average, about half the size it was 40 years ago. This is a much bigger decrease than what was previously reported, as a result of a new methodology which aims to be more representative of global biodiversity. In Figure 4, the causes of the decline in biodiversity are outlined, such as habitat loss, degradation, exploitation (through hunting and fishing).

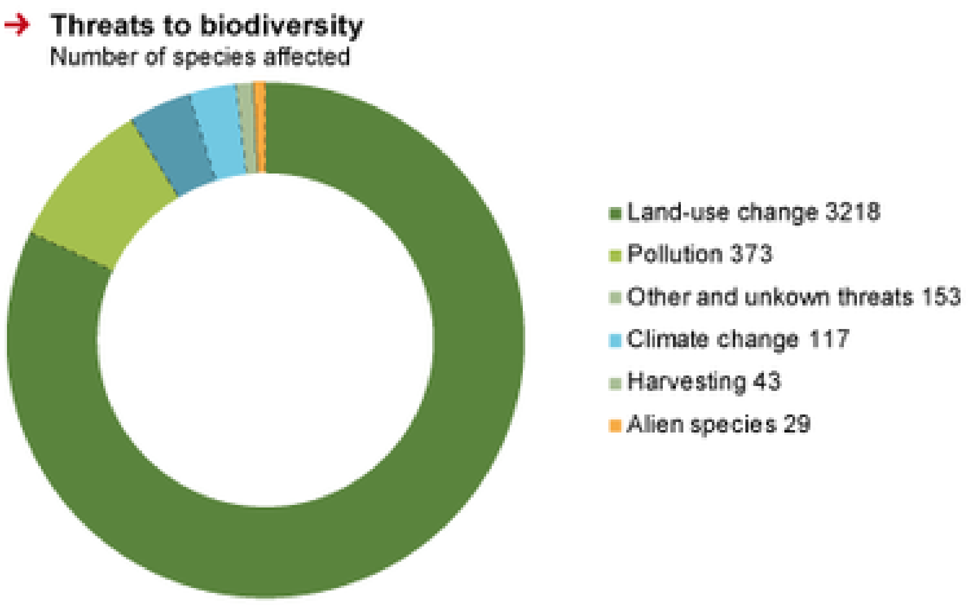


Figure 4: Threats to biodiversity (NBIC, 2010)

The loss of habitat to make way for human land use – particularly for agriculture, urban development and energy production – continues to be a major threat, compounded by hunting.

2.3.2 Soil degradation

In many parts of the world natural resources have been treated as unlimited and totally resilient to human exploitation. This perception has exacerbated the conflicting agricultural demands on natural capital, as have other exploitative commercial enterprises. Both have affected local culture and had undesirable long-term impacts on the sustainability of resources. The consequences include: land degradation (about 2,000 million ha of land worldwide) affecting 38% of the world's cropland; reduced water and nutrient availability (quality and access), (Figure 5).

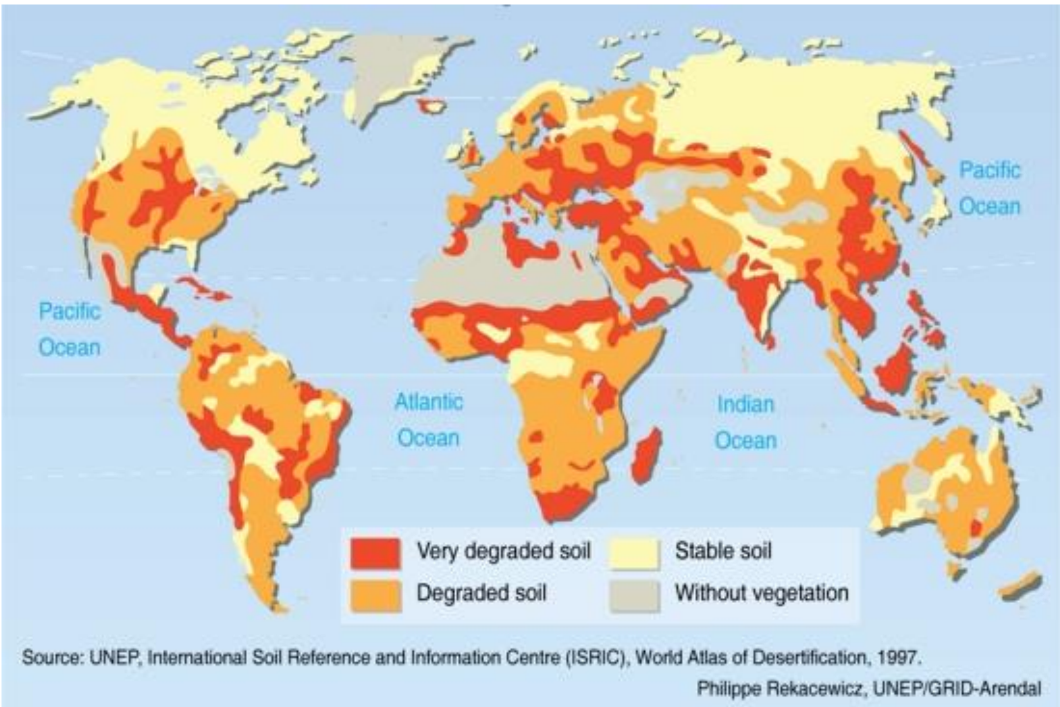


Figure 5: Soil depletion (UNEP/ISIRC, 1997)

Depleted soils increase the risks of malnutrition for farmers. Productivity losses on tropical soils are estimated to be in the range of 0.5-1.5 per cent of GNP, while secondary productivity losses are due to siltation of reservoirs, transportation channels and other hydrologic investments. Soil erosion commonly appears after conversion of forests into agricultural land, thus sweeping away fertile soil, pesticides and the sources of livelihood for humans and wildlife.

2.3.3 Deforestation

Deforestation comes in many forms, including fires, clear-cutting for agriculture, ranching and development, unsustainable logging for timber, and degradation due to climate change. This impacts people’s livelihoods and threatens a wide range of plant and animal species. Some 46-58 thousand square miles of forest are lost each year—equivalent to 36 football fields every minute (WWF, 2015).

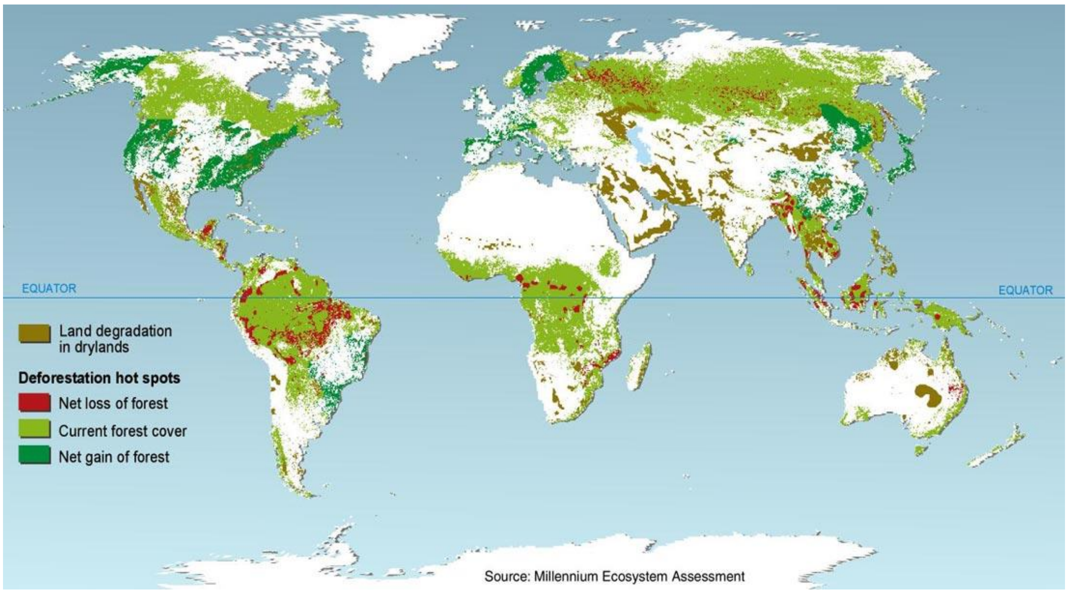


Figure 6: Global deforestation state (Millennium Ecosystem Assessment, 2015)

Forests cover 31% of the land area on our planet. They produce vital oxygen and provide homes for people and wildlife. Many of the world's most threatened and endangered animals live in forests and 1.6 billion people rely on benefits forests offer, including food, fresh water, clothing, traditional medicine and shelter. Death and disease can result from the localized flooding caused by deforestation. Loss of sustainable logging potential and of erosion prevention, watershed stability and carbon sequestration provided by forests are among the productivity impacts of deforestation (Figure 6).

2.3.4 Solid and hazardous waste pollution

Another cause of soil degradation is waste. With the increase in the global population and the rising demand for food and other essentials, there has been a rise in the amount of waste being generated daily. However, not all of this waste gets collected and transported to the final dumpsites. If at this stage the management and disposal is done improperly, it can cause serious impacts on health and problems to the surrounding environment. Diseases are spread by uncollected garbage and blocked drains; the health risks from hazardous wastes are typically more localized, but often acute. Waters affect productivity through the pollution of groundwater resources (Desai, 2013).

2.3.5 Water pollution and water scarcity

Perhaps the most obvious examples of a negative human impact on the environment is water pollution. It is evident that water is necessary to survive but few people realize how much we need and just how much is available. Water covers 70% of our planet, however, freshwater is incredibly rare. Only 3% of the world's water is fresh water, and two-thirds of that is tucked away in frozen glaciers or otherwise unavailable for our use. As a result, some 1.1 billion people worldwide lack access to water, and a total of 2.7 billion find water scarce for at least one month of the year. Inadequate sanitation is also a problem for 2.4 billion people who are exposed to diseases, such as cholera and typhoid fever, and other waterborne illnesses. Two million people, mostly children, die each year from diarrheal diseases alone.

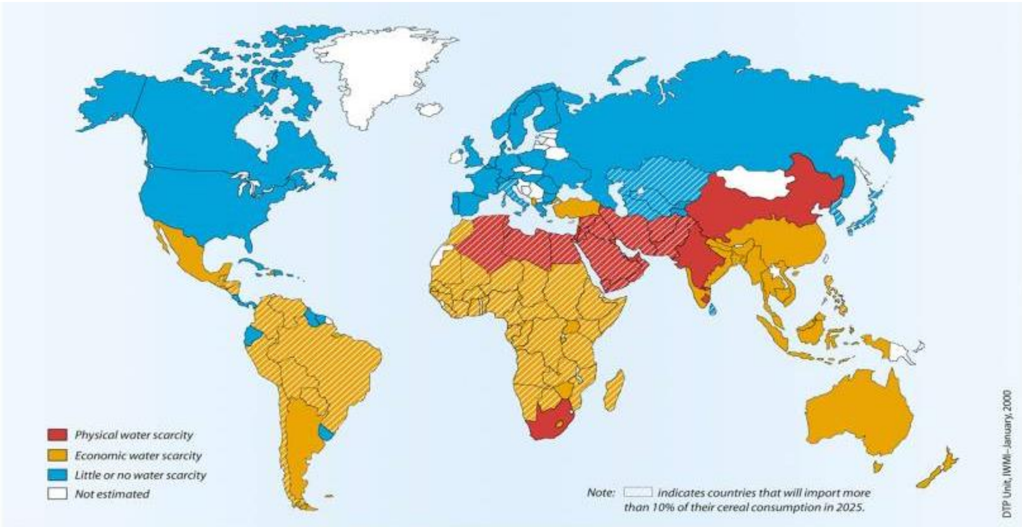


Figure 7: Projected Water Scarcity (IWMI, 2000)

Many of the water systems that keep ecosystems thriving and feed a growing human population have become stressed. Rivers, lakes and aquifers are drying up or becoming too polluted to use. More than half the world's wetlands have disappeared. Agriculture consumes more water than any other source and wastes much of that through inefficiencies. Climate change is altering patterns of weather and water around the world, causing shortages and droughts in some areas and floods in others. At the current consumption rate, this situation will only get worse. As shown in Figure 7, by 2025, two thirds of the world's population may face water shortages. And ecosystems around the world will suffer even more

2.3.6 Air pollution

Air pollution is one such form that refers to the contamination of the air, either indoors or outside. A physical, biological or chemical alteration of the air in the atmosphere can be termed as pollution. It occurs when any harmful gas, dust, or smoke enters the atmosphere and makes it difficult for plants, animals and humans to survive as the air becomes dirty.

Air pollution can further be classified into two sections: visible air pollution and invisible air pollution. Another way of looking at air pollution could be any substance that holds the potential to hinder the atmosphere or the well being of the living beings surviving in it. The sustainment of all living things is due to a combination of gases that collectively form the atmosphere; the imbalance caused by the increase or decrease of the percentage of these gases can be harmful for survival.

The Ozone layer considered as crucial for the existence of the ecosystems on the planet is being depleted by increased pollution. Global warming, a direct result of the increased imbalance of gases in the atmosphere has come to be known as the biggest threat and challenge that the contemporary world has to overcome in a bid for survival.

The causes of air pollution are:

- Burning of fossil fuels: sulphur dioxide emitted from the combustion of fossil fuels like coal, petroleum and other factory combustibles is one the major cause of air pollution. Pollution emitting from vehicles including trucks, jeeps, cars, trains, airplanes cause an immense amount of pollution. We rely on them to fulfil our daily basic needs of transportation but their overuse is killing our environment as dangerous gases are polluting the environment. Carbon monoxide caused by an improper or incomplete combustion and generally emitted from vehicles is another major pollutant along with nitrogen oxide, that is produced from both natural and manmade processes.

- Agricultural activities: ammonia is a very common by-product of agriculture-related activities and is one of the most hazardous gases in the atmosphere. The use of insecticides, pesticides and fertilizers in agricultural activities has grown significantly. They emit harmful chemicals into the air and can also cause water pollution.
- Exhaust from factories and industries: manufacturing industries release large amounts of carbon monoxide, hydrocarbons, organic compounds, and chemicals into the air thereby depleting the quality of it. Manufacturing industries can be found at every corner of the earth and there is no area that has not been affected by it. Petroleum refineries also release hydrocarbons and various other chemicals that pollute the air and also cause land pollution.
- Mining operations: mining is a process wherein minerals below the earth are extracted using large equipments. During the process dust and chemicals are released in the air, thus causing massive air pollution. This is one of the reasons accounting for the deteriorating health conditions of workers and nearby residents.
- Indoor air pollution: household cleaning products, painting supplies emit toxic chemicals in the air and consequently cause air pollution.

2.4 Climate Crisis

Climate change has long since ceased to be a scientific curiosity and is no longer just one of many environmental and regulatory concerns. As the United Nations Secretary General has said, it is the major, overriding environmental issue of our time, and the single greatest challenge facing environmental regulators. Taking into consideration climate change effects, frequent and extreme weather events are growing, but the effects of climate change are not only described by data and scenarios, climate change is redrawing the world economy and is dramatically worsening human lives (IPCC, 2014, World Bank Report 2012). As a consequence, it is a growing crisis with the economy, health and safety, food production, security, and other dimensions (UNEP, 2015). Carbon dioxide is probably the most important greenhouse gas as it accounts for the largest proportion of the 'trace gases' and is currently responsible for 60% of the 'enhanced greenhouse effect'. Global emissions of carbon dioxide (CO_2) continued their upward trend and those in 2011 were almost 50 per cent above their 1990 level.

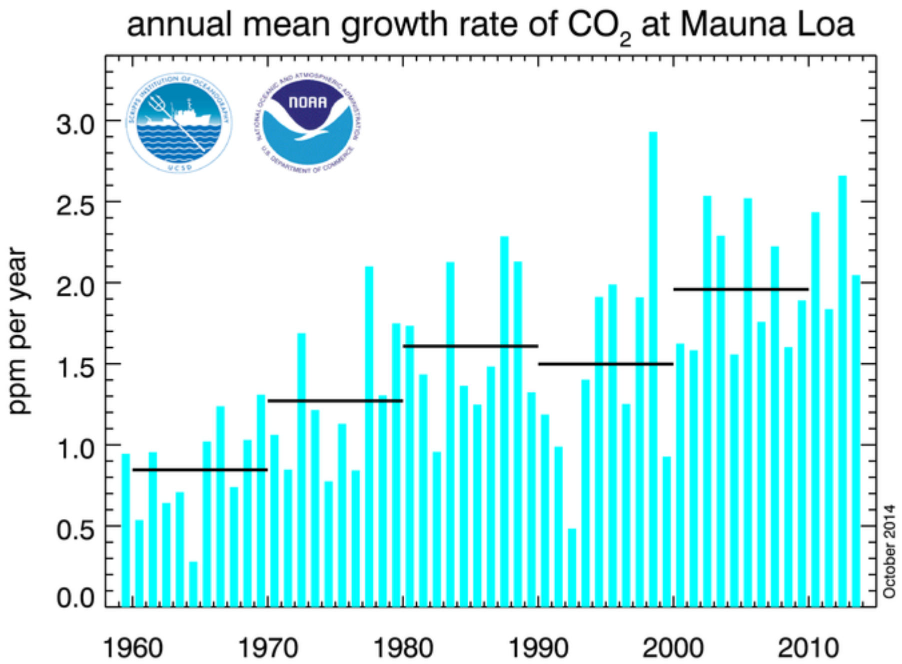


Figure 8: Annual mean growth rate of CO_2 at Mauna Loa (NOAA/ESRL, 2014).

The graph (Figure 8) clearly shows annual mean carbon dioxide growth rates for Mauna Loa. Based on the comparison of atmospheric samples contained in ice cores and more recent direct measurements, it provides evidence that atmospheric CO_2 has increased since the Industrial Revolution. Correspondingly, observations, theoretical studies and model simulations indicate an overall warming since the mid-20th century. It is at least 95% certain that human activities have caused more than half of the temperature increase since the 1950s. This warming is responsible for climate change effects worldwide.

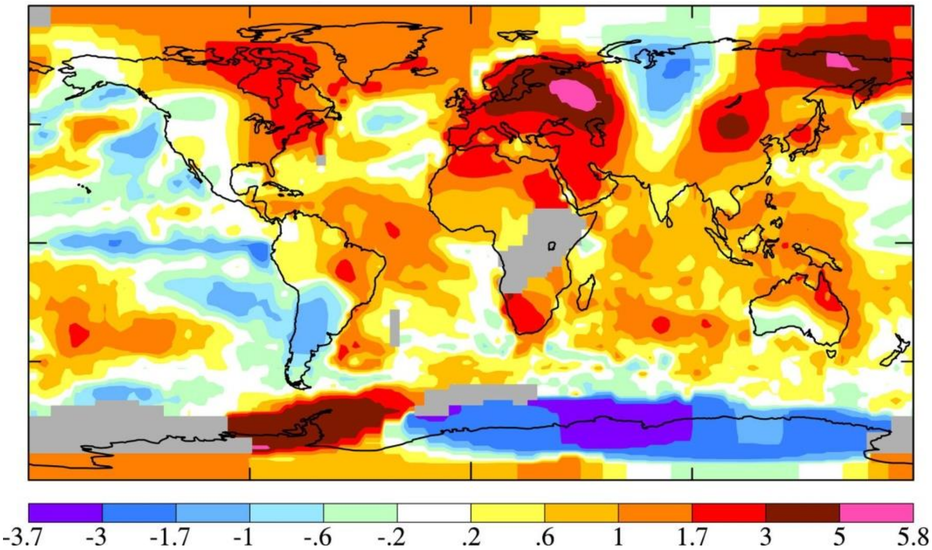


Figure 9: Surface Temperature Anomaly (° C) in July 2010, base period 1951-1980

Figure 9 shows that the surface temperature over the land and ocean temperature is rising across the globe. The map shows the temperature anomaly relative to the month of July 2010 in comparison with the period 1951-980. The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC)[1] strongly shows that human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems. Human activities, particularly the emission of carbon dioxide, are

[1] The Fifth Assesment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) is the most detailed assessment of climate change ever. It is based on more data, contains more detailed regional projection and it is more confident about its conclusion than any global assessment to date.

causing a sustained and unequivocal rise in global temperatures. Concurrently, the rise in global temperatures is causing changes in all geographical regions: the atmosphere and oceans are warming, the extent and volume of snow and ice are diminishing, sea levels are rising and weather patterns are changing. Many changes are unprecedented over decades to millennia. Climate models project continued changes under a range of possible greenhouse gas emission scenarios over the 21st century. Climate change evidently affects all regions of the world. To this purpose, figures 10a, 10b and 10c provide climate change information and evidence from various credible sources across the globe and also specific data concerning the Italian region of Emilia-Romagna. It can be observed that there is strong evidence of climate change. It has been taking place within the atmosphere, land, ocean, snow and ice systems with an unprecedented frequency over decades to millennia. The rising levels of greenhouse gases (particularly carbon dioxide) from the burning of fossil fuels and land-use changes (such as deforestation) are in large part driving warming. According to IPCC (2015) natural processes (like changes in solar activity) are responsible for only a very small proportion of recent temperature changes. Therefore, in this most recent period of the Earth's history, starting in the 18th century, the activities of humans first began to have a significant global impact on the Earth's climate and ecosystems. This period has been called Anthropocene, a term coined in 2000 by the Nobel Prize winning scientist Paul Crutzen (Steffen et al., 2011).

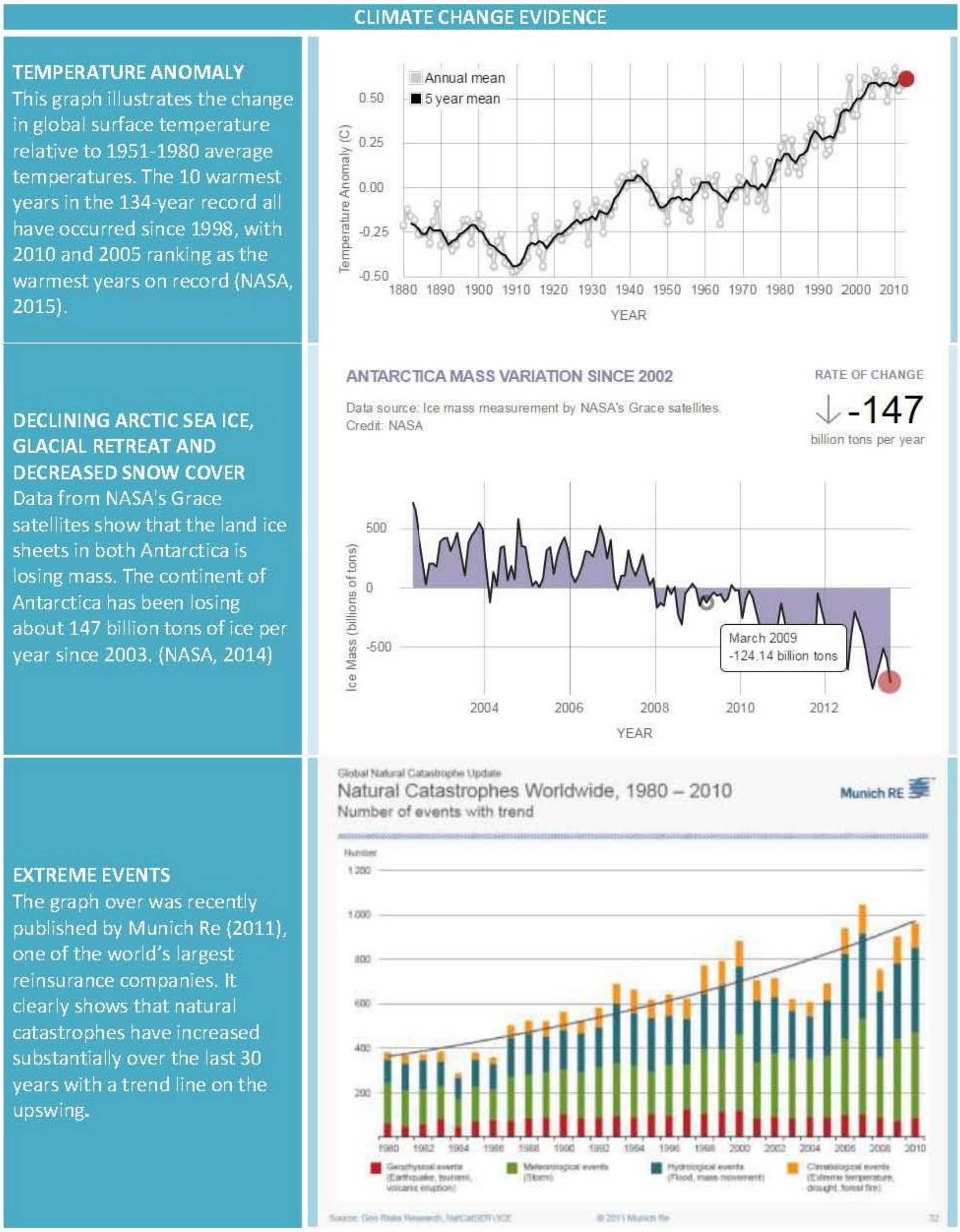
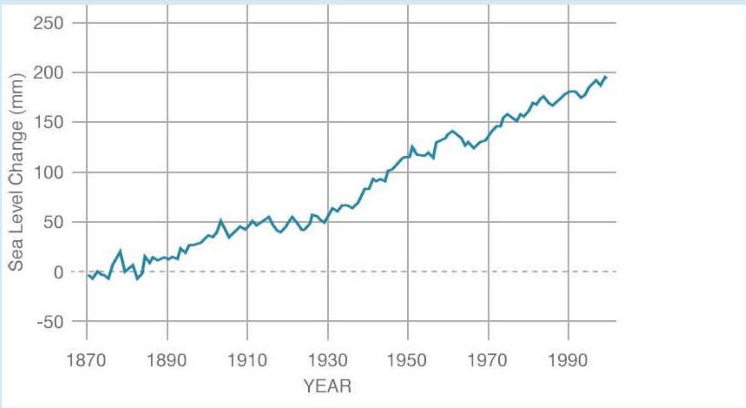


Figure 10a: Global Climate change information and evidence

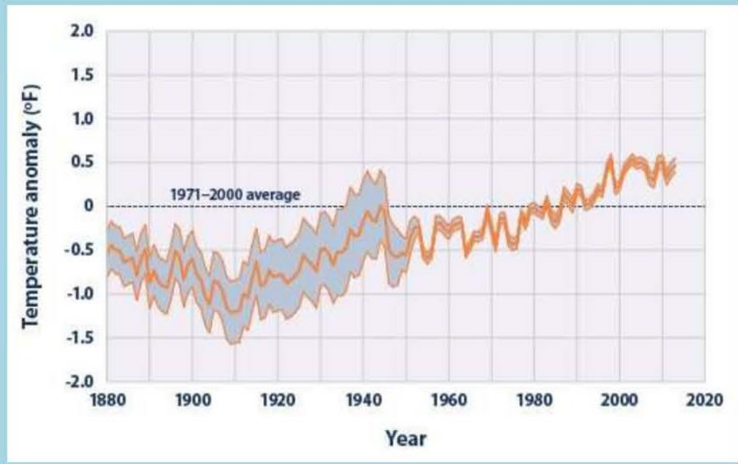
SEA LEVEL RISE

The chart (derived from coastal tide gauge data), shows how much sea level changed from about 1870 to 2000. The main causes of sea level rise over the past 50 years are ocean warming (water expands when it is warmed) and melting glaciers and ice sheets. The evidence is therefor that the rate at which global mean sea level is rising has accelerated over the past 200 years. (Coastal tide gauge records).



WARMING OCEANS

This graph shows how the average surface temperature of the world's oceans has changed since 1880. Sea surface temperature increased over the 20th century and continues to rise. From 1901 through 2013, temperatures rose at an average rate of 0.13°F per decade. Sea surface temperatures have been higher during the past three decades than at any other time since reliable observations began in 1880 (EPA, NOAA).



SEA ACIDIFICATION

This graph shows the time series of atmospheric CO_2 at Mauna Loa, surface ocean pH, and pCO_2 at Ocean Station ALOHA in the subtropical North Pacific Ocean. There can be observed a correlation between rising level of carbon dioxide in the atmosphere at Mauna Loa with rising CO_2 levels in the nearby ocean at Station Aloha. As more CO_2 accumulates in the ocean, the pH of the ocean decreases (Doney et al., Annual Review of Marine Science, 2009).

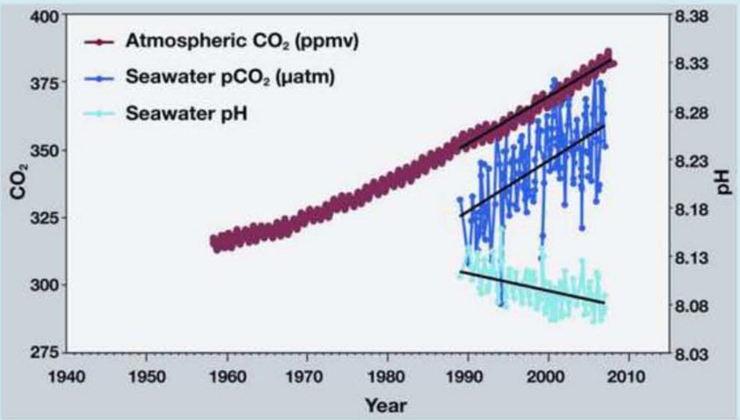


Figure 10b: Global Climate change information and evidence

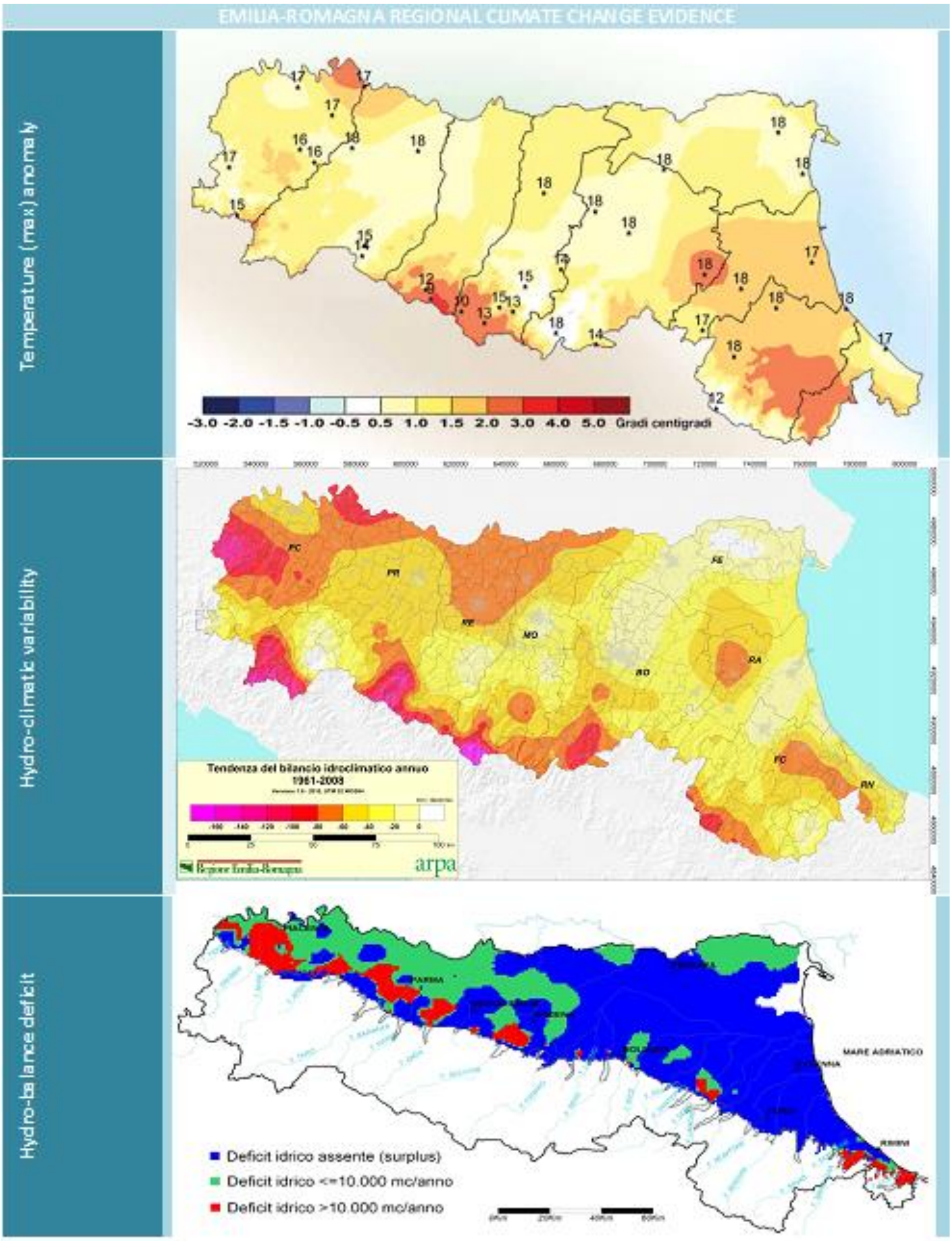


Figure 10c: Regional Climate change information and evidence (ARPA, 2015).

2.5 Energy crisis

We rely on coal, oil and gas (the fossil fuels) for over 80% of our current energy needs – a situation which shows (Figure 11) little sign of changing over the medium-term without drastic policy changes. On top of this, energy demand is expected to grow by almost half over the next two decades. Understandably this is causing some fear that our energy resources are starting to run out, with devastating consequences for the global economy and global quality of life.

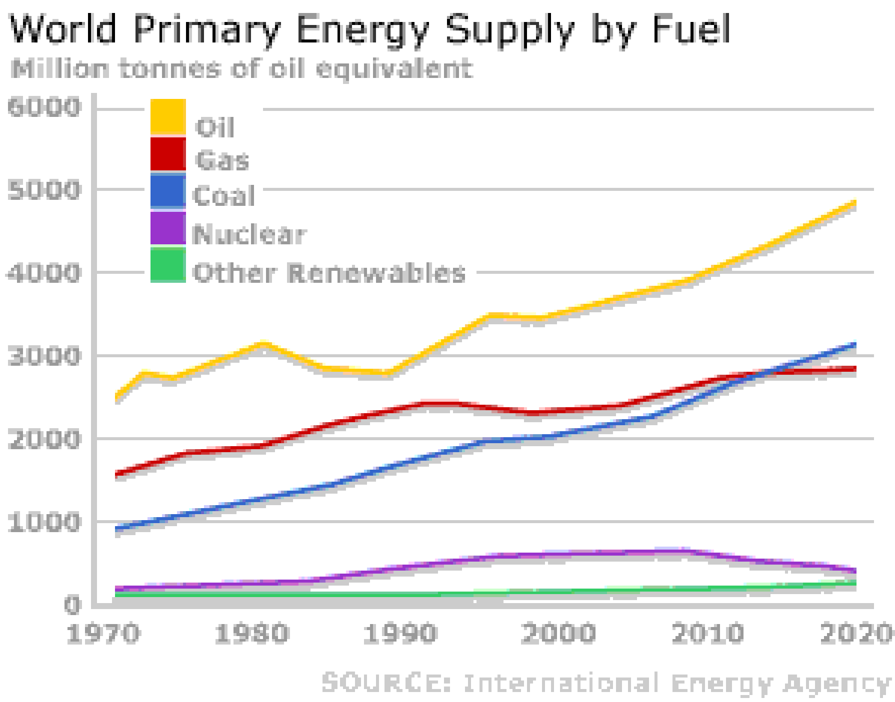


Figure 11: World Primary Energy Supply by Fuel (IEA, 2013)

The potential for crisis if we run out of energy is very real but there is still time before that occurs. In the past two decades proven gas reserves have increased by 70% and proven oil reserves by 40%. At expected rates of demand growth we have enough for thirty years supply. Moreover, better technology means that new oil and gas fields are being discovered all the time while enhanced recovery techniques are opening up a potentially huge array of unconventional sources, including tar sands, shale gas and ultra-deepwater. Ultimately, the near-unlimited supply potential of renewable energy sources should ensure that the world does not fall short of its energy needs.

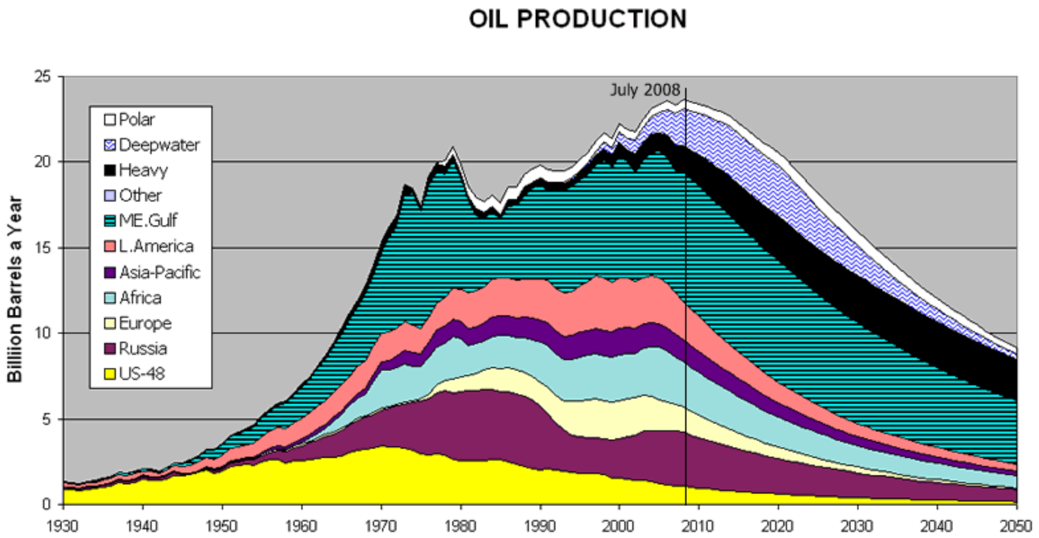


Figure 12: Oil Production by geographic area.

The *security* of global energy supplies is problematic. Today, oil and gas reserves are in the hands of a small group of nations, several of which are considered politically unstable or have testy relationships with large consuming countries. Eighty per cent of the world's proven oil reserves are located in just three regions: Africa; Russia and the Caspian Basin; and the Persian Gulf (Figure 12). And more than half of the world's remaining proven gas reserves exists in just three countries: Russia, Iran, and Qatar. Concerns over energy security prompt policymakers to seek independence from foreign sources of energy. In Europe, new coal-fired power stations are back on the political agenda, partly because Russia is no longer seen as a reliable supplier of gas. In the US, home-grown biofuels have been promoted by successive administrations as an alternative to Middle Eastern oil imports, despite being more expensive. These reactions are a natural consequence. The more governments can free themselves from the dependence on foreign energy resources, the more secure they feel.

2.6 Global financial crisis

The financial crisis of 2007–2008, also known as the Global Financial Crisis and 2008 financial crisis, is considered by many economists to have been the worst financial crisis since the Great Depression of the 1930s. The crisis played a significant role in the failure of key businesses, declines in consumer's wealth estimated in trillions of U.S. dollars, and a downturn in economic activity leading to the 2008–2012 global recession and contributing to the European sovereign-debt crisis. The financial crisis was triggered by a complex interplay of policies that encouraged home ownership, providing easier access to loans for borrowers, overvaluation of bundled subprime mortgages based on the theory that housing prices would continue to escalate, questionable trading practices on behalf of both buyers and sellers, compensation structures that prioritize short-term deal flow over long-term value creation, and a lack of adequate capital holdings from banks and insurance companies to back the financial commitments they were making. Questions regarding bank solvency, declines in credit availability and damaged investor confidence had an impact on global stock markets, where securities suffered large losses during 2008 and early 2009. Economies worldwide slowed during this period, as credit tightened and international trade declined Governments and central banks responded with unprecedented fiscal stimulus, monetary policy expansion and institutional bailouts. Figure 13 shows real Gross Domestic Product (GDP) growth rates for 2009 (*countries in brown were in recession*).

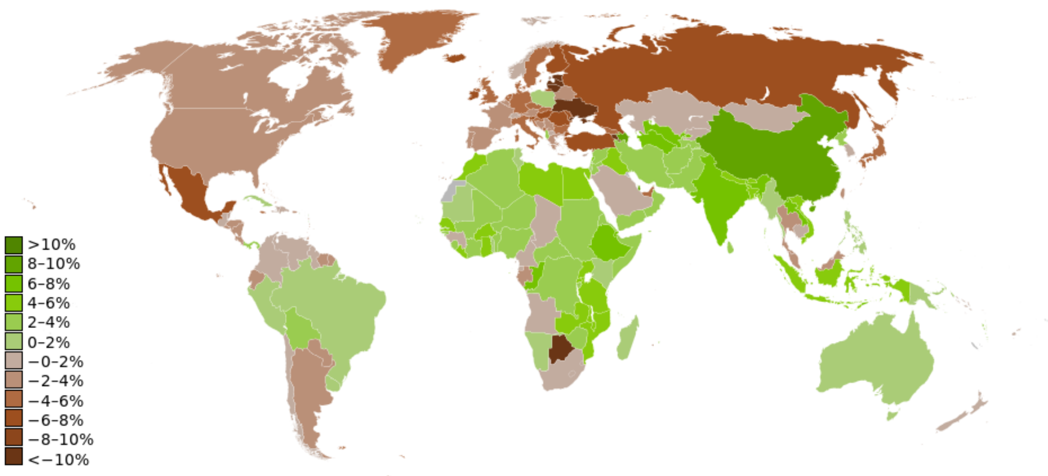


Figure 13: GDP growth rates for 2009.

In 2013, the Monitoring Report of the EU Sustainable Development Strategy states that 8.7 million more people were at risk of poverty or social exclusion in the EU between 2008 and 2012. Impacts of the economic crises have deflected the EU from its 2020 target path. Between 2008 and 2012 the number of people at risk of poverty or social exclusion increased considerably by about 7.5 %, from 115.7 million in 2008 to 124.4 million in 2012 (Figure 14). In the period before the economic crisis, this number had been steadily decreasing, reaching a minimum of 113.7 million in 2009. Since then, in the aftermath of the crisis, the number has grown again.

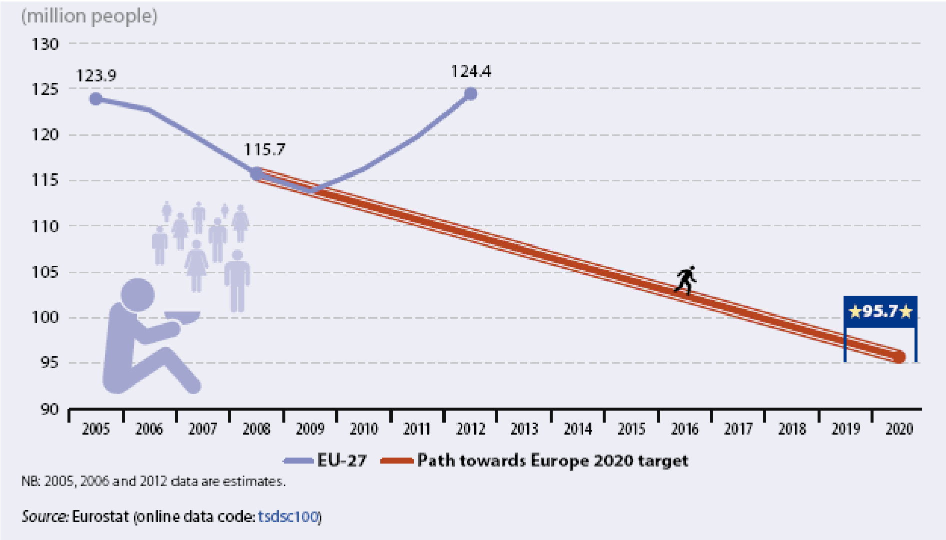


Figure 14: People at risk of poverty or social exclusion, EU-27 (million people)

In 2012, the Rio+20 Summit resolved to finish the job of ending extreme poverty and hunger as a matter of urgency. It also endeavored to place poverty reduction within the broader context of sustainable development. According to MDGs, hunger continues to decline, but immediate additional efforts are needed to reach the MDG target. The proportion of undernourished people in developing regions has decreased from 24 per cent in 1990–1992 to 14 per cent in 2011–2013. However, progress has slowed down in the past decade. Meeting the target of halving the percentage of people suffering from hunger by 2015 will require immediate additional effort, especially in countries which have made little headway. Chronic undernutrition among young children declined but one in four children is still affected in 2012, a quarter of all children under the age of five years were estimated to be stunted—having inadequate height for their age (Figure 15). This represents a significant decline since 1990 when 40 per cent of young children were stunted. However, it is unacceptable that 162 million young children are still suffering from chronic undernutrition.

2.7 Population Growth

Overpopulation is another social issue and main cause of global crisis. In the history of our species, the birth and death rate have always been able to balance each other and maintain a population growth rate that is sustainable. However, in the past fifty years the growth of population has boomed and has turned into overpopulation. Overpopulation is an undesirable condition where the number of existing human population exceeds the carrying capacity of the Earth. A number of factors have determined overpopulation. Firstly, the reduced mortality rate due to better medical facilities. Effectively, growing advances in technology with each coming year has affected humanity in many ways. One of these has been the ability to save lives and create better medical treatment for all. A direct result of this has been an increased lifespan and the growth of the population. Another cause is the depletion of precious resources. If lands are not able to sustain life it is possible for a sparsely populated area to become densely populated. This phenomenon is also well-known as urbanization.

2.7.1 Urbanization

Cities pose new challenges to securing adequate living conditions for the poor. As urbanization continues apace, half of the world's population now lives in cities. There are currently 1 billion slum dwellers (projected to increase to 2 billion by 2030) who are especially food insecure and disconnected from (or dependent on highly over-priced) government water and energy services. While in principle services can be provided more efficiently in cities than in rural areas, urban living promotes more resource intensive lifestyles and concentrates consumption and waste production. In a global context of a world marketed energy consumption that is expected to increase by 44% from 2006 to 2030 and by 73 % from BRICST countries. European Union cities are now responsible for about 70% of the overall primary energy consumption, and this share is expected to increase to 75% by 2030. From a research conducted in 2009 by the U.S. Environmental Protection Agency (EPA) emission from electricity generation accounted for the largest portion of Greenhouse Gases (GHG) emissions (about 29%). Transportation activities accounted for the second (27%) and the emissions from industry made up the third largest portion. According to the UN report "Hot Cities: battle-ground for climate change" (UN, 2011) cities are responsible for 70% of the global carbon footprint, and a big component is referred to energy consumption. Hoff (2011) asserts that continuing urbanization, often driven by deteriorating rural living conditions and a quest for a 'better life', means that city dwellers now account for 50% of the total global population. With about 800,000 new urban residents every week, that proportion is projected to reach 70% by 2050. Resource demand and waste products are concentrated in cities because of higher population density and higher per-capita resource consumption compared with rural areas; for example, cities account for about 75% of all greenhouse gas emissions. Another issue related to urbanization is the Urban Heat Island Effect (UHIE). UHIE represents the temperatures difference between rural and urban areas, where the second one generally have a higher average temperature than surrounding areas. According to Gaffin and Susca (2011), UHIE “mainly depends on the modification of energy balance in urban areas which is due to several factors”. Landsberg (1981) underlines the role of buildings that create urban canyons. Moreover, other UHIE factors have deeply been studied in the last years such as the role of building materials thermal properties (Montavez et al., 2000), the high distribution of hard surfaces that provide high thermal mass, and the huge transformation of green areas into impervious surfaces with a high limitation in evapo-transpiration (Takebayashi and Moriyama, 2007) and reduction of urban albedo (Akbari and Konopacki, 2005). Furthermore, cities are spatially disconnected from their resource base, which increases the need for transport, for example long haul transfers of real and virtual water.

2.8 New approaches for Sustainability Challenge

Despite substantial progress in many areas, human development has been inequitable: around a seventh of the world’s population – the so called ‘bottom billion’ – does not have a secure food supply and has only limited access to clean water, sanitation or modern sources of energy (FAO, 2012). At the same time humans are over exploiting natural resources in many regions. We have severely modified or completely replaced many terrestrial and aquatic ecosystems, and many ecosystem services are degraded. According to Hoff (2011), another challenge to the task of safeguarding resources is the rapidly increasing demand for them. Population growth, an expanding middle class with changing lifestyles and diets, and the urgent need to improve water, energy and food security for the poorest all place growing pressure on limited resources. Unless there are significant changes to the ways that we produce and consume, agricultural production will have to increase by about 70% by 2050 and about 50% more primary energy has to be made available by 2035. Such increases would have far-reaching implications for water and land resources. According to Global Footprint Network (2015), humanity currently uses the equivalent of 1.5 planets to provide the resources we use and absorb our waste. This means it now takes the Earth one year and six months to regenerate what we use in a year. Moderate UN scenarios suggest that if current population and consumption trends continue, by the 2030s, we will need the equivalent of two Earths to support us. Turning resources into waste faster than waste can be turned back into resources puts us in a global ecological overshoot, depleting the very resources on which human life and biodiversity depend. The result is collapsing fisheries, diminishing forest cover, depletion of fresh water systems, and the build-up of carbon dioxide emissions, which creates problems like global climate change. These are just a few of the most noticeable effects of overshoot. Overshoot also contributes to resource conflicts and wars, mass migrations, famine, disease and other human tragedies—and tends to have a disproportionate impact on the poor, who cannot buy their way out of the problem by getting resources from somewhere else. In 2014, the date at which our Ecological Footprint exceeded our planet's annual budget was August 19th (Earth Overshoot Day). Global Footprint Network estimates that approximately every eight months, we demand more renewable resources and C02 sequestration than what the planet can provide for an entire year. Individuals and institutions worldwide must begin to recognize ecological limits. We must begin to make ecological limits central to our decision-making and use human ingenuity to find new ways to live, within the Earth's bounds. Climate change is also likely to aggravate pressure on resources and so add to the vulnerability of people and ecosystems, particularly in water scarce and marginal regions. With this purpose, the necessity to identify a new approach to face sustainability challenge has arisen.

2.8.1 Planetary boundaries approach

Since 2009, Rockström and Steffen (2009) have identified different global priorities relating to human-induced changes to the environment. These priorities were defined *planetary boundaries* associated with key Earth System processes and dangerous thresholds. The Planetary boundaries approach was built on different backgrounds:

- limits-to-growth (Meadows et al. 1972, 2004),
- safe minimum standards (Ciriacy-Wantrup 1952, Bishop 1978, Crowards 1998),
- the precautionary principle (Raffensperger and Tickner 1999),

- tolerable windows (WBGU 1995, Petschel-Held et al. 1999).

Preliminarily boundaries were estimated for seven processes strictly connected to the self-regulating capacity of the Earth System: climate change, stratospheric ozone depletion, ocean acidification, biogeochemical flows (phosphorus and nitrogen cycles), change in biosphere integrity (biodiversity loss and species extinction), land-use change (for example deforestation) and freshwater use. Subsequently, the processes of aerosol loading (microscopic particles in the atmosphere that affect climate and living organisms) and the introduction of novel entities (e.g. organic pollutants, radioactive materials, nanomaterials, and micro-plastics) have been added. Even though there is insufficient knowledge to suggest quantitative boundaries for the last two processes. In the figure, the nine processes are illustrated.

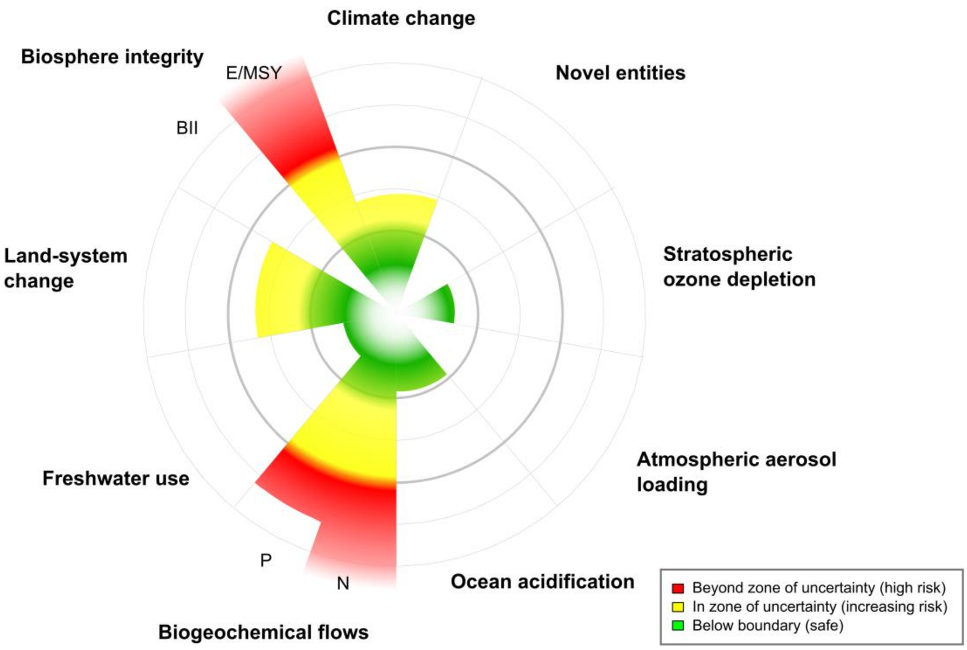


Figure 15: Nine processes affecting planetary boundaries (Steffen, 2011)

The inner green shading represents the proposed safe operating space for the nine planetary systems. The yellow wedges are in zone of uncertainty. The red wedges represent an estimate of the current position for each variable. It can be observed that the boundaries in three systems (rate of biodiversity loss, climate change and human interference with the nitrogen cycle) have already been exceeded. In addition, Rockström and colleagues (2009) emphasize that these boundaries are strongly connected - crossing one boundary may seriously threaten the ability to stay within safe levels of the others. The study stresses that the planetary boundaries approach does not offer a complete roadmap for sustainable development, but does provide an important element by identifying critical planetary boundaries. Within these boundaries, humanity has the flexibility to choose pathways for our future development and well-being. Finally, future researches will need to explore ways in which society can develop new approaches of a safe and sustainable operating space for human development within these boundaries.

2.8.2 Mitigation approach

A first approach to endorse sustainability is mitigation. *Mitigation* was defined by the Environmental Impact Assessment (EIA) Directive as *measures envisaged in order to avoid, reduce and, if possible, remedy significant adverse effects* (EC/85/337). Therefore mitigation is aimed to reduce the magnitude of the global impacts. Additionally, mitigation is aimed to avoid and to minimize impacts and to compensate for remaining unavoidable impacts. In Figure 16, a hierarchy for mitigation measures can be observed.

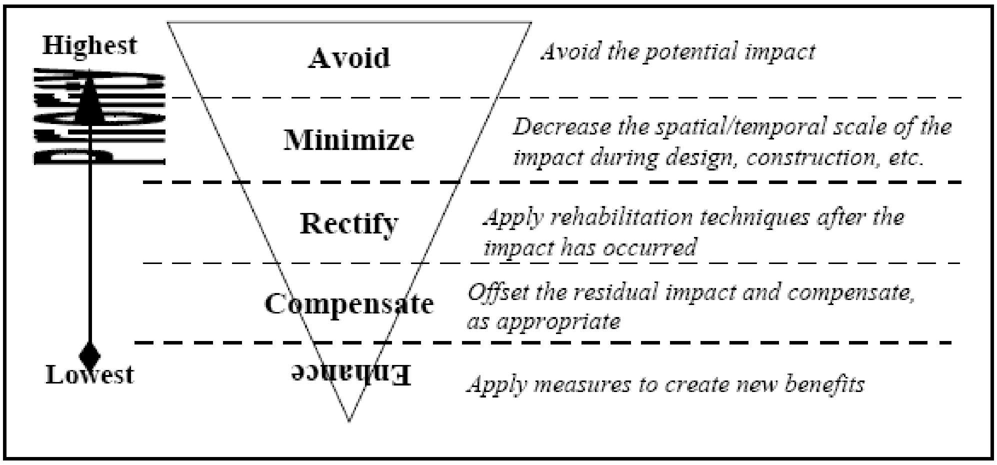


Figure 16: Hierarchy of mitigation strategies (Rajvanshi, 2008)

2.8.3 Adaptation approach

Secondly, *adaptation*, involves efforts to limit the vulnerability of a system. Vulnerability refers to the propensity of a social and ecological system to suffer harm from exposure to external stresses and shocks. Research on vulnerability can, for example, assess how large the risk is that people and ecosystems will be affected by climate changes and how sensitive they will be to such changes. As seen in the previous paragraphs, climate change and other critical issues are not a distant threat looming on the horizon. A global crisis is already here. To date, much emphasis has been placed on the need to mitigate impacts and to reduce problems. However, it is equally important to develop comprehensive strategies that enable people to cope with vulnerability. This imperative is particularly urgent for vulnerable communities in developing countries. The capacity to thrive and to resist under a condition of crisis is called resilience. Resilience is the opposite of vulnerability. In the following paragraphs the importance of developing resilience is underlined.

2.8.4 Crisis and resilience

According to Berkes, Colding and Folke (2003), resilience is the long-term capacity of a system to deal with change and continue to develop. For an ecosystem such as a forest, this can involve dealing with storms, fires and pollution, while for a society it involves an ability to deal with political uncertainty or natural disasters in a way that is sustainable in the long-term. Therefore, resilience means robustness not only from a technical point of view, but also as the system ability to resist to external disturbances, such as economic and social crises, and building cohesion and connections. An increased knowledge of how we can strengthen resilience in society and nature is becoming more and more important in coping with the stresses caused by climate change and other environmental impacts. Resilience thinking is an important part of the solution, as it strives to build flexibility and adaptive capacity rather than attempting to achieve stable optimal production and short-term economic gains. The resilience approach focuses on the dynamic interplay between periods of gradual and sudden change and how to adapt to and shape change. Sometimes change is gradual and things move forward in roughly continuous and predictable ways. At other times, change is sudden, disorganizing and turbulent reflected in climate impacts, earth system science challenges and vulnerable regions. Evidence points to a situation where periods of such abrupt change are likely to increase in frequency and magnitude. This challenges the adaptive capacity of societies. A resilience approach to sustainability focuses on how to build capacity to deal with unexpected change. A Complex Adaptive System (CAS) is a system of interconnected components that has the capacity to adapt and self-organize in response to internal or external disturbance or change (Biggs et al., 2012). The Stockholm Resilience Centre (Biggs, Schluter and Schoon, 2014) has developed seven principles for building resilience in social-ecological systems (Figure 17).

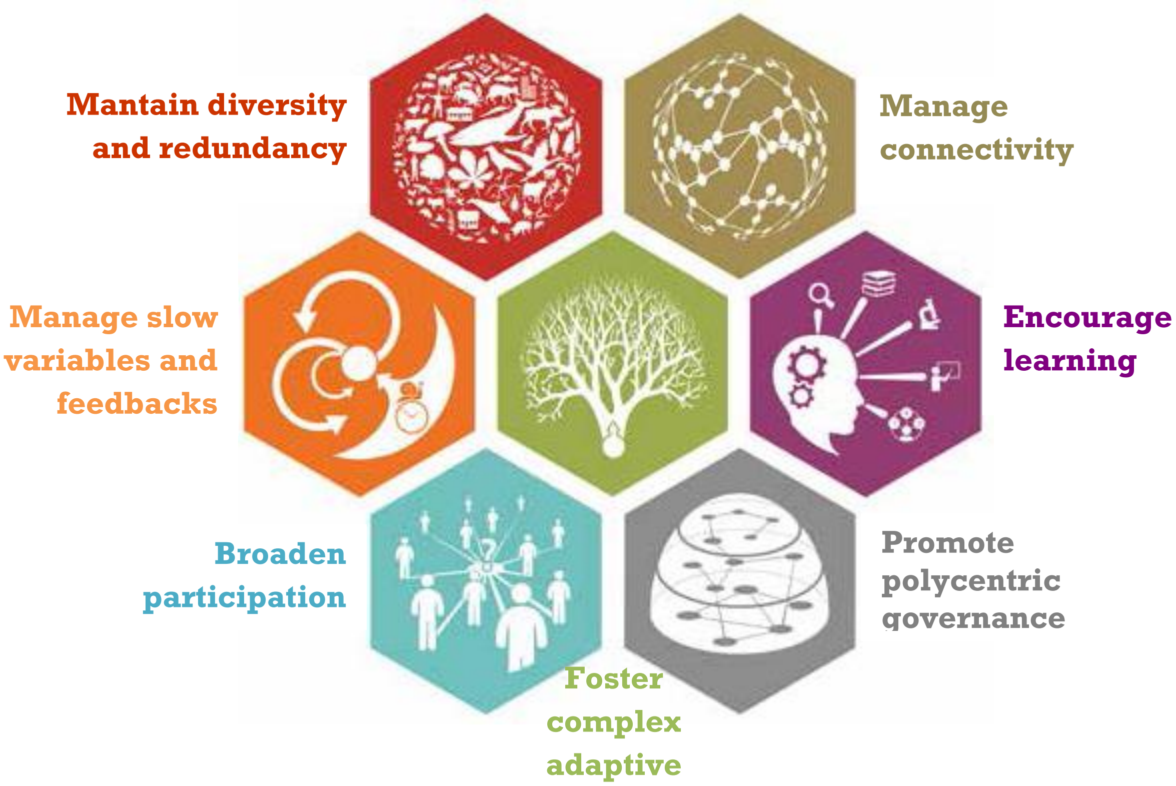


Figure 17: Seven principles for building resilience (Steffen, 2011).

1. **Maintain diversity and redundancy**: in a social-ecological system, components such as species, landscape types, knowledge systems, actors, cultural groups or institutions all provide different options for responding to change and dealing with uncertainty and surprise.

2. **Manage connectivity**: connectivity can be both a good and a bad thing. High levels of connectivity can facilitate recovery after a disturbance but highly connected systems can also spread disturbances faster.
3. **Manage slow variables and feedback**: social-ecological systems can often be "configured" in several different ways. In other words, there are many ways in which all the variables in a system can be connected and interact with one another, and these different configurations provide different ecosystem services. Feedback is a mechanism, a process, or a signal that loops back to influence the SES component emitting the signal or initiating the mechanism or process.
4. **Foster complex adaptive systems thinking**: in order to continue to benefit from a range of ecosystem services, we need to understand the complex interactions and dynamics that exist between actors and ecosystems in a social-ecological system. Management based on 'complex adaptive systems thinking' that appreciates these interactions and the often complex dynamics they create can enhance the resilience of social-ecological systems.
5. **Encourage learning**: the knowledge of a system is always partial and incomplete and social-ecological systems are no exceptions. Efforts to enhance the resilience of social-ecological systems must therefore be supported by continuous learning and experimentation.
6. **Broaden participation**: active engagement of all relevant stakeholders is considered fundamental to building social-ecological resilience. It helps build the trust and relationships needed to improve legitimacy of knowledge and authority during decision-making processes.
7. **Promote a polycentric governance system**: polycentricity means a governance system in which multiple governing bodies interact to make and enforce rules within a specific policy arena or location. It is considered to be one of the best ways to achieve collective action in the face of disturbance and change.

This approach moves beyond viewing people as external drivers of ecosystem dynamics and rather looks at how we are part of and interact with the biosphere – the sphere of air, water and land that surrounds the planet and in which all life is found. People also change the biosphere in a multitude of ways through activities such as agriculture, and building roads and cities. A resilience thinking approach tries to investigate how these interacting systems of people and nature can best be managed to ensure a sustainable and resilient supply of the essential ecosystem services on which humanity depends.

2.8.5 The need of the nexus approach

On one hand, the planetary boundaries approach has introduced the concept that the interactions of land, ocean, atmosphere and life together provide conditions upon which our societies depend. On the other hand, Hoff (2011) has introduced a nexus approach recognizing that efforts to address only one part of a systemic problem by neglecting other inherently inter-linked aspects may not lead to desirable and sustainable outcomes.

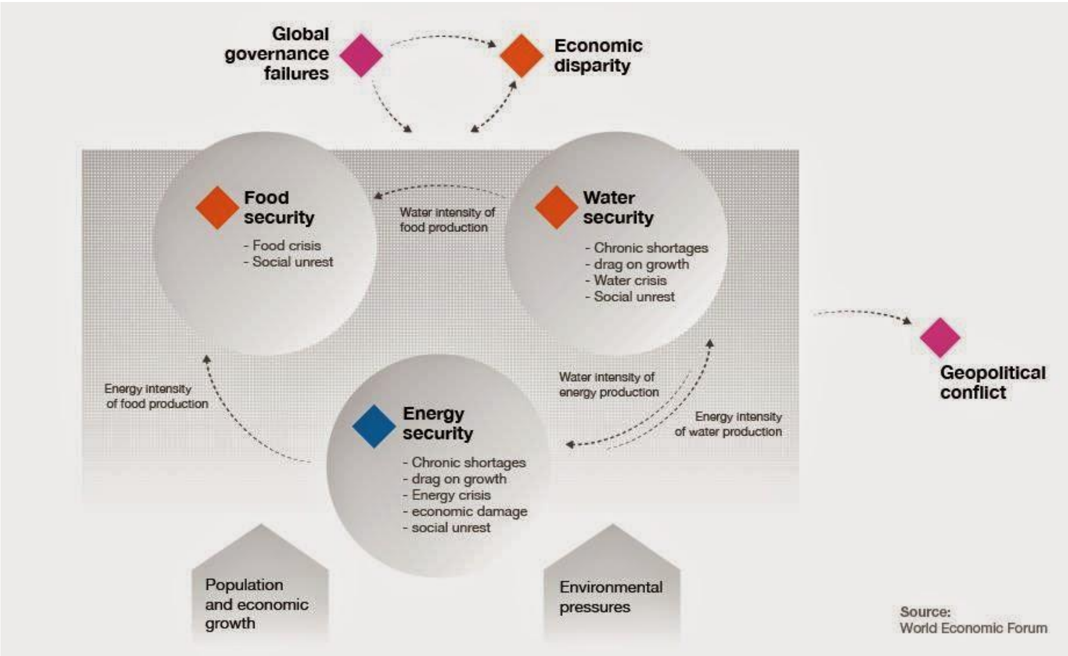


Figure 18: : Water, Energy and Food Security Nexus (Hoff, 2011)

The concept of *nexus* provides a key to understanding for the human-environment interaction founded on establishing a link between the scientific knowledge and real-world experiences. Therefore a nexus approach is needed in order to redress the direction of the current global developments (Figure 18). In this perspective, the nexus approach reduces tradeoffs and builds synergies across sectors, and helps to reduce costs and increase benefits for humans and nature compared to independent approaches to the management of water, energy, food and the environment.

2.9 Future Agenda for SD

Today’s problems will expand dangerously without an urgent and radical change of course. The world needs an operational sustainable development framework that can mobilize all key actors: national and local governments, civil society, business, science, and academia in every country to move away from the Business-as-Usual (BAU)[2] trajectory towards a Sustainable Development (SD) path. Since 2000, when the MDGs were adopted, the world has changed profoundly. In particular, five shifts will make the coming fifteen-year period, 2015-2030, different from the MDG period ending in 2015: the feasibility of ending extreme poverty in all its forms, a drastically higher human impact on the physical Earth, rapid technological change, increasing inequality, and a growing diffusion and complexity of governance. At present, two international initiatives are contributing to identifying future directions for SD: the implementation of the post-2015 global sustainable development agenda (Agenda Post-2015) and the design of Sustainable Development Goals (SDGs). The Post-2015 Development Agenda is building on the progress achieved through the MDGs in order to address persistent issues and new challenges facing people and the planet. Correspondingly, the UN Sustainable Development Solutions Network (SDSN) was launched as part of UN Secretary- General Ban Kimoon’s initiatives to promote sustainable development. In fact, the MDGs faced criticism for not

[2] Business as usual (BAU) - the normal execution of standard functional operations within an organization - forms a possible contrast to projects or programmes which might introduce change.BAU may also stand in contradistinction to external events which may have the effect of unsettling or distracting those inside an organization.

sufficiently covering the environmental dimension of sustainable development and for not addressing inter-linkages between its dimensions. This framework and the Sustainable Development Goals (SDGs) should identify the main objectives and strategies needed to make this shift. In 2013, an intergovernmental Open Working Group was also launched to make recommendations to the UN General Assembly on the design of these goals. Both the Post-2015 and the SDG processes are moving rapidly towards their conclusion in 2015, when a new universal Sustainable Development Agenda, likely to extend until 2030, will be launched. The aim is to mobilize global scientific and technological knowledge on the challenges of sustainable development.

2.10 Conclusion

The human footprint on the planet's environment is now so vast that the current geological period should be labelled as the 'Anthropocene' - the age of man. Human pressure has reached a scale where the possibility of abrupt or irreversible global change can no longer be excluded. The challenges of the 21st century – resource constraints, financial instability, inequalities, environmental degradation – are a clear signal that 'business-as-usual' cannot continue. We are the first generation having the knowledge of how our activities influence the Earth as a system, and thus the first generation with the power and the responsibility to change our relationship with the planet. International commitment to formulate new S*ustainable Development Goals* (SDGs) needs to be guided by the 'planetary boundaries' concept which aims at creating a scientifically defined safe operating space within which humanity can continue to evolve and develop. Poverty alleviation and future human development cannot take place without such a wider recognition of nature's contribution to human livelihoods, health, security and culture. The issue at stake extends beyond climate change to a whole spectrum of global environmental changes that interplay with interdependent and rapidly globalising human societies. A *nexus approach* is needed in order to avoid damaging consequences for the human prosperity and other vital ecosystem services. Several initiatives are framing the nexus approach within the Post-2015

Development Agenda. Furthermore, the importance of joining mitigation and adaptation measures and strategies is a crucial necessity in our time. The current global crisis requires both mitigation measures to be more sustainable and adaptation measures to be more resilient. The Earth's resilience and resource base cannot be stretched infinitely and we are uncomfortably aware that we are heading in the wrong direction. Therefore, developing sustainable and resilience-building systems has become a strict and increasing necessity for our future. Improving the capacity to absorb disturbances and to adapt to stress and change is a commitment involving not only researchers but also the whole society. Science has a great responsibility in this respect to provide a better understanding of the multiple challenges facing humanity and to explore solutions for sustainable development in an increasingly unpredictable world. It is time for a new social contract for global sustainability rooted in a shift of perception – from people and nature seen as separate worlds to interdependent systems. This provides exciting opportunities for societal development in collaboration with the biosphere; a global sustainability agenda for humanity.

3 Evolution of Innovation Approaches towards Sustainability

The significant problems we face cannot be solved at the same
level of thinking we were when we created them.
Albert Einstein

3.1 The urgency of Sustainable Innovation

According to EIO (2013), innovation is about change. It is about how business, citizens, research, and government can both activate and contribute in change to co-create the kind of future we want. The word innovation originate from the Latin word *innovatus,* and generally refers to the creation or improvement of products, technologies, or ideas. The dictionary meaning of innovation is the 'introduction of new things or methods' (Oxford, 2015). Innovation is the creation of better or more effective products, processes, services, technologies, or ideas that are accepted by markets, governments, and society. Innovation differs from invention in that innovation refers to the use of a new idea or method, whereas invention refers more directly to the creation of the idea or method itself. A definition commonly referred to is that of Schumpeter: "the commercial or industrial application of something new – a new product, process or method of production; a new market or source of supply; a new form of commercial, business or financial organisation" (Schumpeter, 1934). In a practical sense, innovation is, the application and commercialisation of creative ideas into practice (Bala Subrahmanya 2005; Schumpeter 1942 as cited in Massa and Testa 2008). A well-defined and readily accepted definition of innovation for the purpose of this research is, 'implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations' (OECD and Eurostat, 2005). Economic theorists such as Adam Smith, Karl Marx and Schumpeter emphasise the enormous contribution of innovation in economic growth (Mytelka and Smith 2002). To have a dynamic and a prosperous economy; "Innovation is a key driver of economic growth. The development, introduction, or implementation of new or significantly improved goods, services, or processes is innovation" (Sachdeva & Agarwal, 2011).

Based on the sustainability concept, sustainable innovation can become a key driver not only of economic growth, but also of all the sustainability dimensions: economic, environmental, social and governance. In the previous chapter, we have seen that global problems are calling for an effective transformation towards sustainability. More and more institutions and individuals around the world are trying to address these problems and are demanding immediate solutions. In effect, the growing global crisis trend requires the implementation of new ways to reach sustainable development goals, especially to reduce resources use, water emissions, recycle waste, and find new energy sources, as well as protect the environment in general. (Cheng, 2012) Therefore, the urgency of innovation towards sustainability has become fundamental in order to tackle the dynamic, complex factors fuelling the global crisis of our days. At the same time, according to Nidumolu, Prahalad & Rangaswami (2009), Kenski (2013), sustainability can become a key driver for effective innovation and for developing new models for our society. In this chapter, the concept of Sustainable Innovation is investigated with the aim to identify effective approach resulting in significant and demonstrable progress towards the goal of sustainable development (EC, 2011).

3.2 Evolution of the concept of sustainable innovation

Over the last decade the concept of sustainable innovation has been widely diffused. Nevertheless, the number of definitions in the academic literature is limited. On the other hand, terms like eco-innovation and environmental innovation are more widely defined (Carrillo-Hermosilla et al., 2010). According to Martin Charter & Tom Clark (2007) the terms of eco-innovation and sustainable innovation are often used in literature interchangeably. Even though, eco-innovation is generally referred to environmental and economic dimensions and sustainable innovation is broader to the social and ethical dimensions. In this chapter the evolution of the concepts of eco-innovation and sustainable innovation is illustrated. This evolution is related to the distinguishing approaches applied during the specific periods in order to face sustainable development challenges (OECD 2009). According to many researchers (see for example Carrillo-Hermosilla et al., 2010; EIO, 2013; Jackson, 2009), an historical background based on the main approach used in a specific period to address sustainability problems could be provided. In the following, an historical evolution of the approaches to address sustainability problems is deeply examined. Consequently, a connection between the approach used in a specific period and the sustainable innovation concept is identified. The aim is to characterize an effective approach to address the global problems and to reach sustainability in a wide way.

3.3 First approaches to face environmental burdens

At the beginning of the industrial era, when the environmental impacts from production processes was first noticed, the solution to the problems were thought to be to lower the concentration of the harmful substances. Instead of releasing the emissions close to where the humans resided, pipes and chimneys were built. Later on, in the 1960s and 1970s, people saw that the consequences of the emissions were still there, even though they did not have an acute impact on human beings any longer. The reduction of environmental impacts was done through by end-of-pipe pollution control technologies. According to Hemmelskamp (1997), end-of-pipe technologies are “disposal methods and recycling technologies that follow the actual production and consumption process”. They dispose of or modify the gross accumulating emissions in such a way that they become less polluting or less environmentally-harmful or can be better stored, but there is no emission reduction in terms of quantity. According to this approach, the first concept of eco-innovation has embraced a corrective approach. Indeed, one of the first definitions of eco-innovation is

"new products and processes which provide customer and business value but significantly decrease environmental impacts" (James, 1996).

Thanks to this corrective approach, several regulations and laws were introduced. As a result, emissions and effluents were treated with filters, chemical treatments or combustion, correspondingly waste from the processes was less hazardous. Nevertheless, a large amounts of waste and pollution were still produced. Therefore, a next step towards environmentally friendly processes was made. In the 1980s, cleaner production strategies were introduced with the aim of cleaning the process and decreasing the amounts of waste sent to landfill and lowering the extraction of raw material from non-renewable resources. Malaman (1996) defines cleaner technologies, as: “all modifications in processes and products which reduce impact on the environment, as compared to the processes and products which they have substituted”. Similarly, the cleaner production approach adopted for eco-innovation was primarily characterized by a process perspective and the focus was on the prevention and reduction of the production process impacts. In this context, the following eco-innovation definitions incorporate the preventive approach promoted by cleaner production.

“Environmental innovations are new and modified processes, equipment, products, techniques and management systems that avoid or reduce harmful environmental impacts.” (Kemp and Arundel, 1998; Rennings and Zwick, 2003)

“New or modified processes, techniques, practices, systems and products aimed at preventing or reducing environmental damage .”(Rennings, 2000)

In the cleaner production approach, the scope of innovation was mainly devoted to achieve a technological change. According to Huber (2004), “Technological environmental innovations (TEIs) may help to reduce the quantities of resources and sinks used, be they measured as specific environmental intensity per unit of output, or as average consumption per capita, or even in absolute volumes. Overriding priority, however, is given to improving the qualities and to changing the structures of the industrial metabolism. Rather than doing less of something, TEIs are designed to do it cleaner and better by implementing new structures rather than trying to increase eco-productivity of a suboptimal structure which has long been in place. TEIs are about using new and different technologies rather than using old technologies differently.

3.4 Eco-efficiency approach

As said above, the cleaner production approach incorporates the principle of “anticipate and prevent”. Therefore the focus was on the earlier stages of the industrial process which were sources of pollution. In order to identify areas in which environmental pollution are produced, cleaner production approach started to entail also the organizational aspects. Subsequently, cleaner production innovation entailed improvements and changes both to existing manufacturing processes and to organizational structures and procedures. According to Frondel (2007), the adoption of cleaner production approach began to reveal several barriers and inefficiencies in the organizational and managerial activities. This allowed the introduction of the concept of eco-efficiency approach. Since 1996, the WBCSD defined eco-efficiency as “competitively priced goods and services that satisfy human needs and bring quality of life while progressively reducing environmental impacts of goods and resource intensity throughout the entire life-cycle to a level at least in line with the Earth's estimated carrying capacity”. One of the main principle raised with the eco-efficiency approach was “doing more with less”. Hence, based on this principle, concepts as Factor 4 which calls for halving the use of resources while doubling wealth (Von Weizsäcker, Lovins and Lovins, 1998) and Factor 10 (a 90% reduction of resource uses) were established. The eco-efficiency approach was revealed especially suitable for companies and organizations that started to consider environmental and sustainability aspects as a part of their mission. Thanks to eco-efficiency, several voluntary instruments, such as Environmental Management Systems (EMS) or environmental certification and standard were growing adopted. Indeed, these instruments can be useful not only for improving environmental performance of manufacturing process (OECD, 2009) but also for meeting increasing pressures from stakeholders, improving the corporate image and reducing risks of environmental liability and non-compliance (Perotto et al., 2008). In the following a definition of eco-innovation strictly connected to the *eco-efficiency approach* is provided.

"Eco-efficiency innovation contributes to company competitiveness in at least four ways: Operational advantages thanks to greater resource efficiency resulting in lower resource costs; commercialisation of the innovation; reduced environmental costs of pollution control and waste management; improvements in image, marketing and stakeholder relations". (Kemp & Munch Andersen, 2004)

Since then, we have seen that formerly eco-innovation has focused mostly on technological change. Due the introduction of eco-efficiency innovation, also non-technological aspects such as organizational structure were directly engaged in the eco-innovation process. As a result, the organizational dimension of eco-innovation has emerged. According to OECD (2005), organizational eco-innovation includes the introduction of new management methods such as EMSs and corporate environmental strategies. While these areas concern general environmental business practices, organizational eco-innovation can also take place through changes in the company workplace, such as the centralization or decentralization of environmental responsibilities and decision-making powers or the establishment of training programme for employees designed to improve environmental awareness and performance. Organizational eco-innovation also includes changes in how companies organize their relations with other firms and public institutions, such as the participation in public-private partnerships for environmental research and projects.

3.5 Towards a Life Cycle Thinking

In spite of eco-efficiency innovation is aimed to help society to grow and prosper and achieve environmental improvements, according to Boulanger (2010), eco-efficiency approach is affected by some often unforeseen limits that are known as *rebound effects* (Herring and Sorrell 2009). Rebound effects account for the fact that eco-efficiency improvements do not necessarily lead to equivalent reductions in consumption of the resource concerned by firms and households and can even, in some circumstances, trigger an increase in use at the micro and/or macroeconomic level (the so-called ‘backfire’ effect). Indeed, more efficiency means lower costs. Hence lower market prices means increasing the effective demand for the good that benefited from the efficiency improvement thanks to the income saved in consuming the first good. Therefore the efficiency of goods and services could sometimes succeed in higher environmental impacts. A familiar example concerns the increase in the energy efficiency of car engines (mileage per gallon). Thanks to the income not spent in fuelling the car, this innovation has led to more mileage/car. In addition more flights have been made affordable by the efficiency improvements in the air transport (more efficient engines and flight procedures). (Schettkat 2009, Small and Van Deder 2005). This example demonstrates that it will not be more effective making the production process cleaner if the life-cycle phases are not addressed. As a matter of fact, it was observed that many products had the largest impact not necessary associated to the production phase. Therefore, it is necessary put the attention on the environmental impact generated throughout the life-cycle. This is the basis of the *life cycle thinking*.

According to UNEP and SETAC (2015), “Life Cycle Thinking (LCT) is about going beyond the traditional focus and production site and manufacturing processes to include environmental, social and economic impacts of a product over its entire life cycle”. Life cycle thinking aims at a reduction of the cumulative environmental impacts from the "cradle to the grave". “Cradle-to-grave” begins with the extraction of raw materials from natural resources in the ground and the energy generation. Materials and energy are then part of production, packaging, distribution, use, maintenance, and eventually recycling, reuse, recovery or final disposal. The key aim of LCT is to prevent individual parts of the life-cycle from being addressed in a way that just results in the environmental burden being shifted to another part. Accordingly, Life Cycle Thinking started to drive the eco-innovation process and ecodesign strategies helped to enhance the preventive approach. In the previous paragraph the preventive approach mainly concerns cleaner production defined as the continuous re-design of industrial process and products to prevent pollution and waste generation at their source and minimise risks to humans and the environment. This approach initially applied to industrial processes (hence cleaner technologies), became more inclusive till considering the industrial products themselves (hence cleaner products). As a result, the eco-innovation concept began to encompass not only clean production innovation but also to introduce a life cycle thinking.

"Eco-innovation is the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organisation (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives." (Kemp and Pearson, 2007)

"Eco-innovation is "the production, assimilation or exploitation of a novelty in products, production processes, services or in management and business methods, which aims, throughout its lifecycle, to prevent or substantially reduce environmental risk, pollution and other negative impacts of resource use (including energy*)*." (EC, 2004)

"In a broad sense, environmental innovations can be defined as innovations that consist of new or modified processes, practices, systems and products which benefit the environment and so contribute to environmental sustainability." (Oltra and Saint Jean, 2009)

The life cycle philosophy and management approaches have laid the foundation for a range of relatively new and proactive environmental initiatives and innovation, in which environmental considerations go beyond the manufacturing facility to the entire value chain. In this way, eco-innovation is not just about clean technologies but encompasses all changes that reduce resource use across the life-cycle, regardless of whether these changes were intended to be 'environmental' or not. As seen before, the cleaner production approach was mainly devoted to achieve a technological change . TEIs are characterized as being upstream rather than downstream, i.e., upstream in the manufacturing chain or product chain respectively, as well as upstream in the life cycle of a technology (Huber, 2004). On the other hand, the adoption of a life cycle perspective requires not only technical specialists such as product designers, but also non-technical skills in order to look beyond their own knowledge and in-house data such as policy developers, environmental managers. At the same time, LCT also provides an opportunity to use the knowledge that has been gathered to gain significant economic advantages. LCT has introduced an innovation also at the policy level and this change is reflected in *Extended Producer Responsibility* (EPR) initiatives. Especially, for the European Union, the Integrated Product Policy has sought the extension of the responsibility of producers to the entire product life cycle. As a consequence, LCT requires cooperation up and down the supply chain. According to Seuring and Muller (2007), another concept emerged from life cycle thinking is therefore the *Green Supply Chain Management* (GSCM). GCSM includes environmental considerations in the total value chain from original source of raw materials, through the various companies involved in extracting and processing, manufacturing, distributing, consumption and disposal (OECD, 2009). The adoption of GSCM is very demanding as it requires, in addition to various elements of cleaner production and the implementation of EMS, the development and maintenance of close co-operative relations with external entities such as suppliers and retailers. In recent years, the pressure for companies to be accountable for their environmental and social responsibilities has risen. This has led to the concept and practice of corporate social responsibility (CSR) whereby companies, on a voluntary basis, declare their commitment to consider the ethical consequences of their business activities and to take responsibilities for them beyond legal requirements.

3.6 The shift to challenge-led Eco-innovation

Thanks to the life cycle approach, a broader approaches to sustainable innovation have thus begun to evolve. A significant evidence of the necessity to broad the domain of eco-innovation is confirmed by an initiative supported by DG Environment of the European Commission: the Eco-Innovation Observatory. In the 2011, EIO published the Annual Report “The Eco-innovation challenge: pathways to a resource-efficient Europe” with the aim at putting eco-innovation into the context of global challenges. As seen in Chapter 2, main global challenges are linked to the overuse of global resources. Definitely, the most prominent environmental problems and social inequalities shows a undoubted nexus to global resource consumption. In addition, wealth and prosperity created by current occidental economic system came at a price of high throughputs of resources. According to European 2020 Strategies (EC, 2010), the EIO established resource consumption as the key focus of eco-innovation and identified the ecoinnovation challenge as the necessity to decouple economic success from resource consumption (Figure 19). According to UNEP (2010) **decoupling** will require significant changes in government policies, corporate behaviour, and consumption patterns by the public. These changes will not be easy and will be driven by sustainability-oriented innovations in systems of resource extraction and use, as well as economic innovations that could lead to a new indicator that couples the measurement of GDP to evaluations of environmental restoration and social development.

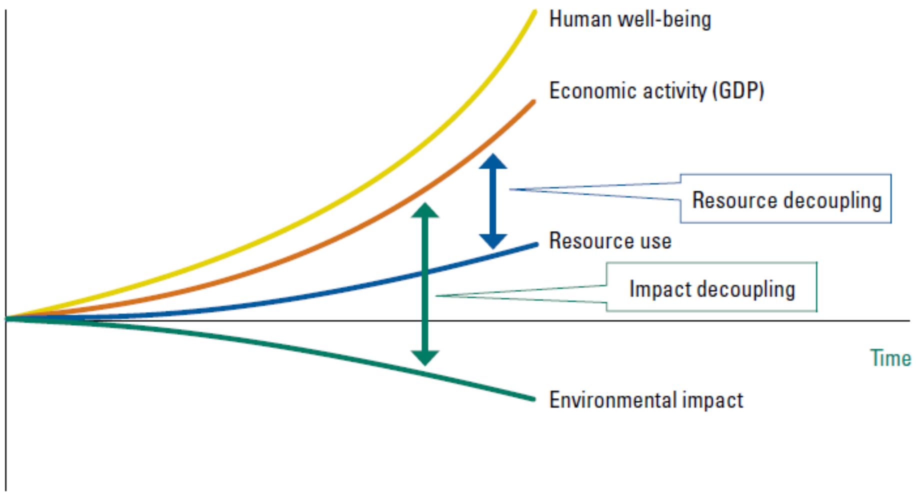


Figure 19: Two aspects of decoupling (UNEP, 2010)

In consequence, decoupling is about shifting from debt-financed consumption (which is unsustainable) as the primary economic driver of our economies, to sustainability-oriented investments in innovation as the primary economic driver of our economies. This unites the developed and developing world: provides developed economies with a way out of the recession by creating new opportunities for investment, it ensures that poverty is eradicated in the developing world using policies that result in real resource efficient growth rather elite consumption based on new infrastructures that foster resource and energy intensive growth. Consequently, decoupling has to be part of a transition to a low carbon, resource efficient and green economy needed in order to stimulate growth, generate decent kinds of employment and eradicate poverty in a way that keeps humanity's footprint within planetary boundaries.

3.6.1 Green economy

In this context, the concept of green economy has emerged. Basically, *green economy* is a “low-carbon, resource efficient and socially inclusive economy and results in improved human well-being and social equity, while significantly reducing environmental risk and ecological scarcities” (UNEP, 2010).

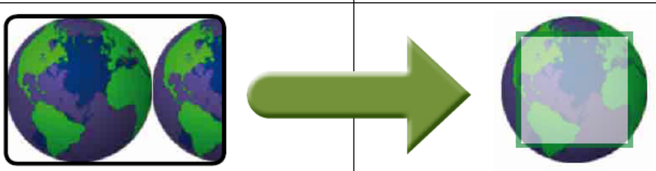
	Current global economy	Green global economy
		
Environment	1.5 planets are needed to regenerate renewable resources and absorb the CO_2 waste at current levels of consumption (WWF et al. 2012)	Resource extraction and emissions are within the planetary boundaries. For the EU, this requires reducing total consumption levels of primary materials, land, water and energy.
Social	870 million people were chronically undernourished in 2010-12 (FAO 2012) and 1.29 billion people lived in extreme poverty in 2008 (World Bank 2012). People in industrialised countries consume up to 20 times more materials than people in least developed countries (Giljum et al. 2011).	Available global resources are more equitably distributed across the global. For the EU, this implies substantially reducing total per capita resource consumption (see Table 2.2 for preliminary targets).
Economic	Economic prosperity is coupled with resource use. Relative decoupling has been observed for the EU, but not absolute decoupling (EIO 2011a).	Economic prosperity is decoupled from primary resource consumption. For the EU, this means transforming the economy to find growth opportunities in resource efficiency, recycling, re-use and new business models.

Figure 20: Comparison between current economy and green economy dimensions (EIO, 2013)

According to the latest EIO Report (2013), the green economy concept combines environmental, social and economic dimensions of sustainability (Figure 20) and eco-innovation can play a role in the transition to green economies. Indeed, eco-innovation will clearly be a key tool for motivating and joining actors across the economy towards change. In this sense, the green economy is the framework for change and eco-innovation is a key part of the pathway to it.

3.6.2 Business models innovation for sustainability

Green economy calls for a new approaches which integrate environmental sustainability to meet customer needs in novel ways, leading to the development of eco-innovations across value chains and in the value propositions of companies. With this purpose, the role of business is crucial in reaching the green economy (EIO, 2013). As Sommer (2012) established, "In addition to ordinary product and process innovations, (business) can change 'the rules of the game' within an industry towards environmental sustainability." Thus, one of the major roles of business in the transition to a green economy will be to redefine itself and to transform the way business is done. Many companies and a few governments have started to use the term eco-innovation to describe the contributions of business to sustainable development while improving competitiveness. According to Gaziulusoy and Twomey (2014b); Ryan (2013a); Tukker & Tischner (2006); Whiteman, Walker & Perego (2013), the need to make fundamental changes to existing business models and to the systems that support them has been arisen. Business models is defined as the 'fundamental structures for how companies create, deliver and capture value' (Osterwalder & Pigneur 2010). In addition Gaziulusoy and Twomey (2014b), describe business models as the components, which together establish the conceptual architecture of businesses. Although these components are referred to using a variety of terms in the literature, fundamentally, business models need to articulate value proposition, target customer, distribution channels, customer relationships, arrangement of activities and resources, core competencies, partner network, cost structure and revenue model. Any novel approach used to develop and/or connect one or more of these components can be defined as business model innovation. Correspondingly, sustainable business model can be defined as a business model that generate competitive advantage through higher customer value and contributes to a sustainable development of the company and society. In the following Figure 21, the four areas which provide a framework for developing and implementing eco-innovation across business model are described.

Figure 21: Integrating eco-innovation across business model (EIO2013 compilation based on Osterwalderand Pigneuer, 2010)

According to Gaziulusoy and Twomey (2014b), the creation of sustainable business model can provide a vehicle to coordinate technological and social innovations towards sustainability. As a consequence, redefining business models and making sustainability an integral part of business models is crucial to the transition (EIO 2013). In recent times, several approaches are emerging with the aim to promote the creation of sustainable business models (Gaziulusoy and Twomey, 2014b). In the following, two interesting approaches which can characterize sustainable business models are described. The first one is product-service system (PSS). PSS encourages companies to increase the reuse and remanufacturing of products with the final goal to achieve an integrated functional solution in order to meet client demands. Functional solutions are oriented to the function delivered by the product, that is the way of answering needs.

3.6.3 Product-Service System (PSS)

A first definition of PSS is provided by Tukker (2004), product-service systems describe business strategies that have “tangible products and intangible services designed and combined so that they jointly are capable of fulfilling specific customer needs”. Tukker and Tischner (2006) note that the concept is essentially the same as the concept of “value-added services”, which has been developed in business management literature. In this sense, there seems to be a merging of environmental and economic disciplines concerning ideas on future business models. Another definition of PSS is proposed by the LeNS project (Vezzoli et al., 2014): “an offer model providing an integrated mix of products and services that are together able to fulfill a particular customer demand (to deliver a ‘unit of satisfaction’) based on innovative interactions between the stakeholders of the value production system (satisfaction system), where the economic and competitive interest of the providers continuously seeks environmentally beneficial new solutions.” Broadly, Product-Service System provide possible and promising sustainable business strategies potentially capable of helping achieve the leap which is needed to move to a more sustainable society. PSS innovation ‘continuously strives to be competitive, satisfy customer needs and have a lower impact than traditional business models’ (Mont 2002), ‘as a consequence of innovative stakeholder interactions and related converging economic interests’ (UNEP 2002). Thus PSS innovation derives from a new convergence of interest between the different stakeholders: innovation not only at a product (or semi-finished) level, but above all as new forms of interaction/partnership between different stakeholders, belonging to a particular value production system (Porter and Kramer 2006). As a result, the PSS approach moves away from phase based servicing and discrete resource optimization, to system resource optimization which is utility based. In Figure 22, several examples of PSS implementing a whole system optimization beyond a single product life cycle are provided.

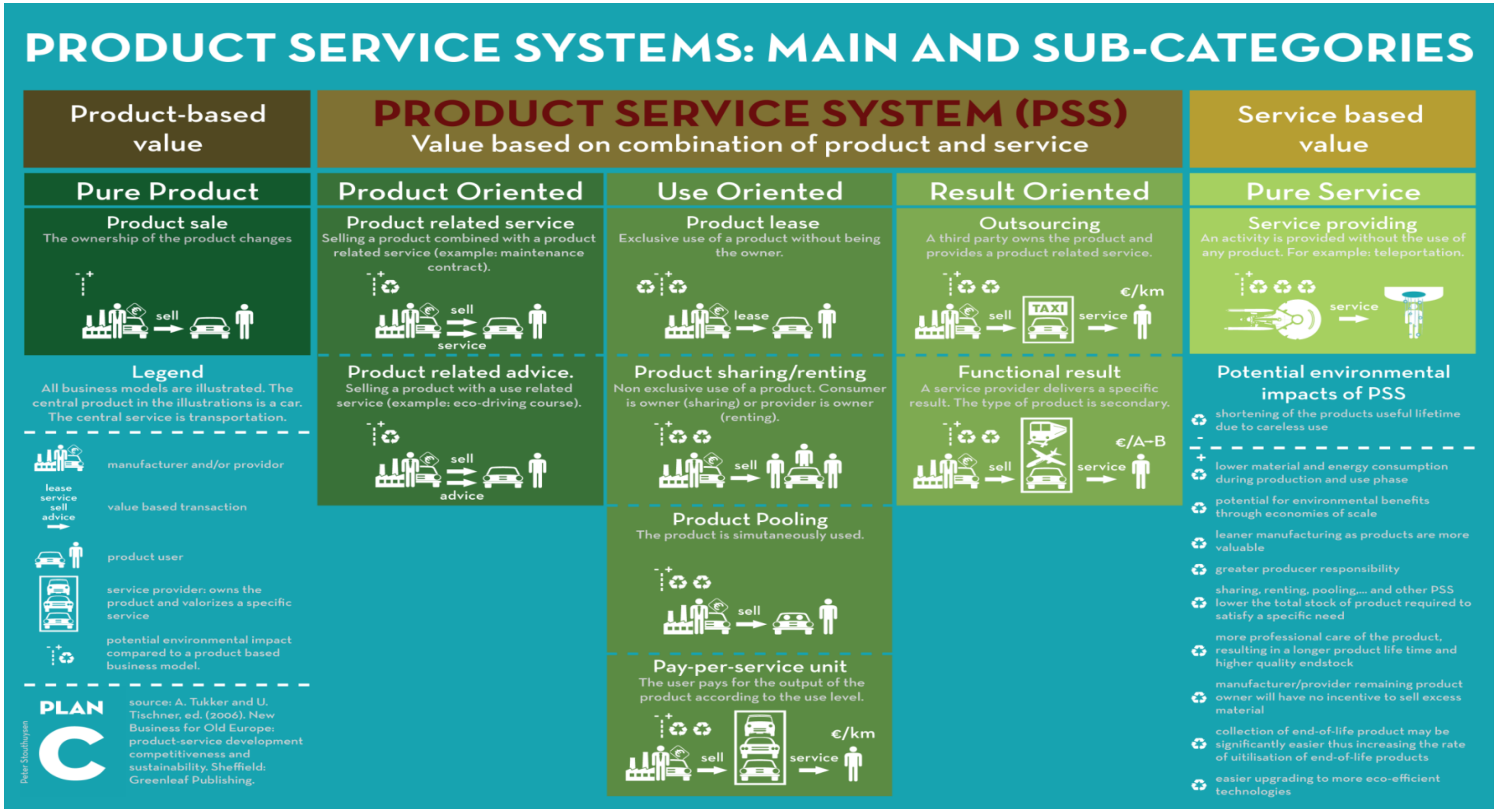


Figure 22: Product service Systems examples (Bochen et al., 2015)

3.6.4 Closed-loop approach

Another emerging approach of business model innovation is the *closed-loop production*, that can be similar to life cycle thinking but distinguishing itself by closing the material resource cycle. Effectively, the key principle of closed-loop approach is based on the development of circular models, instead of traditional linear production methods. In 2014, The European Commission adopted the Communication "Towards a circular economy: a zero waste programme for Europe". *Circular economy* means boosting recycling and preventing the loss of valuable materials; creating jobs and economic growth; showing how new business models, eco-design and industrial symbiosis can move us towards zero-waste; reducing greenhouse emissions and environmental impacts (EC, 2014). According to EEA (2014), the term 'circular economy' foresees a production and consumption system that generates as little loss as possible. In an ideal world, almost everything would get re-used, recycled or recovered to produce other outputs. Redesigning products and production processes could help minimize wastage and turn the unused portion into a resource. Accordingly, the closed-loop approach is aimed to minimize or eliminate waste in order to maximize resource efficiency in production–consumption systems. Basically, closed-loop approach is characterized as 'cradle to cradle' production (McDonough and Braungart, 2002) or 'industrial symbiosis' (Chertow & Ehrenfeld 2012). Generally, the adoption of closed-loop production approach results in a drastically reduction of need for virgin materials throughout the maximisation of recycling of materials that already exist in the production system. (Gaziulusoy and Twomey, 2014b) Additionally, advanced solutions adopt an even more holistic view, such as 'industrial ecology' (Ayres & Ayres 2002; Frosch & Gallopoulos 1989), in which the effluents of one producer's operations are used in another's production.

3.6.5 Sustainable consumption and production (SCP)

We have seen that at first, the environmental impact of industrial production has historically been dealt with by dispersing pollution in less harmful or less apparent ways. Driven in part by stricter environmental regulations, industry has used various control and treatment measures to reduce the amount of emissions and effluents. More recently, its efforts to improve environmental performance have moved towards thinking in terms of lifecycles and integrated environmental strategies and management systems, and companies have also begun to accept larger environmental responsibilities throughout their value chains. Thanks to the adoption of more integrated and systematic methods to improve sustainability performance has laid the foundation for new business models or modes of provision which can potentially lead to significant environmental benefits (Figure 23). Efforts to create closed-loop, circular production systems have particularly focused on revitalizing disposed products into new resources for production, for example establishing eco-industrial parks where economic and environmental synergies between traditionally unrelated industrial producers can be harnessed. All in all, manufacturing industries have the potential to become a driving force for the creation of a sustainable society (OECD, 2009). They can design and implement integrated sustainable practices and develop products and services that contribute to better environmental performance.

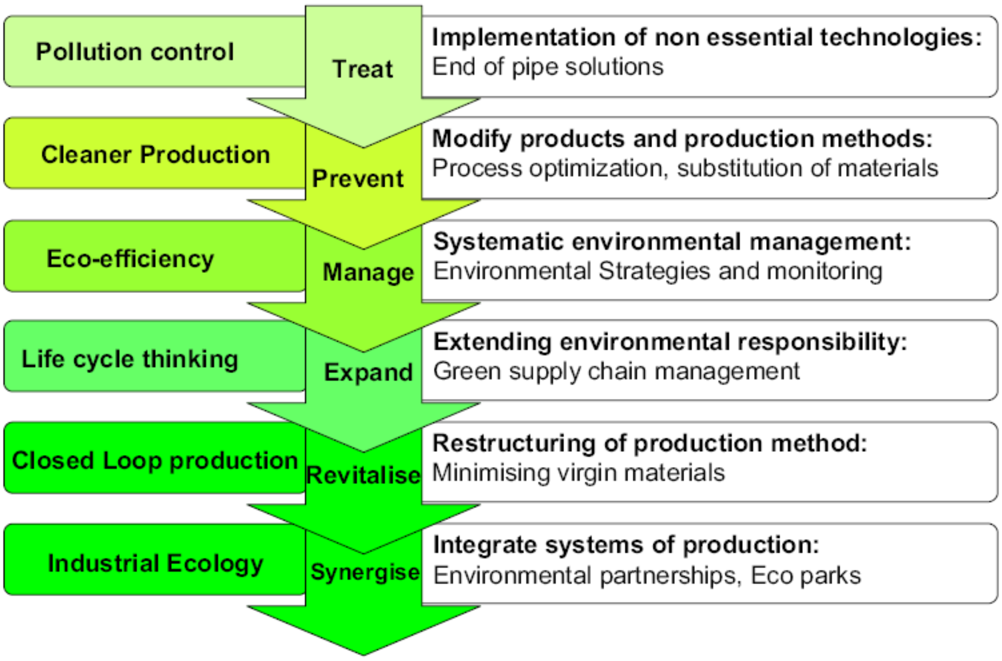


Figure 23: Evolution of sustainable production approaches practices (OECD, 2009)

Although sustainable production has this significant influence on sustainability, the fundamental proof of this is still missing. An example is the effectiveness assessment of eco-parks. According to von Hauff & Wilderer (2008) and Orsato (2009), eco-parks are built upon principles of industrial ecology, but it became clear that top-down public programs could not facilitate the formation of collaborative networks to make eco-parks successful in a business sense. This indicates that institutional changes are necessary if industrial ecology is to play a role in transitions towards sustainability. Hence, innovation is something that happens in, and between, companies, but it can also be a change induced by people According to Maxwell et al. (2006), this requires a shift in the perception and understanding of industrial production and the adoption of a more holistic approach to conducting business. For an effective sustainable innovation, engagement between customers and business is therefore key to co-creating desirable products and services at less resource costs.

3.6.6 Green marketing

To achieve that, there is the need of perspective oriented to a sustainable consumption and production (SCP). According to the European Commission (EC, 2008), SCP is a way of producing and using products and services in order to meet the basic needs for sustainability. On one hand, sustainable production focuses on reducing the environmental impacts of production processes and designing better products. On the other hand, consuming sustainably concerns lifestyle, buying behaviour and how consumers use and dispose of products and services. Hence, SCP means using natural resources and energy more efficiently and reducing greenhouse gas emissions and other environmental impacts. The aim is to maximise the potential of business to transform environmental challenges into economic opportunities while providing a better deal for consumers. Sustainable goods and services are aimed at reducing environmental impacts and bringing about a better quality of life and also ensuring that there are sufficient resources left for future generations. Consumers can play an important role in protecting the environment through the choices they make when buying products.

The consideration of the sustainable consumption as integral part of eco-innovation includes market-based dimensions of behavioral and lifestyle change and the ensuing demand for green goods and services. Therefore, sustainable innovation affects also the marketing dimension and the concept of green marketing incorporates a broad range of activities, including product modification, changes to the production process, packaging changes, as well as modifying advertising. *Green or Environmental Marketing* consists of all activities designed to generate and facilitate any exchanges intended to satisfy human needs or wants, such that the satisfaction of these needs and wants occurs, with minimal detrimental impact on the natural environment (Polonsky 1994).

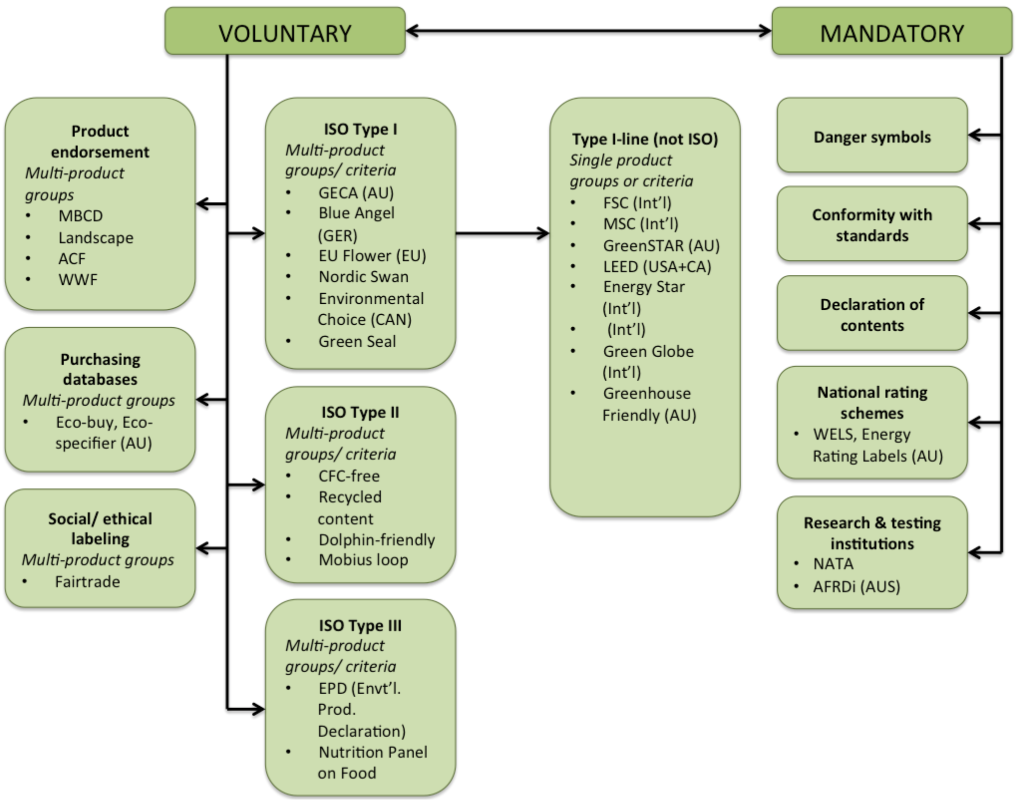


Figure 24: Voluntary and mandatory instruments of green marketing

As shown in Figure 24, there are a number of labelling systems that help consumers by providing details about the environmental performance of certain products (Horne, R.E. 2009). In a *green marketing approach*, companies that intend to generate competitive advantage from strategies based on eco-labelling need to observe three basic pre-requisites (Reinhardt, 1998): consumers must be willing to pay for the costs of ecological differentiation; reliable information about product's environmental performance must be available to the consumer; and the differentiation should be difficult to be imitated by competitors. Consumers need to perceive a clear benefit for their purchase. According to Orsato (2009), marketing differentiation based on the environmental attributes of products constitutes one of the most straightforward strategy towards sustainable consumption and production. In effect, "a firm differentiates itself from its competitors when it provides something unique that is valuable to buyers beyond simply offering a low price." (Porter, 1985). In this context, green or eco-products and services represent a defined market niche explored by companies worldwide. In the case of industrial markets, the benefits are normally translated into cost savings, better performance of the product, and a cost reduction of risk management. For instance, equipment and machinery that consume less energy and reprocess by-products might reduce the costs of operation for the client. The vendor can explore these ecological attributes commercially (less environmental impact) that result in gains during product use. In case the company is not working in a price-sensitive market, a price premium can be obtained. In consumer markets, the attributes associated with the products allow companies to charge higher prices for co-labeled products. Hence, in both cases—industrial and consumer markets—it is essential that the consumer is willing to pay for ecological differentiation. Credible information is the second pre-requisite for environmental product differentiation. The third requirement for environmental product differentiation involves barriers to imitation. If product environmental differentiation is to be successful, environmental innovation should not be easily replicated. To this purpose, to introduce sustainable innovation in marketing needs new ways of integrating environmental aspects in communication and sales strategies (OECD, 2009). Eco-innovative marketing concerns the company's orientation towards customers and can play a significant role in leveraging environmental benefits by influencing them. The concept of green marketing appears in the definition of eco-innovation.

"Eco-innovation is the introduction of any new or significantly improved product (good or service), process, organizational change or marketing solution that reduces the use of natural resources (including materials, energy, water, and land) and decreases the release of harmful substances across the life-cycle." (EIO, 2010)

All things considered, sustainable innovation need to occur both at the consumption and at the production level. The focus needs to be on not only products and services, but also the way that consumer needs and wants are defined and/or fulfilled and the ways companies and other stakeholders define their roles and relationships. Generally speaking sustainable consumption implies a departure from current accepted standards of living (and the economical patterns they are based on) that are directly linked to increased material and energy consumption. There is the need of moving the demand for products and services towards different, more dematerialized consumption patterns. In addition, it may also include new business models that change the way products are priced, offered and promoted such as the adoption of PSS. An example is the so-called user-led innovation, meaning that the functionality of new goods is developed with stakeholders, thereby minimizing the risk of superfluous product features. In some cases, the user may use the product in an unintended way (e.g. like mountain biking or using call credit for transferring funds) to create a market for new products (e.g. high-tech mountain bikes or mobile banking) or the user may directly develop a new product entirely (e.g. Facebook). Another significant experience of sustainable consumption is product sharing, which may lead to an absolute decrease of material use without diminishing the quality of services they provide to users. Furthermore, social dimension also involves the creative potential of society, with examples of innovative green living concepts. Co-development of a vision is key to make stakeholders "owners" of a vision and open to change. Therefore, social dimension can both use and contribute to sustainable innovation throughout co-creating high quality lifestyles that are more sustainable. Finally, the role of individual stakeholders in the transition are just as important as the new forms of collaborations between them. New strategic alliances of “fast movers” will develop and implement eco-innovation demonstrating desirable alternatives to business-as-usual (BAU).

3.7 Social innovation and institutional dimensions

From the previous considerations, it has arisen that sustainable innovation has two significant and distinguishing characteristics. On one hand, sustainable innovation reflects the concept’s explicit emphasis on a reduction of environmental impact, whether such an effect is hidden or not (OECD, 2009). On the other hand, sustainable innovation is not limited to innovation in products, processes, marketing methods and organizational methods, but also includes innovation in social and institutional structures (Rennings, 2000). In social science, the *institutions* are the rules of the games in society, such as regulations, routines that govern the interactions and behaviors of actors and organizations. The term institutions is sometimes also used for major societal domains, for example state, civil society, market. The consideration of societal aspects in the innovation process, especially referred to sustainable consumption, allow to introduce the concept of *social innovation*. According to EIO (2013), social innovation is “innovative activities and services that are motivated by the goal of meeting a social need and are predominantly developed and diffused through organizations whose primary purposes are social”. Additionally, Phills et al. (2008) stated that social innovation is “a novel solution to a social problem that is more effective, efficient, sustainable, or just than existing solutions and for which the value created accrues primarily to society as a whole rather than private individuals”. Therefore, sustainable innovation and its environmental benefits go beyond the conventional organizational boundaries of the innovator to enter the broader societal context through changes in social norms, cultural values and institutional structures. Furthermore, sustainable innovation not only reduced impacts on the environment, but also re-structure social relations in one form or the other. Another non-technological concept of innovation is *inclusive innovation*. As stated by George et al. (2012), *inclusive innovation* refers to “the development and implementation of new ideas that aspire to create opportunities to enhance social and economic wellbeing for disenfranchised members of society". In the following, other definitions which specify an expanded concept of eco-innovation including the social dimension are given.

"Eco-innovation is generally the same as other types of innovation but with two important distinctions: 1) Eco-innovation represents innovation that results in a reduction of environmental impact, whether such an effect is intended or not; 2) The scope of eco-innovation may go beyond the conventional organisational boundaries of the innovating organisation and involve broader social arrangements that trigger changes in existing socio-cultural norms and institutional structures". (OECD, 2009)

"Eco-innovation is the creation of novel and competitively priced goods, processes, systems, services, and procedures designed to satisfy human needs and provide a better quality of life for all, with a life-cycle minimal use of natural resources (materials including energy, and surface area) per unit output, and a minimal release of toxic substances." (Europa INNOVA, 2006)

3.7.1 The role of policy instruments

In order to take the challenges of sustainability into account, not only the organisational structure needs to change, but also new governance models have to be built on a shared vision. Several contributions address the determinants of sustainable innovation, including policy instruments, on econometric grounds, (for example, Brunnermeier and Cohen, 2003; Jaffe and Palmer, 1997; Mazzanti and Zoboli, 2006). In the European Union (EU), eco-innovation is considered to support the wider objectives of its Lisbon Strategy for competitiveness and economic growth. The concept was promoted primarily through the Environmental Technology Action Plan (EC, 2004). Environmental technologies have been also considered to have promise for improving environmental conditions without impeding economic growth in the United States, where they are promoted through various public-private partnership programmes and tax credits (OECD, 2009). As seen before, the promotion of eco-innovation has focused mainly on environmental technologies, but there a tendency to broaden the scope of the concept is emerged. Eco-innovation is thus seen as an overarching concept which provides direction and vision for pursuing the overall societal changes needed to achieve sustainable development. This extension of eco-innovation’s scope corresponds to the more integrated application of sustainable manufacturing described above. A growing stream of evolutionary-minded applied research projects addresses technological and organisational innovations associated to policy experiences, and in particular the role of institutional settings, observed industrial strategies, and policy-design approaches in influencing innovation (see, among others, Hemmelskamp et al., 2000; Klemmer, 1999; Kemp, 1997; Rennings et al., 2003; Cappellaro et al. 2011). According to Quist (2012), the evolution of the sustainable innovation concept from belonging solely to the environmental approach to being integrated in other aspects represents a shift in understanding about eco-innovation. This widespread understanding is reflected, notably, by the launch of the European Commission’s Eco-Innovation Action Plan (EcoAP) in December 2011(EC, 2011). EcoAP replaced the Environmental-Technologies Action Plan that was focused on promoting environmental industries. The main aim of EcoAP is to put eco-innovation at the heart of all European policies. As a result, the European Action Plan introduces the following definition of eco-innovation which include not only the sustainability goal but also the resilience enhancement

“Eco-innovation is any form of innovation resulting in or aiming at significant and demonstrable progress towards the goal of sustainable development through: reducing impacts on the environment, enhancing resilience to environmental pressures and achieving a more efficient and responsible use of natural resources." (EC, 2011)

3.7.2 Innovation in informal institutions

In the context of sustainability, however, a small but growing body of literature argues that changes in social norms, cultural values and institutional structures can be considered eco-innovation in themselves or constitute integral parts of an eco-innovation (Rennings, 2000). This view is gaining ground from a policy perspective. Literature distinguishes between informal institutions such as social norms and cultural values, which tend to be endogenous, and formal institutions such as codified laws, regulations, and formal institutional frameworks and arrangements, which tend to be based on policy and economic decisions. Therefore Eco-innovation in *informal institutions* refers to changes in value patterns, beliefs, knowledge, norms, etc., that lead to improvements in environmental conditions through social behaviour and practices. For instance, this would include shifts in the choice of transport modes, i.e. from personal automobiles or flights to trains, buses or bicycles because of users' higher environmental awareness or education. It may also include the growth of self-help health groups, community action for cleaning up the surrounding environment, organic food movements, etc.

BOX 2.1 Example of social innovation: grassroot innovation

According to Seyfang and Smith (2007), **grassroots innovations** are defined as: networks of activists and organizations generating novel bottom–up solutions for sustainable development; solutions that respond to the local situation and the interests and values of the communities involved. In contrast to mainstream business greening, grassroots initiatives operate in civil society arenas and involve committed activists experimenting with social innovations as well as using greener technologies.
Grassroots innovations differ from market-based innovations in several key ways: their driving force is social and/or environmental need, rather than rent seeking; their context is civil society rather than the market economy; they display diverse organizational forms including cooperatives, voluntary organizations and community initiatives, rather than firms; their resource base is voluntary input, grant funding, mutual exchange, and reciprocal relations rather than business loans and commercial income; they are grounded in local and collective values, based on notions of solidarity, rather than efficiency and profit-seeking; and their niche protection consists of being a space for alternative – i.e. green, sustainability-oriented- values to be expressed, as opposed to shielding from market forces.

3.7.3 Innovation in Formal institutions

Formal institutional eco-innovation refers to structural changes that redefine roles and relations across a number of independent entities. It typically relies on legal enforcement, international agreements, or voluntary but formal multi-stakeholder arrangements. Institutional eco-innovative solutions may range from agencies to administer clean local water supplies, financial platforms for funding the development of environmental technologies and the establishment of eco-labelling schemes and environmental reporting frameworks to new regimes of global governance such establishment of an institution with responsibility for global clip/ and biodiversity issues (Rennings, 2000). Another example of formal institutional eco-innovation is described in the box 2.2.

BOX 2.2 Example of formal institutional: GPP

Green Public Procurement (GPP) is "a process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life-cycle when compared to goods, services and works with the same primary function that would otherwise be procured". Public authorities in Europe spend 2 trillion EUR (nearly 20% of EU GDP on average). From constructing energy efficient public buildings to buying low emission vehicles, from buying organic or Fairtrade food to installing water-saving toilets, public procurement can have a huge impact in driving the market towards sustainability. The concept of GPP has been widely recognized in recent years as being a useful tool for driving the market for greener products and services and reducing the environmental impacts of public authorities' activities. Green Public Procurement (GPP) is one of the key tools of European SCP environmental policy. This tools is able both to stimulate the market and to support the technological innovation. Actually, GPP is aimed at promoting the development of the market of high environmental efficiency products acting on the public demand. According to EU policy, Member States are adopting specific National Action Plans (PAN) to endorse the practice of GPP. One important step is the definition of GPP criteria for specific products categories. GPP criteria aim at assisting authorities in identifying and procuring greener products, services and works. For that reason GPP criteria have to found on evidence-based data, embracing available scientific data and adopting a life-cycle approach. Italy has currently developed GPP criteria rules for 14 groups of products and services and recent GPP criteria are related to cleaning services.

Product	Product eco-innovation includes both goods and services. Eco-innovative goods are produced so that the overall impact on the environment is minimized, and eco-design is a key word in this area. Future product design will take into account resource constraints with a higher priority than is happening today, especially if commodity prices continue to increase. Designing a product in a manner that leads to decreased environmental impacts and less resource use during operation and that allows recovery options like repairing, remanufacturing or recycling should become key business strategies to not only save costs, but also to enhance the supply security and resilience of markets. Eco-innovative services include green financial products (such as eco-leases), environmental services (such as waste management) and less resource intensive services (for instance car sharing) (Kemp and Pearson 2007).
Process	Process eco-innovations concern production method or procedure aimed at reducing material use, lower risk and result in cost savings. Examples include the substitution of harmful inputs during the production process (for example replacing toxic substances), optimization of the production process (for instance improving energy efficiency) and reducing the negative impacts of production outputs (such as emissions) (Reid and Miedzinski 2008). In addition, reducing material inputs, so-called 'ecological rucksacks', of production and consumption processes can also be captured by process eco-innovation. Common terms linked with process eco-innovations include cleaner production, zero emissions, zero waste and material efficiency (Bleischwitz et al. 2009).
Marketing	Marketing eco-innovation involves changes in product design or packaging, product placement, product promotion or pricing. It involves methods for the promotion and pricing of products, and other market-oriented strategies to drive people to buy, use or implement eco-innovations. In marketing terms, brand (a collection of symbols, experiences and associations connected with a product or service by potential customers) is key to understanding the process of commercialization of products or services. While green branding is important, in practice, it is not the only or best way of selling eco-innovations. Labelling is also an aspect of marketing eco-innovation, i.e. eco-labelling
Organizational	Organizational eco-innovation is the introduction of organizational methods and management systems for dealing with environmental issues in production and products (Kemp and Pearson 2007). Such organizational changes are *the socio-economic dimension of process innovation*, such as the structure of management and the distribution of responsibilities and additionally it is closely linked to learning and education (see Bleischwitz 2003). It includes pollution prevention schemes, environmental management and auditing systems and chain management (cooperation between companies to close material loops and avoid environmental damage across the whole value chain) (Kemp and Pearson 2007). As such, organizational eco-innovation may also include an enquiry into various collaborative organizational forms and their potential eco-innovative qualities; this can range from business networks and clusters to advanced solutions in industrial symbiosis.
Institutional	According to OECD 2009, the concept of institutions generally covers a wide range, from social norms and cultural values to codified laws, rules and regulations, and from loosely established social arrangements to deliberately created institutional frameworks. It can be distinguished informal institutions such as social norms and cultural values, which tend to be endogenous, and formal institutions such as codified laws, regulations, and formal institutional frameworks and arrangements, which tend to be based on policy and economic decisions.
Social	Social eco-innovation considers the human element integral to any discussion on resource consumption. It includes market-based dimensions of behavioral and lifestyle change and the ensuing demand for green goods and services. Some firms are experimenting with so-called user-led innovation, meaning that the functionality of new goods is developed with stakeholders, thereby minimizing the risk of superfluous product features. Another important aspect is product sharing, which may lead to an absolute decrease of material use without diminishing the quality of services they provide to users. The social dimension also involves the creative potential of society, with examples of innovative green living concepts.

Table 2: Targets of sustainable innovation (EIO, 2013)

3.8 Categorization of the dimensions of sustainable innovation

At the end of this chapter aimed at describing the evolution of the concept of sustainable innovation, different dimensions of eco-innovation which consider the whole aspects investigating above can be distinguished. Based on an the extension of the definition of innovation in the OECD Oslo Manual (OECD and Eurostat, 2005) and on the existing literature, eco-innovation can be understood and analysed according to its targets (the main focus), its mechanisms (methods for introducing changes in the target) and its impacts (the effects on environmental conditions).

3.8.1 Target dimension

In particular OECD (2009) identifies **targets** as the focus areas of eco-innovation. According to Oslo Manual (OECD and Eurostat, 2005) and to OECD (2009), a definition of eco-innovation based on the target dimension states: "Eco-innovation can be described as the implementation of new, or significantly improved, products (goods and services), processes, marketing methods, organizational structures and institutional arrangements which, with or without intent, lead to environmental improvements compared to relevant alternatives". Basing on the EIO Report (2013), the targets are expanded from product, process, marketing, organizational, institutional eco-innovation to the inclusion of social sustainable innovation (Table 2).

3.8.2 Mechanism dimension

Another dimension which describes the nature of eco-innovation is the **mechanisms**. According to OECD (2009), mechanisms are the ways in which changes are made in the targets and consist of modification, redesign, alternatives and creation. Additionally, these mechanisms can be also associated with the underlying nature of the eco-innovation, whether the change is of a technological or non-technological character (OECD, 2007). Figure shows that ecoinnovation in products and processes tends to rely heavily on technological development;

alternatively eco-innovation in marketing, organizations and institutions relies more on non-technological changes.

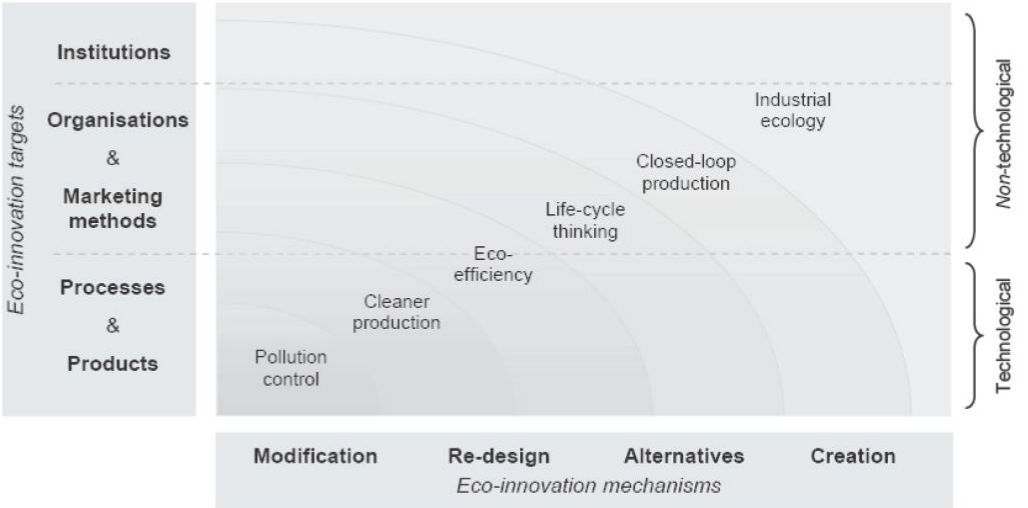


Figure 25: Relation between different innovation approach of sustainable production (OECD, 2009)

In Figure 25 is also described how the sustainable production innovation approaches (end-of-pipe, cleaner production, eco-efficiency, life-cycle thinking and finally industrial ecology) are related to targets, mechanisms and technological or non-technological sustainable innovation dimension.

Modification	A small, progressive product and process adjustments.
Re-design	Referring to significant changes in existing products, processes, organisational structures, etc.
Alternatives	The introduction of goods and services that can fulfil the same functional need and operate as substitutes for other products.
Creation	The design and introduction of entirely new products, processes, procedures, organisations and institutions.
Co-creation	The creation of experimental place with creative phases where the innovation process can be guided directly by the user. The focus is the experience and interactive relationships. Co-creation allows and encourages a more active involvement from the user to create a value rich experience.

Table 3: Typologies of Sustainable Innovation Mechanism (OECD, 2009).

Since in Table 2, the sustainable innovation targets include also social innovation, another mechanism related to both these targets can be introduced. According to Maase (2006), co-creation is a typical way supporting social innovation. Therefore, in Table 3, sustainable mechanisms expansion is proposed beyond the basic mechanisms, adding co-creation.

3.8.3 Impact dimension

Finally, OECD (2009) identifies *impacts* as the eco-innovation dimension which describes the effects of eco-innovation on the environment, across its lifecycle or some other focus area. Potential environmental impacts of an eco-innovation stem from the interplay between the innovation's design (target and mechanism) and the socio-technical environment in which the innovation is introduced. From an analytical perspective, the assessment of this impact is very important because it determines whether or not the eco-innovation can in fact be classified as such. Also, from a practical point of view, it is important to show that the eco-innovation improves overall environmental conditions. However, the impact assessment of eco-innovation requires extensive knowledge and understanding of the innovation and its contextual relationships. According to Reid and Miedzinski (2008), eco-innovation assessments must consider the eco-innovation's life cycle at several levels, including the behavioural and systemic consequences of the innovation's application and/or usage. These can be categorized according to the innovation's characteristics at the micro level, referring to companies and individuals; at the meso level, including supply chains, sectoral structures, local perspectives, etc.; and at the macro level, referring to countries, economic blocs and the global economy.

3.9 Drivers and barriers to sustainable innovation

Corresponding to the emerging concept and nature of sustainable innovation, several studies have identified *factors that drive and impede* sustainable innovation process (Kammerer, 2009; Dangelico and Pujari, 2010). As noted above, the notion of eco-innovation has grown in importance in relation to sustainable manufacturing but its characteristics and impacts are often obscure to both policy makers and companies. Quantitative measurement of eco-innovation activities would improve understanding of the concept and practices and help policy makers to analyze trends and identify drivers and barriers. It would also raise awareness of eco-innovation among industry, policy makers and other stakeholders, and would make improvements achieved through eco-innovation more evident to producers and consumers alike.

3.9.1 Production side

According to Rennings and Zwick (2003), five drivers to eco-innovation have a positive influence on the production side:

1. regulation,
2. demand from users
3. capturing new markets
4. cost reduction
5. improving firm’s image.

Among them, the compliance with environmental regulations is revealed determinant for different kinds of eco-innovation. As ETAP (EC, 2004) affirms, good legislation can effectively stimulate eco-innovation. On the other hand, in some cases regulations and standards may act as barriers to innovation when they are unclear or too detailed. Concerning the barriers which can have an effect on sustainable innovation, there are different factors affecting both the sustainable production and sustainable consumption innovation. An example of sustainable production barrier is economic factors as market prices which do not reflect the external costs of products or services, such as health-care costs due to urban air pollution. Another factor is the higher cost of investments in environmental technologies because of their perceived risk, the size of the initial investment, or the complexity of switching from traditional to green technologies. In the following table an overview of barriers for sustainable production is provided (OECD, 2009; Buttol et al. , 2011).

Technological	lack of available technology or performance capabilities;
Financial	high costs of research, inability to predict future liability costs, impact on competitiveness, or a lack of economies of scale; limited market incentives/recognition for environmentally friendly behavior;
Human resources	limited human resources and expertise for dealing with compliance;
Regulatory	disincentives to invest in recycling, regulatory uncertainty, focus on end-of-pipe treatments;
Consumer-related	tight product specifications or risk of losing customers owing to a change in product characteristics;
Supplier-related	lack support for maintenance;
Managerial	a lack of co-operation among different functions within the firm, a reluctance to change operating methods or a lack of education and training of employees

Table 4: Barriers for sustainable production

Other aspects relating drivers and barriers at the production side are arisen by a survey conducted by Eurobarometer in 2011 (Gallup, 2011). This survey has investigates the behavior, attitudes and expectations of entrepreneurs towards eco-innovation. As a results, interesting drivers and barriers are came out (Figure 26 and 27).

The principal drivers which are emerged from the Gallup survey (2011), have mainly concerned the following aspects: efficiency and cost-savings, stakeholders involvement, knowledge capacity development and finally evolving regulations. First of all, one in two respondents considered current high energy prices were an important driver of eco-innovation in their company. A similar proportion (52%) said the same about the expected future increases in energy prices. A majority of respondents across all countries also agreed that the current high material prices were an important driver of eco-innovation in their company.

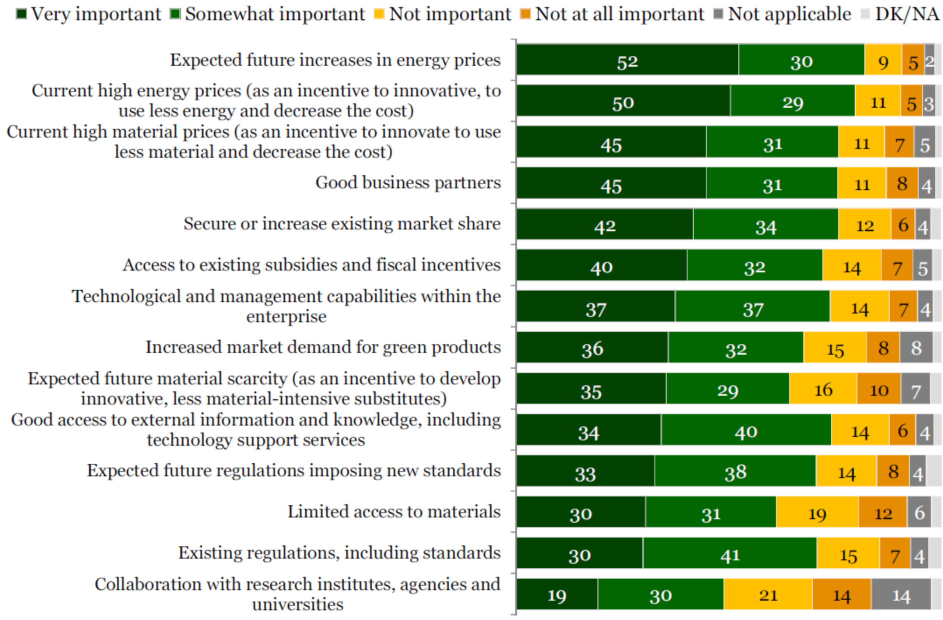


Figure 26: Drivers that could accelerate eco-innovation uptake and development (Gallup, 2011)

In addition, expected future material scarcity was a very important driver of eco-innovation. Another important driver of accelerated eco-innovation development is the presence of a good business partners, about 45% of respondents sustain that. In addition, almost 37% managers said that technological and management capabilities within their enterprise were a very important driver of eco-innovations. Therefore the knowledge capacity development is important for the 34% who asserted the importance of good access to external information and knowledge, including technology support services. Finally, existing regulations and standards and expected future regulations and new standards were considered very important eco-innovation drivers by, respectively, 30% and 33% of respondents. Correspondingly, access to existing subsidies and fiscal incentives was described as being very important by 40% of entrepreneurs.

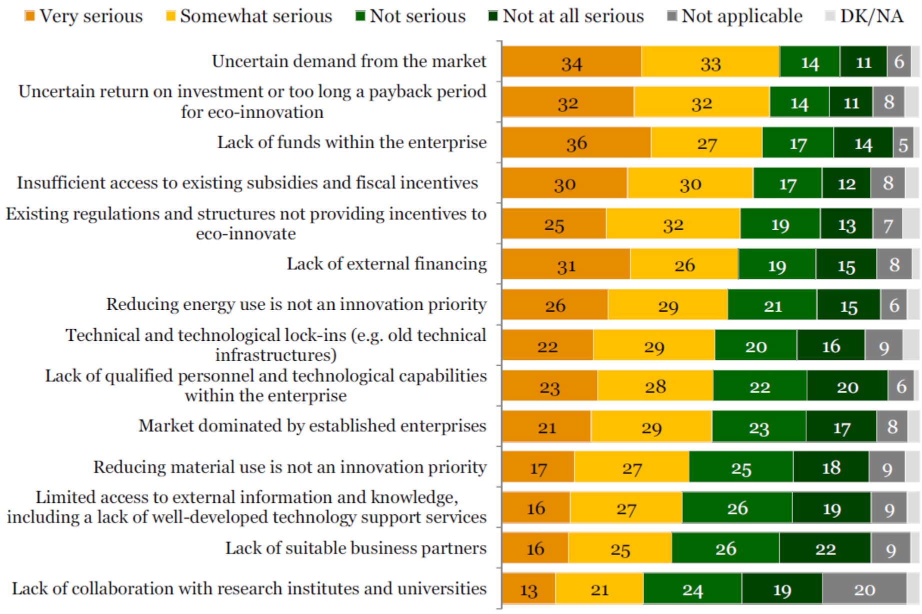


Figure 27: Barriers to accelerated eco-innovation uptake and development (Gallup, 2011)

As regards barriers, two-thirds of managers said that the uncertain demand from the market was a hurdle to a faster uptake of eco-innovation in their company. More than a third (36%) of managers said that a lack of funds within their enterprise was a very serious barrier. Lack of qualified personnel and technological capabilities is found to be a much important barrier than lack of cooperation with research institutes and universities. Another barrier concern the limited access to external information and knowledge.

3.9.2 Consumption side

Concerning the sustainable consumption, aspects for behavioral changes are complex. As described in Figure, the changing of behaviors can be understood in terms of the *theory of planned behavior* (Ajzen, I. 1991; Armitage, C., & Conner, M., 2001; Grizzell, J., 2007).

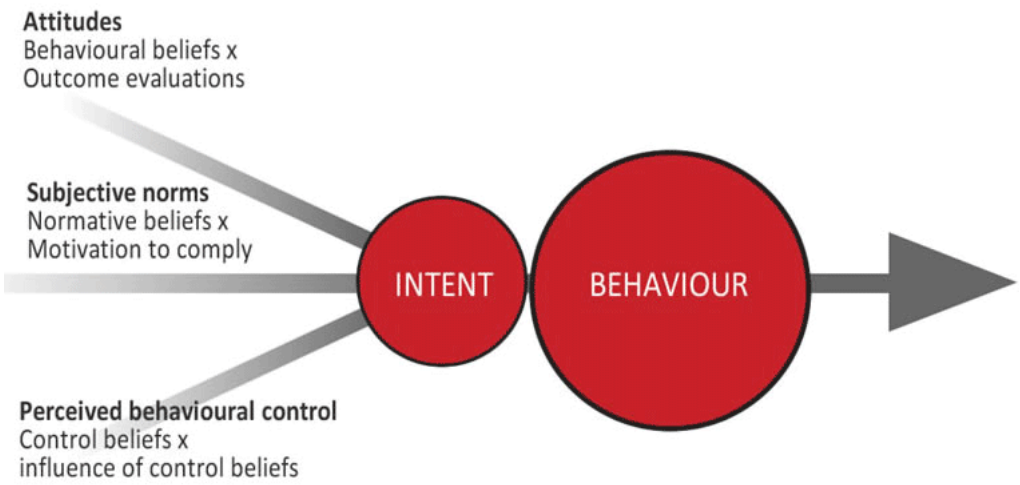


Figure 28: Theory of planned behavior (Holland, 2011 adapted by Ajzen, 1991)

Furthermore, other researchers (Prochaska et al., 1998) developed the Stages of Change Model that describes the process by which all behaviors change (Figure 28)

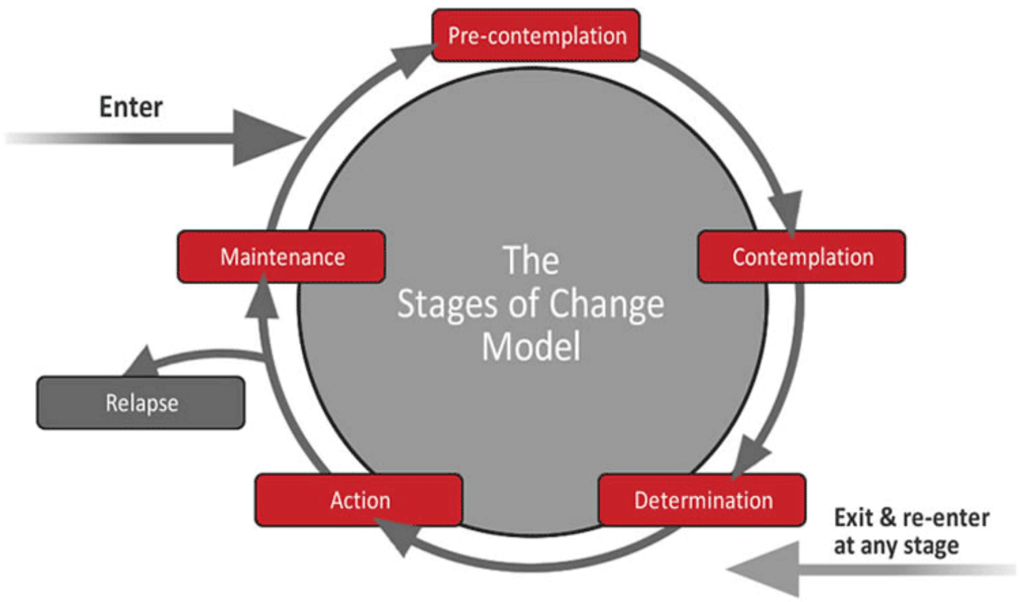


Figure 29: Stages of Change Model (Holland, 2011 adapted by Prochaska et al., 1998)

Other factors which can undoubtedly affect mass behaviour change, are rules. However, the change they make may not always be what is expected. A large body of literature exists that deals with barriers to behavioral change. According to Faber et al. (2012), barriers to behavioral change are factors that prevent an intention from being developed or as factors that prevent an intention turning into a behavior. An often used distinction is that between individual barriers and societal barriers. Although many consumer decisions are not made in a rationalized way, analyzing primary motives for certain choices helps to find barriers for behavioral change. Consumers make trade-offs between advantages and disadvantages of certain lifestyles and product choices. These advantages and disadvantages may be related to costs, comfort, health, convenience, safety, quality, etc. Based on a review of the literature, in the table a categorization of barriers for behavioral change is provided (see Table 5):

Factors	**Barriers**
Individual (internal) barriers	
Social and psychological	attitude, interest, beliefs, feelings and self-efficacy/confidence
Knowledge-based	limitations in knowledge of the subject, or the ease with which it can be found.
Unconscious behaviour	routines and habits
Demographic	age, education, gender, income.
Societal (external) barriers	
Infrastructural	lack of necessary infrastructure(e.g. people are less motivated to take the bike if no good structure of cycling lanes exists)
Cultural	social norms and traditions, (e.g. the custom to eat meat every day)
Economic	financial constraints (e.g. people's ability to invest in environmentally friendly technologies may be limited by financial constraints)
Institutional	law, politics and organisational structures (e.g., the organisational structure of a firm may be a barrier for working at home)

Table 5: Barriers for behavioral change (Faber et al., 2012)

3.9.3 Final remarks

At the end of this paragraph, it would be useful to introduce some concepts which stem from socio-economic science and relate to socio-technical barriers. Firstly, the term "regime" means coherent and dominant rules and institutions that guide actors (e.g. firms, users, policy actors, scientists) in a specific direction, by enabling and constraining their choices. A distinction among can be made between:

- Regulative rules or institutions: formal rules, laws, sanctions, incentive structures, reward and cost structures, governance systems, power systems, protocols, standards, procedures
- Normative rules or institutions: values, norms, role expectations, authority systems, duty, codes of conduct
- Cognitive rules or institutions: priorities, problem agendas, beliefs, bodies of knowledge (paradigms), models of reality, categories, classifications, and jargon/language.

When innovations do not come easily, the principal cause lays on existing regimes characterized by a locked-in mechanism. The first explanation for the term *"lock-in"* outcomes from the idea that the nature and direction of technological advance is strongly shaped by the cognitive framework of actors. Nelson & Winter (1977) use the term technological regimes to describe these frames while Dosi (1982) refers to them as technological paradigms. Both, however, point to the existence of certain "rules", "heuristics" or "principles" that define the boundaries of thought and action by members of the technological community (engineers, firms, technology institutes, etc.). These include, for example, engineering ideas about the nature of the technological problem and the worthwhile set of possible solutions. The key concept of *lock-in* is that technologies and technological systems follow specific paths that are difficult and costly to escape. Consequently, they tend to persist for extended periods, even in the face of competition from potentially superior substitutes. Thus, lock-in is said to represent the continued use of a range of supposedly inferior technologies. Lock-in also means that a particular technology or product is dominant. Another concept are persistent problems which are embedded in the dominant regime/institutions. Persistent problems are complex and uncertain because they involve many and various actors who have to work together for a solution but most often have varied goals. For this reason, persistent problems are difficult to solve and often recur notwithstanding various efforts to overcome them.

3.10 Conclusion

In this chapter, the different approaches to face sustainability challenge has been investigated. The approach towards sustainable innovation has evolved from pollution control, the end-of-pipe approach, to preventive cleaner production and life-cycle approaches till the emerging approaches as closed-loop production and industrial ecology. Finally, sustainable innovation approach has been expanded till to include both the production and the consumption side. Actually, at the **production side**, it is emerged that business has contributed significantly to sustainable innovation via a variety of mechanisms: ‘end-of-pipe,’ cleaner production, eco design, closed-loop and new business models. Generally, the primary focus of innovation in sustainable production has based on technological advances, typically with products or processes as eco-innovation targets, and with modification or re-design as principal mechanisms. Nevertheless, even with a strong focus on technology, a number of complementary changes have functioned as key drivers for these developments. Effectively, the changes have been either organizational or institutional in nature. On the other hand, several barriers still affect the achievement of a radical change in the production. The result is the maintenance of current business-as-usual trend. There is the need to indentify novel approach for sustainable innovation which contribute to long-term continuity and help to form, in another way, a win-win situation, then businesses have a clear motivation to pursue sustainability goals. Furthermore, the chapter has also explored the innovation at the **consumption side**. Really, consumers have a crucial role in the sustainable innovation process. For example, they can drive change via voting power in the market, and via their roles as political agent, NGO, worker, investor and citizen, capable of bottom-up action. At the same time, consumers may also find that sustainable choices do not always lead to the same quality or level of experience as less sustainable choices. The chapter has described the barriers that make consumers locked into contexts due to certain behavioral changes difficult. In this context, the perspectives for future sustainable innovation does not necessarily require a new technological product or process, but rather can involve changing aspects (or the entirety) of a value structure. The emerged necessity is to identify approach which change the business-as-usual practices by changing customers' habits so that resources are used more efficiently, while functions or utilities are still delivered. This changes is in thinking and doing things differently and in making other agents in a system perform differently that bring about systemic transformation. Therefore, the heart of sustainable innovation approach cannot necessarily be represented adequately by a single set of target and mechanism characteristics. Instead, sustainable innovation seems best examined and developed using a range of characteristics varying from modifications to creations across products, processes, organizations, social and institutions. The characteristics of a particular innovation furthermore depend on the observer's perspective. The analytical framework can be considered a first step towards more systematic analysis of sustainable innovation.

4 Analysis of two case study towards a co-evolutionary approach of sustainable innovation

You never change things by fighting the existing reality.
To change something, build a new model that makes the existing model obsolete.
Richard Buckminster Fuller

In the last chapter, the growing importance of actors and networks in the innovation process towards sustainability has been arisen. This trend is aligned with modern innovation theory that has moved towards the recognition that innovation is a joint activity involving a large number of actors with different interests, perceptions, capabilities and roles (Gaziulusoy and Twomey, 2014a). Unlike the traditional "linear model" of innovation introduced by Schumpeter (1934, 1942) that put a strong priority on research and development (R&D) and on the role of entrepreneur as the driver of innovation, a demand-pull perspective was later acknowledged (Schmookler 1966). Therefore, the demand for products and services has been recognized more important in stimulating innovation activity. A particularly interesting development is the growing recognition of the importance of users (firms and individual consumers) in the innovation process. It is not just that product and service developers are more sensitive to the wants and needs of users, but rather that users are increasingly developing or adapting their own goods and services (Bogers et al 2010; von Hippel 2005). This has led in many areas to thriving user innovation communities and rich intellectual commons, which also feedback to manufacturers to mass produce new products and services. Another important feature of modern approach is the interactivity among agents and feedbacks between different stages of the innovation processes (Kline and Rosenberg 1986). Like the previous theme, this resonates strongly with the field of complexity science which investigates how relationships between parts give rise to the collective behaviors of a system, and emphasizes non-linear dynamics, heterogeneous agents, networks, evolution and the emergence of system properties (Mitchell 2011). The complexity of interaction and interdependence also occurs between (as well as within) systems and, as Foxon et al. (2013) note, this is highly relevant to analyzing sustainability issues in which there are complex interactions between economic, social and ecological systems.

In this framework, it has emerged the central role of institutions in enabling, constraining and shaping our behaviors and practices (Gaziulusoy and Twomey, 2014a). Therefore, two dominant approaches advocate to achieve sustainability: the first one is technology-oriented and the second behavior-oriented. According to Brand (2003), there is no actually the necessity to have a dichotomy between them. But a *co-evolutionary approach* could be adopted with the aim to overcome a competitive perspective towards collaborative and inclusive approach. Sartorius (2006) states that "*co-evolution implies that successful innovation in general and successful sustainable innovation in particular, has to acknowledge the involvement of, and mutual interaction between, more than the mere technical and economic spheres*". Hence, co-evolution occurs when different sub-systems have mutual interactions which affect the development of each system (Geels 2005c; Foxon 2008). Co-evolution is finally a way to embrace the nexus approach. In the present chapter, two case studies have been analysed in light of the co-evolutionary approach. The aim is to understand sustainable innovation through the inter-action of technologies, institutions, social practices and business strategies. The former is a case of sustainable innovation regarding an industry sector as automotive is (Bonoli, 2013). The latter concerns a sustainable innovation practicing at urban level and it consists in the introduction of a water fountain in a small town of Italy (Cappellaro et al., 2013). At the end of this chapter, both cases are analyzed throughout the recognition of the aspects which describe the nature of innovation, such as target, mechanism, impact (micro, meso, macro), drivers and barriers, and the mutual interaction. This analysis can allow to identify the requirements and the key-factors which drive the innovation approach for an effective transition towards sustainability.

4.1 Sustainable Innovation in the Automotive Sector. An experience of Automobile Shredded Residues (ASR) light fraction recovery.

4.1.1 The context

In the automotive sector the problems of resources consumption and waste disposal are crucial. Since 1989, end-of-life vehicles (ELVs) have been identified as a priority waste stream by the Commission's Community Strategy for Waste

Management. With the aim at preventing waste from vehicles and improving environmental performances of ELVs, the European Union's has been established the Directive 2000/53/EC, well known as ELV directive. The directive has introduced increasing recycling/recovery/reuse (RRR) targets till to achieve by January 2015 the final objective of 95% rate of reuse and recovery on a mass basis, including a rate of 85% for reuse and recycling. The literature on eco-innovation emphasizes that regulation has an important influence on innovation (del Rio, 2009; Kammerer, 2009; Rennings et al., 2006; Rennings, 2000; Hemmelskamp et al., 2000; Klemmer, 1999; Zoboli, 1998; Kemp, 1997). The introduction of the "producer responsibility principle" (PRP) in waste and recycling policy has influenced innovation when the relationships between various manufacturing industries with different interests about innovation are involved . Several authors (Brunnermeier and Cohen, 2003; Jaffe and Palmer, 1997) analyze the effect of legislation which adopt the "extended producer responsibility" (EPR) and assert that EPR type legislation can provide a tool to gain market and develop innovation. ELV directive is EPR type (Konz, 2009; Smith and Crotty, 2008) and as a consequence an extensive set of technological and organizational innovations has been pursued by different industrial actors in the car making (upstream) and ELVs treatment chains (downstream, post-consumer) (Henry, 2011; Johnson and Wang, 2002; Zoboli, 2000;). Driven by the ELV directive targets, several car companies has been realizing innovative activities and most of them concern the steadily increased use of plastic materials in car manufacture. Plastics are lightweight and have some desirable mechanical and physical properties resulting in the reduction of the total mass of the car and of its fuel consumption. (Bellmann and Khare 1999, 2000). Most of the developed innovations in the automotive sector are targeted at emissions reduction, fuel efficiency and energy consumption, but they are not still sufficient to achieve the level of end-of-life vehicles targets (Gerrad and Kandlikar, 2007). On the other hand, the innovation with the highest potential contribution (plastic recycling) is the less developed due to technical and/or economic reasons. Currently, the recycling process concerns mainly the metallic fractions, both ferrous and non-ferrous, which are recovered by dismantling (spare parts) and shredding. The other remaining materials (plastics, rubber, paper, wood, other metallic materials, inert materials such as glass, paint, soil) constitute the Automobile Shredder Residue (ASR). This fraction is about the 25% of a car total weight, an estimated 2.2 million tons in the EU. (Noureddine, 2007). The final disposal of ASR is generally landfill, but currently there are growing problems. In Europe ASR is classified as hazardous waste because it contains contaminants such as metals like lead, copper, zinc and cadmium, petroleum hydrocarbons, volatile and semi-volatile organic compounds (Fiore et al., 2012; Gonzales et al., 2008). In addition, ELVs directive stated that by 2015, only the 5%-wt of a vehicle may be landfilled, and the 10%-wt may be incinerated, leading to a mandatory 95% of a ELV total weight recycled and recovered. As Mazzanti and Zoboli (2006) emphasize, specific innovation can't allow to attain the targets of ELV Directive, if taken alone. Therefore, there is the need of implementing an innovation process, composed by alternative and complementary sequences of interrelated innovative activities able to fulfill the ELVs targets and pushed toward one of the most unsolved problem: the recycling of plastic materials from ELVs. This case focus on a technology innovation for the recovery of light fraction from ASR. An overview on how plastics affect ELVs environmental problems is provided, especially on ASR generation. In order to solve environmental issues, advantageous ecodesign strategies are also presented. This case proposes a method for reaching the targets by the optimization of an emerging technology for the extensive shredder residue separation: the sink-float separation. The case study regards a pilot plant which applies this technology. Further improvements to increase the light fraction recovery and scenarios for secondary plastic materials are proposed.

4.1.2 Investigating strategies for improving plastics recycling

In the automotive sector, plastics have been becoming central to vehicle production (McAuley,2003). Plastic materials offer esthetics, light weight and technological advantages: greater design flexibility, improved vehicle aerodynamic and weight reduction (20 -30 % less then metals), meaning greater fuel economy. Other advantage of plastics is the high resistance: high tolerance to the water and weather effects, low surface degradation under the effects of sun, frost or chemicals. On the basis of chemical compositions there could be other advantages, such as heat insulating, low friction, dielectric properties or electric conductivity. Consequently, plastic materials need a minimal maintenance (Kumar and Sutherland, 2008; Kistenmacher , 2004; Okö -Istitut, 2003). Plastics are employed in over 1000 parts of a vehicle, including seats (12%), bumpers (10%) , dashboards (14%), interior trim (19%), fuel systems and upholstery (8%) and they represent, on average, 10% of the vehicle weight (Panaitescu et al. 2008; Muñoz et al., 2006) The use of plastics in European cars has been increasing by 50% over the past 20 years and the trend is to increase from the current percentage of 6-8% up to 10-15% in new cars (Passarini et al., 2012, Nemry et al.., 2008, GHK/BIOIS, 2006). Despite all these benefits and versatility, plastics present a critical consequence in the amount of waste generated per vehicle and affecting the end of its running life. The increasing use of light materials causes the increase of the Automobile Shredder Residues quota and efficiently processing of several plastics contained within the ASR is certainly a difficult task. Therefore new and innovative lightweight car designs have benefit for less impact during use phase, but they could encounter problems in future to reach the required recycling quota of 85% and the recovery quota of 95% by 2015. As explained before, plastics are the most critical components for reaching the EU-target and ASR is one of the greater challenge with regard to recovery rate. Furthermore, car plastic recycle keeps on not being fully exploited due to high dismantling and logistic costs(Santini et al. 2010; Castro et al., 2003). A way for achieving the recycling rates targeted by the ELV Directive is to implement ecodesign strategies (Mayyas et al., 2012). Ecodesign provides an exhaustive overview of the options for improving the environmental profile of a product throughout the different stages of its life cycle (Brezet and van Hemel,1997). Currently, several carmakers are working on the development of ecodesign strategies with the aim to implement recyclability of materials and components, including the introduction of lists of not admitted or undesired substances/materials in the technical specifications imposed to component suppliers. As described by Ferrão and Amaral (2006a), one of the most remarkable practice to improve the recyclability in ELVs is Design for Recycling (DfR). Adopting DfR strategies is useful to increase the recycling possibilities and, at the same time, to gain economic advantages (Borchardt et al., 2011, Parlikad and McFarlane, 2010, Johansson and Luttropp, 2009, Luttropp, 2006). A classic example of DfR strategy is the pursuit of a simplification in the material composition throughout reducing the number of different materials. Another strategy consists in optimizing the disassembly activities and it is also known as Design for Disassembly (DfD) (Lambert 1999, 2002). DfD may imply small changes in the part-assembling systems or some changes and adaptations of components and parts. Another example to facilitate identification during dismantling can be the labeling of plastic parts. Nevertheless, the costs associated to disassembly operations of ELVs are relatively high. In order to increase the recovery rate, the general trend is the development of post shredder technologies (PSTs). PSTs are actually ten times less expensive than the manual dismantling undertaken by specialist companies and therefore offer the most promising avenue for meeting the targets for 2015. (Vermeulen et al. 2011; COM, 2009, Ferrao and Amaral 2006b)

4.1.3 Emerging technologies for extensive shredder residue separation.

Post-shredder technologies are referred both to ASR treatment for energy recovery by thermic process and ASR separation technologies for material recycling using mechanical treatment. As Reuter et al. (2005) emphasize the recyclability of a product is not only determined by the intrinsic property the different materials used, but by the quality of the recycling streams, which is determined by the mineral classes (combination of materials due to design, shredding and separation), particle size distribution and degree of liberation (multi-material particles) and the efficiency of physical separation. Currently in order to reach the 95% of recovery and recycling as expected by EU directive and by national legislation, many studies and pilot plants are spreading to improve the recovery of ASR and in particular of light fraction. The main new mechanical treatment processes are Galloo, Sicon and Scholz.

Galloo process	Galloo is a process based on a density separation using an heavy medium mixture (iron-silica) in water, in order to separate the heavy fraction, constituted ferrous and non-ferrous metals destined to the recycle, and the light fraction, consisting of RDF fraction (~45%-wt), containing rubber, mixed plastics, textile, etc. for the energy valorization), polymers (~10%-wt) as PP, PS and ABS for material recycling, inert fraction (~40%-wt) and light residual fluff (~5%-wt) both destined to landfill.
Sicon process	Sicon process comprises granulation and mechanical separation. Light car-fluff fraction is separated in order to recover PE, PP, ABS, PA, PVC and EPDM (about 30% of fluff), fibers and textile (27%), metals (8%), as iron, aluminum and copper; residual smelt (5%) is destined to energy recovery. Technology pioneer plants adopting Sicon process are actually developed in Belgium, Austria, Nederland and USA (Schulke and Quidousse, 2007).
Scholz process	Scholz process (Scholz et al., 2007) uses a traditional separation technology in order to separate three fractions: metals (~72%-wt), high density SR (~12%-wt) and low density SR (~16%-wt). In relation with high density SR fraction, vibrating screens produce four different materials with following diameter: d < 20 mm; 20 <d <65 mm; 65<d <100 mm; d>100 mm. A subsequent magnetic separator separates metallic and non-metallic fractions. Low density SR fraction is classified at the following dimensions: d< 2 mm ("mineral product", ~50%-wt, destined to landfill covering), 2<d<20 mm, 20<d< 65 mm and d>65 mm; a subsequent aeraulic separation obtains heavy fluff (~10%-wt, destined to a re-treatment with heavy SR fraction) and light fluff, constituted by plastics for recycling or recovery (~8%-wt) and by light residues (as textiles, wood, fibers, etc.,~30%-wt) destined to energy recovery. The first pilot plant using the Scholz process is in Espenhain, Germany.

Table 6: Mechanical treatment for extensive shredder residue separation

Industrial applications using PSTs based on mechanical separation have demonstrated that the ELV directive's reuse and recycling targets can be achieved (Verburg, 2011; Christen, 2006).

4.1.4 Float/sink separation for polymeric fraction

The case study describes a simple sink-float separation test realized in an Italian ELV crushing plant (Italmetalli-Bologna, Fiori Group). The technologies uses water to separate the polymeric component (PP, PE) of car fluff: polypropylene and polyethylene float, because lighter than water, while the other heavier components sink. The tested ASR, having size d< 20 mm in a total quantity of material of 400 kg, was constituted by metals (about 15% -wt), plastics (~65%-wt) and an heterogeneous mixed fraction of other materials (as wood, textile fibers, foam rubber, etc., ~20%-wt,). In particular PP and PE weighted 56 kg, about the 14% of the ASR total, and polyurethane and other plastics weighted 204 kg. The material has been entered in the basin and in few minutes polyurethane, wood, polyolefin and other plastics floated. After removing the surface material, it has been necessary a subsequent manual separation in order to collect polyolefin and deposit it in big bags. In the big bags, it has been recovered the following quantities: 18,8 kg of polyolefin (PP e PE) and 110,1 kg of polyurethane and other plastics. The residual fraction has sunk. In table 7 the float/sink test results.

		Output kg	Output %
Float	Polyolefin (PP, PE)	18,8	4,7
	Polyurethane, other plastics	110,1	27,5
Sink		271,1	67,8
TOTAL		400	100

Table 7: Outputs from the sink-float process

In Table 8 the Separation Efficiency for Polyolefin, Polyurethane and other plastics is reported. As known, Separation Efficiency (%) represents the quantity of recovered material in relation with the quantity of the same material in treatment feeding. Esep is calculated as the rate of each material quantity in output (qout) and its quantity in input (qin): Esep = qout /qin.

	E_{sep} (%)
Polyolefin (PP, PE)	18
Polyurethane and other plastics	54

Table 8: Separation Efficiency for plastic fractions

A simple separation test has provided a first result in light ASR fraction treatment showing the possibility to separate plastics from other light fraction in a very easy and inexpensive way. PP and PE represent about the 14% in weight of the total, but they could increase in an interesting rate the total recovery of ASR fraction. The test has shown a low efficiency (about 18% for PP and PE recovery and 54% for polyurethane and other plastics), but the process can be reiterate, in order to improve the polyolefin recovery rate. Actually the sunk material still contains PP and PE inside the small mixed fraction, but the basin can be fed in subsequent steps with the aim to achieve the maximum separation efficiency. At the same time, improving the separation efficiency allows to obtain a cleaner sink that can be usefully recovered. The plastic fraction obtained by the sink-float process can be subsequently processed by “traditional” mechanical treatments, consisting in granulation, washing, milling, drying and final extrusion. The final product is an interesting material that can be recycled as a secondary raw material and then may be used in new car manufacturing. The analyzed sink-float separation process demonstrates the possibility to increase the reuse, recycling and recovery of materials from ELVs and to improve the environmental performance of operators involved in the production and maintenance of vehicles and in the treatment of ELVs.

4.2 Sustainable innovation of water provision and consumption. The case study of Water Fountain Project in San Leo .

4.2.1 The context

The case study describes the analysis of the introduction of a public fountain in San Leo, a small Italian town. Italy is one of the main consumers of bottled water in the world (Figure 30). In the last 10 years the national mineral water production has grown from 6.100 million liters to 9.150 million liters, with an annual value of almost two and a half billion euros. The average annual cost is about 300 euros for every Italian family. Surprisingly, Italy appears to be a country rich in high quality water springs (more than 500 branded) and at the same time the first consumer of bottled water in Europe, third in the world. As a consequence, more than 6 billion bottles generate a significant environmental impact due the transport and their subsequent disposal.

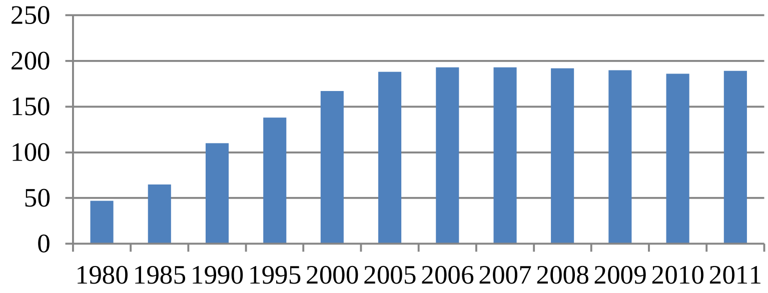


Figure 30: Annual consumption in Italy - liters per capita

To this purpose, there is the need to investigate an alternative system with the aim to reduce the impact connected to the supply and demand of bottled water and to assure economic and environmental advantages for all the involved stakeholders: local authorities, businesses and final consumers.

An emerging solution is the water public fountain (namely in Italy "Casa dell'acqua"): a point where delivers sanitized and refreshed water collected from the main system of public provision at extremely low cost (5 euro cents per liter) or for free. The "Casa dell'acqua" system allows the citizen to take advantage of the precious resource which is water, directly in his village, small town or city.

Mostly, the installation of the public fountain is commissioned by the municipalities to suppliers present on the market, while indirect customers are real end-users or the citizens.

4.2.2 The water fountain project in San Leo, Italy

This analysis evaluate a local initiative promoted by the Municipality of a small town in Province of Rimini, Italy San Leo (Figure 31). The initiative consist in the installation a public fountain in the fraction of San Leo, called Pietracuta. The village of Pietracuta has 993 residents and is located on a road with heavy traffic. Such as to be visible from the roadway, the public fountain is located in a strategic position, equipped with parking that facilitate the up and downloading of the bundles, and thus favors the access to people not resident in Pietracuta. This particular location is provided with the presence of an adjacent dispenser of fresh milk, two cafeterias and comfortable footpath that allows for a more secure accessibility by several kind of users. This location is certainly behind the success of the initiative. The population of San Leo territory is composed equally by people of both sexes and with high incidence of retired, blue and white collars, and students. Furthermore San Leo has a high demographic concentration in a dozen streets, in the main of which the public fountain is located.

Figure 31: Water fountain launch in 2012, San Leo, Rimini, Italy

The water fountain of San Leo is branded Fonte Alma and produced by Celli spa. Celli is a leading Italian company in the field of systems and equipment for the beverage dispensing and one of the main landmarks in the world.

4.2.3 Investigating citizens attitude throughout behavioral and geo-marketing analysis

In order to better understand the benefits from that installation of this kind of system can reach, the local administration has decided to carry out a survey.

Two were the goals set by the municipal administration in commissioning the survey

- Ensure the use of the public fountain, the perception of the water and of service offered, and ultimately assess the degree of satisfaction of the citizens

- Use the survey as an opportunity for communication and involvement of citizens in the initiative and have ideas and tools for the subsequent management of the stakeholders and the citizens themselves.

From the methodological point of view (Petts Leach, 2000), two surveys were carried out:

- quantitative, with a sample survey with direct interview (in most cases) using two questionnaires for users and non-users

- qualitative using focus groups, assessing in-depth the issues that emerge as critical or interesting after the previous quantitative survey

In parallel, a geo-marketing analysis was made, aimed at identifying the characteristics of the context, related to the geographic area on which it is investigated. The quantitative survey on users involved 123 people (12.4% of the population of Pietracuta), while the investigation of non-users involved only 30 people (2.8% of the population of Pietracuta), highlighting a certain distrust of theme. In general a high level of satisfaction has resulted concerning both the quality of the water and the offered service offer. It was observed a high use of the public fountain (1 to 3 times a week in most cases), with an average consumption of 6-12 liters (but with a range up to 20 liters and more). The average user is resident in the municipality and most often near the center of the village (80%) but more than 10% is also passing through or occasional. Young and the very old people are less present, and in general retirees are more present. Unfortunately, it was found that the majority of consumers (81%) get to the public fountain by car . This is justified by the fact that for many people it can be difficult to carry one or two packs of water, or because of the location.

The motivations that encourage people to use the “Casa dell’acqua” are essentially linked to a perceived "quality" (45.5%, synthetic index 240), price (31.4%, 202), but also related to ecological aspects (9.9%, 73) and convenience/proximity/ (6.6%, 57). It is interesting to note that the concept of quality expressed by the users reassume several factors like safety, clarity, taste, freshness (perception partly due to water chiller).

In the majority the water withdrawn is used by the whole family (96%) and exclusively for drinking (88.5%), but it is not always the only one used. 54.3% of respondents said they have abandoned any other type of consumption relative to water, while 30.6% say they consume, in addition to public fountain water, even bottled water, even if only almost branded. Only 10.7% also consumed tap water. Before the public fountain was installed in Pietracuta, the 77% of respondents, drunk exclusively bottled water (often on promotion), and only the 6.6% used only tap water. It follows that the water of the public fountain has replaced almost exclusively the water in the bottle and not the tap water which is almost certainly used for different purposes from the quench. In general water fountain service has replaced the low price bottled water.

In a comparison with tap and bottled water on 13 attributes of quality, the public fountain water comes out winning on almost all fronts. In particular, the best attributes are significantly higher on freshness, good taste, purity, safety, absence of salts, ecological impact, while it has some weaknesses, especially compared to bottled water on the possibility of storage and stock, and the presence of useful salts. On the other side, tap water is almost always the loser, with the exception of price and salty (perhaps due to local water characteristics).

It was of particular interest the comparison with non-users, whose profile is far different from the user: generally they are younger, working, professionals

Almost all (96%) know the “Casa dell’acqua”, and 32% used it but decided not to use any more generally giving reasons of problems of convenience (44%), but also of taste (22%). Typically they use drink bottled water (62%), with plastic package (83%) and mainly on the promotion(75%), or at the lowest price. There isn’t therefore a strong loyalty to certain brands of bottles water. The 38%, then, drinks tap water, and 36% of these use some tool for the water purification (in 50% of a filtration system on tap).

Finally, it is interesting to investigate if there was a relationship between the use of the public fountain and the ecological sensitivity of respondents Through the use of some questions we has built an index that rank users and non-users into three groups of high, medium and low ecological sensitivity.

Ecological Sensitivity	**Users**	**Non-Users**
High	14,0 %	4,5 %
Medium	82,6 %	68,2 %
Low	3,4 %	27,3 %
Total	100,0%	100,0%

Table 9. Ecological sensitivity of users and non-users of water fountain

Table 9 shows that users were significantly more sensitive to issues of environmental sustainability than non-users (although in-depth investigation revealed practices such as the use of plastic bottles for water supplies, or lack of cleaning of the same, or the exposure on the terrace of the house ... under the sun). And this has confirmed that the fact that good practices in the use of water flourish best in "land" already inclined to issues of environmental sustainability.

4.2.4 Assessment of environmental aspects of San Leo Water Fountain

The previous analysis has shown several aspects concerning the behavior and the perception of San Leo water fountain final users. In order to assess all the sustainability aspects of the public fountain system in San Leo, an environmental analysis adopting a Life Cycle Assessment approach has been performed in compliance with the standards ISO (ISO 14040:2006, ISO 14044:2006). The analysis has compared the consumption of drinking water from public fountains, refined at the municipal level instead of bottled water. The assessment was carried out using a "from cradle to grave " approach considering as functional unit the Italian pro capita water consumption per year (196 litres) referring to the 2011 data (Breedveld, 2009).

The life cycle of the service provided by the water public fountain has been divided in 5 different phases: material consumption, maintenance operations, energy consumption, transports, end of life of materials substituted during the maintenance operations. In particular, the materials consumption phase comprises the glass production for the packaging and the water consumption to fill in the bottle, i.e. pro capita water needed per year plus the losses in the distribution net (235,2 litres). The maintenance operation includes energy and water consumptions, the filters, the UV lamp, the pipes and the cleaning agents. Additionally, the maintenance comprises also the end of life phase that consist landfilling or recycling in compliance with the current end of life scenarios for the Italian wastes. Concerning the energy consumption, this phase includes the overall energy request to run the machine (pumps, UV lamp, coolers). Finally, transports have been modeled by way of several mobility scenarios, in order to take into account all the effects of the distance modifications. Particularly, the analysis accounts 4 different scenarios:

- km 0 scenario: citizens have been supposed to reach the fountain on foot or by bike

- km 1-5 scenario: citizens reach the fountain by car covering an average distance of 6 km (including the return)

- km 5-15 scenario: citizens reach the fountain by car considering an average distance of 20 km (including the return)

- “real” scenario: citizens reach the fountain in compliance with the results of the interview analysis (walking, by bike, by car based on the declarations in the questionnaire).

The analysis of the travel to the water provision covers the average supply for each provision in order to establish the number of travel done to get the pro capita water amount. Allocation factors have also been applied in order to consider the real car fleet in compliance with the interview answers (51% diesel, 33% gasoline, 8% natural gas, 8% LPG). This percentages are consistent with the Italian national framework.

With the aim to make a comparison between San Leo public fountain and the current scenario where citizens use bottled water, a study of Environmental Product Declaration (EPD) of an Italian bottled water brand has been considered as data source (Breedveld, 2009).

Impact category	***Unit***	***Materials & Maintenance***	***Transport***	***Energy***	***EOL***
Global warming (GWP100)	*kg CO2 eq*	0,451465481	4,69194542	1,362837983	3,11191E-06
Ozone layer depletion (ODP)	*kg CFC-11 eq*	4,66932E-08	6,31003E-07	1,61566E-07	3,59309E-13
Photochemical oxidation	*kg C2H4 eq*	0,000233837	0,004930262	0,000603086	3,24955E-09
Acidification	*kg SO2 eq*	0,001686663	0,008218353	0,00545548	1,50778E-08
Eutrophication	*kg PO4--- eq*	0,000622215	0,001536452	0,001168138	5,08521E-09
Non renewable, fossil	*MJ eq*	7,530028049	67,8764107	18,88197333	5,74009E-05

Table 10. Life Cycle Impact Assessment of fountain water real scenario

The environmental profile outlined by the EPD has been adapted to make real the comparison, specifically the transport phase has been ri-calculated in order to be consistent with the fountain water scenario previous described. The impacts related to the infrastructure construction (both for the public fountain and for the bottling plant) has not been included in the analysis. Table 10 shows the results of the characterization phase for the fountain water *real scenario*. Focusing on global warming potential, the transport phase accounts for more than 70% of the total impact (Table 11).

Impact category	***Total***	***Materials & Mainteance***	***Transport***	***Energy***	***EOL***
Global warming	100%	6,9%	72,1%	20,9%	<<1%

Table 11: Contribution of water fountain life cycle phases to Global warming potential

Starting from the previous results, the comparison of the fountain water and the bottled water environmental profile shows a clear reduction (>70%) for all the impact categories. This result is confirmed for all assumed the transport scenario. Another important results concerns plastic and waste reduction. Indeed, the water fountain service allows to reduce the amount of plastic utilized for the water bottles (0,019 Kg/l), for a total amount of 5748 kg of packaging waste pro year and 4200 Kg of PET pro year. As listed in Table 12, a consequent reduction in waste derived from plastic bottles is achieved.

PET	***Total***	***Separate collection***	***Incinerator***	***Landfill***
Waste (kg)	4.200	765	861	2583

Table 12: Avoided Plastic Waste after one year of water fountain service in San Leo, Italy

At the end, the assessment carried out with a life cycle approach has identified the transport as the most critical phase. Starting from these results, it is possible to set the best transport scenario for the water provision area able to satisfy the CO_2 reduction (20%) that is one of the principal Covenant of Mayor target. As final results, Figure 32 shows two transport scenario where distances are connected to the accomplishment of two CO_2 reduction targets. Area B (15 km radius) allows to achieve the 20% of CO_2 reduction. The second area (9 km) attains the most ambitious target of 50% of CO_2 reduction.

Figure 32: . Extension of water provision areas for CO2 reduction targets

The results of the previous analyses underline how a simple and smart initiatives such as the introduction of a public fountain in a small-town as San Leo is, allows to generate a highly positive advantages in terms of sustainability. The analysis developed, both in terms of environmental and market impact, highlights and summarizes the value system built through the installation and use of the public fountain. To get an overall view, however, this value must be defined at different levels and by different stakeholders: citizens, municipality, community and region-nation. In the following Table 13 a balance of advantages and disadvantages achieved for each different level of stakeholders has been done.

Levels	Advantages	Disadvantages
Citizens	• Cost savings (family of three people annually spends on average about 73€ instead of €438 – considering an average market price of branded bottled water – total saving of € 365, -80%) • Healthy and safe supply • Use of local resources • Less space for waste at home	• Minimum procurement of 1 liter • Waiting time • Less choice (brands, sparkling) • Management of the bottles (washing, replacement, ...)
Municipality	• Revenue for € 18,250 per year (for a public fountain of 1,000 l/ day) • Reduction of disposal costs (approximately € 1,682 / year, equivalent to 8,410 kg PET) • Encouraging re-use • Future environmental certifications • Awareness and attractiveness of the initiatives and of the municipality a • Use of the water fountains as an information point for all the citizens	• Initial investment, in the event that the public fountain was not handled directly by the manufacturer (from €11,000 to €20,000 for a dimension of 1,000 liters / day, about €1,000 for masonry and connection to mains water and electricity system) • Cost of raw material: water (about € 900 / year), electricity (about € 1,200 /year) • Manage project, operations management and bureaucracy • Managing relationships with stakeholders (primarily multi-utilities)
Local community (Pietracuta)	• Reduction of taxes on waste (reduced taxation) • Reduction of environmental impact (bins, collection trucks) • Use of local resources • Raising awareness surrounding municipalities (domino effect) • Raising awareness on the issues of eco-sustainability	• Limited coverage (not the house is not easy to reach from all areas of the village / city) • Impact on revenues of retailers and bars • Social costs for reduced revenues
Regional-national	• Positive impact on revenues, production and employment on companies like Celli Spa (both for developing and producing the fountains, but also for the subsequent management and maintenance). • An estimated decrease of 30,000 tons of PET in landfill and 10,000 tons incinerator[3] • Less transports, pollution, road maintenance funds • Contribution to the 20-20-20 European targets.	• The impact on the turnover of mineral waters production and distribution • The impact on public exercises / bars • The social costs for impacts related to lower production (supply chains) • The reaction of the multi utility companies • The pressure of the stakeholders (particularly due to the impact on employment)

Table 13: Advantages and disadvantages on use of the public fountain.

[3] Given the initial data on the Italian treated PET (190,000 tons, of which recycled 34,200 tons, 116,850 tons to landfill, incinerator 38,950 tons), that if the good practice of the Pietracuta experiment could be expanded at national level, and 1 Italian citizen on 4 decide to change, to quench his thirst, from bottled water to the water fountain, we could get, always at the national level, a decrease of 30,000 tons of PET in landfill and 10,000 tons incinerator.

4.3 Results and discussion

The case studies described in this chapter have been consisted in two simple examples on significant experiences of innovation towards sustainability. Both case studies have highlighted several aspects which have contributed to identify successful factors for achieving a change. Especially, the results can be understood throughout the recognition of the targets, mechanisms, impacts (micro, meso, macro), drivers and barriers.

The ***first case study*** has described a simple case of sink-float separation process in order to investigate the characteristic of sustainable innovation in the automotive sector. In this case the eco-innovation target is a recovery process and the mechanism is the re-design of end-of-life process. The impact acts at micro and meso-level. The case is interesting not so much for the single innovation developed, but rather for the innovation path in which it is part of. Indeed, this specific innovation was driven by regulation as European End of Life Vehicles (ELVs) directive is. Particularly, ELVs Directive is a representative case study of a multiple industry instrument of Extended-Producer-Responsibility (EPR). Therefore, during the last decade ELVs directive has driven an extensive set of technological and organizational innovations. An example of organizational innovation pursued by Europe based car companies has been the creation of networks of dismantlers/shredders linked to individual car companies. Effectively, ELVs Directive has developed an organizational innovation involving the car industry and post-consumer ELV treatments. From a technical point of view, the compliance with the provisions of the ELVs Directive has seen a variety of technological adaptations such as: dismantling techniques, Design for Disassembly, Design for Recycling, innovation in car materials recycling and recovery. Afterwards, the specific reuse, recycling and recovery (RRR) targets has affected all the automotive sector throughout interrelated sequences of single innovations in both upstream (car making) and downstream (car recycling/recovery). Nevertheless, several barriers still limit the complete fulfillment of RRR targets, especially for what concerns the Automobile Shredded Residues (ASR) and the plastic recycling. The role of plastics is a key in reaching the ELVs directive targets and the improvement of post-shredder technologies is a way both to increase the recyclability of ELVs and to create a material market. In this context ASR separation technologies are revealed one of the most promising path, because it combines relatively high “recyclability” with relatively small and well-focused car-design changes. In order to achieve the objectives both to increase RRR rates (especially material recycling and parts reuse) and to reduce ASR landfilling, the case study has described an innovation process leading to material recovery of by the adoption of ecodesign, especially of Design for Recycling strategy. As a results, it emerges that technologies innovation in the automobile shredder residue separation can be a source to increase the quota of plastics recycling and consequently can also strengthen the market of recycled materials. Besides, an improvement of the environmental performance of operators involved in the production and maintenance of vehicles and in the treatment of ELVs. Upgrading the quota of recycled plastics coming from ELV recycling loops allows to create cascade recycling process. The result of this innovation has not only concerned to reduce waste coming from ELVs. Thanks to plastic recovery, the process allows also to reduce the consumption of raw materials, energy and water and their associated environmental impacts. On this point, the waste management transitions from an environmental approach to an economical one: the waste is not only a constraint to minimize but also a resource to optimize leading to a circular economy. At the end, this case study has revealed the success of implementing not a single specific innovation, but a combination of innovation paths consisting in a series of interrelated initiatives. According to Mazzanti and Zoboli (2006), key factors in the achievement of a real change in the industry sector could be the combination and the integration of different technological and organizational changes and the involvement and the interrelation of different industrial actors.

The ***second case study*** has analysed a successful story implemented in an Italian small-town, San Leo concerning the introduction of an innovative system of: public drinking fountain. This case is revealed significant because it has facilitated the behavioral change towards a sustainable water consumption and provision. In this case, the target is social innovation as it concerns the citizens behavioral change in water consumption. The mechanism is the creation and the introduction of a new service with the same function of the traditional product: bottled water. In this context, the water fountain works as Product Service System (PSS). Indeed, with the aim to reduce environmental impacts produced by traditional products, the PSS aims at shifting the business focus from designing and selling physical products only, to selling a system of products and services which are jointly capable of fulfilling specific user demands. In the case of water fountain the impact of the innovation acts at meso and macro-level. Really, as the analysis has demonstrated, the experience of San Leo has contributed to establish a new role of local authorities, away from a regulatory role towards a co-development approach that enables others to act. The driver was a voluntary European movement, the Covenant of Mayors, involving local and regional authorities committed to reach the EU 20-20-20 targets. The water fountain in San Leo is revealed a valid case of sustainable innovation for addressing the impacts of climate change and to achieve economic saving. On one hand, the environmental benefits provided by water fountain contribute to reduce CO_2 emissions and to respond to other environmental issues such as plastic waste production and water resource valorization. On the other hand, the quality and the lower price of the water provided by the public fountain have resulted in a economic advantage for the user. Therefore, the public water fountain has allowed to introduce a new market in a green economy context and to reach several benefits for all the stakeholders. First of all the local authorities that have been able to meet the population needs thanks to the economic and environmental advantages provided by water fountain service. Then, water fountain has opened new business opportunity toward an innovative system of water provision and consumption. Furthermore, the fountain system can act as a novel communication instrument to promote a behavioral change. Water fountain has been revealed as a new space for behavioral change where people meets and finds solution for a sustainable life-style. Thanks to this innovation, the dialogue between citizens and public administration is enhanced and finally the facilitation of new collaborations and local connections that co-operate to realize sustainable developments has been initiated. Starting from a social innovation experiments, the water fountain has broaden the innovation domain and it can constitute a system innovation example.

4.4 Conclusion

Beyond each single positive result of the two analyzed case studies, it is important the understanding of the aspects which have characterized the sustainable innovation and their mutual interaction. Both cases have shown the importance of adopting a co-evolutionary approach taking into account not only of technological aspects, but also of non-technological aspects such as the influence of regulations and societal factors. It is evident that even with a strong focus on technology, a number of complementary agents have functioned as key drivers for change developments. In both cases, the changes have been either organizational or institutional in nature. Especially in the water fountain case study, it has been started exploring more systemic innovation approach through new business models and alternative modes of provision. Therefore, this case studies have confirmed that the heart of a sustainable innovation cannot necessarily be represented adequately by a single set of target and mechanism characteristics. Instead, the sustainable innovation could be best examined and developed using an array of characteristics ranging from modifications to creations across products, processes, marketing methods, organizations and institutions till to involve societal aspects. In order to understand the dynamics of change and therefore to plan and to develop sustainable innovation, a co-evolutionary approach acknowledging the interaction among all components of socio-technical system is essential. Finally, an emerging need has appeared that is effective sustainable innovation occurs at a broad system level. This introduces relatively new interlinked issues into the global debate on sustainable development: the need for system innovation and the co-related need for adopting a socio-technical system approach.

5 System innovation towards sustainability: the emerging approach of Transition

Quand tu veux construire un bateau, ne commence pas par rassembler du bois,
couper des planches et distribuer du travail,
mais réveille au sein des hommes le désir de la mer grande et belle.
Antoine de Saint-Exupéry

The evolution of innovation approaches towards sustainability and the analysis of the case studies in the previous chapters have shown that sustainable innovation can arise from improved products and processes, new technologies and services, and new ways of doing things. Although, for a whole transformation, a mutual interactivity of green technologies, new business models and sustainable behaviors is required. In actual fact, the move to a sustainable future will most likely not rely just on one or even a small number of technological innovations, but is likely to arise from a constellation of interacting systems of innovations, some which involve radical knowledge-based innovation and some involving incremental innovation (Gaziulusoy and Twomey, 2014a). The combination of a series of changes rather than standalone innovations is recognized as system innovation. In this chapter, after a basic understating on how and why systemic thinking is introduced as an useful framework for interpreting the chance of innovation in the need to integrate environmental sustainability, emerging approaches for Sustainability Transition are deeply examined. The chapter concludes identifying an effective framework managing transformative change towards sustainability.

5.1 System innovation

A *system* can be understood as a set of things working together as parts of a mechanism or an interconnecting network; a complex whole. A system in focus can be anything from a house to a city or an entire economy. One of the key principles of system thinking is that the parts of a system can only be understood in relationship to one another and with other systems, rather than in isolation.

In a sustainability perspective, the concept of system eco-innovation is particularly interesting. According to EIO (2013), a "system eco-innovation is above all about identifying the root causes of systemic problems and targeting these levers to shift systems toward sustainability in a co-ordinated way". Concisely, system eco-innovation can be defined as "*a series of connected innovations that improve or create new systems delivering desired functions while reducing environmental impact.*" (EIO, 2013). A key feature of a system innovation is that it improves the performance of an entire system, instead of focusing on its individual components. Hence a systemic approach equips innovators to more easily overcome structural barriers. System eco-innovation can assume different sizes, ranging from "complex products" (e.g. a house) to entire production and consumption social systems (e.g. a city). For example, system eco-innovation related to a home heating system is not about just using a more renewable energy carrier: it is about innovating the design of an entire house (e.g. exchanging windows, insulation, floor plan, etc.) to improve its efficiency. System eco-innovation in cities happen when innovation and planning efforts lead to a combination of changes towards a more sustainable urban life style. This includes, for instance, new mobility concepts that do not focus just on improving individual components of the transportation system (e.g. better public transport, better infrastructures), but innovate the entire mobility systems in relation to actual social mobility needs. This can include the organization of modal shift among the various mobility systems, adapting infrastructure and regulatory frameworks as well as urban functions and urban planning. Transformative eco-innovation system re-arranges the way specific functions or services, such as mobility, shelter and nutrition, are developed and delivered to people. For that reason, system innovation depends generally on the specific system and it is not a "quick fix" strategy, but aims to long-term wins. Consequently, system innovation may require short and long time strategies to be implemented.

5.2 Degree of system innovation

In Chapter 3, we have seen different way to classify sustainable innovation such as targets, mechanisms, impacts. Another way to categorize innovation can be regarded as the degree of changes. According to Carrillo-Hermisilla (2010), "incremental changes refer to gradual and continuous competence-enhancing modifications that preserve existing production systems and sustain the existing networks, creating added value added in the existing system in which innovation is rooted. Radical changes, in contrast, imply discontinuous changes that seek the replacement of existing components or entire systems e and the creation of new networks, creating value added". Similarly, system eco-innovation can vary from a system level adaptation to a more radical transformative system innovation. Indeed, incremental eco-innovation can concern both improved components of products or services and improved processes or streamlined organisational set-ups. Radical eco-innovation thus include not only the development of radical, breakthrough technologies but also a reconfiguration of product-service systems. For example, the "cradle to cradle" approach, closing the loop from resource input to waste output through the development of new business models is a way to reshape business models and consumers behaviour in order to reduce material use.

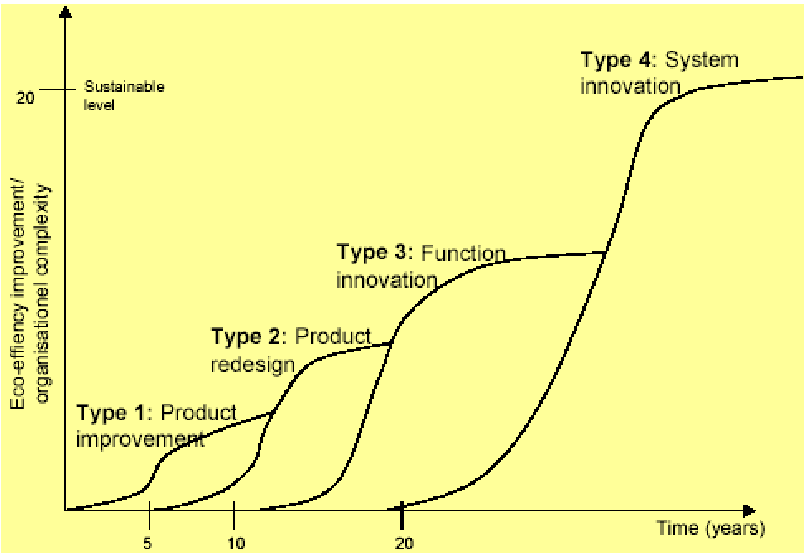


Figure 33: Different types of innovation (adapted from Stevels, 1996)

A way to describe the different degree of eco-innovation can be related to four main types of environmental improvement. Figure 33 adapted from Stevels (1996) and the Table 14 below illustrate the different types of innovation according to the radical or incremental nature of produced technological change and the level of impacts to the system.

Type of eco-innovation	Level of intervention	Descriptions
Type 1	Improvements	Incremental or small, progressive improvements to existing products
Type 2	Re-design or 'green limits'	Major re-design of existing products (but limited the level of improvement that is technically feasible)
Type 3	Functional or 'product alternatives'	New product or service concepts to satisfy the same functional need e.g. teleconferencing as an alternative to travel
Type 4	System	Design for a sustainable society

Table 14: Description of different type of innvation

5.3 Radical and incremental system innovation.

According to Weterings (1997) and Elzen (2004), it can be made a comparison of system optimization via incremental innovations, system redesign that already is more radical, and radical system innovations that allow for radical changes and radical reductions of environmental impacts.

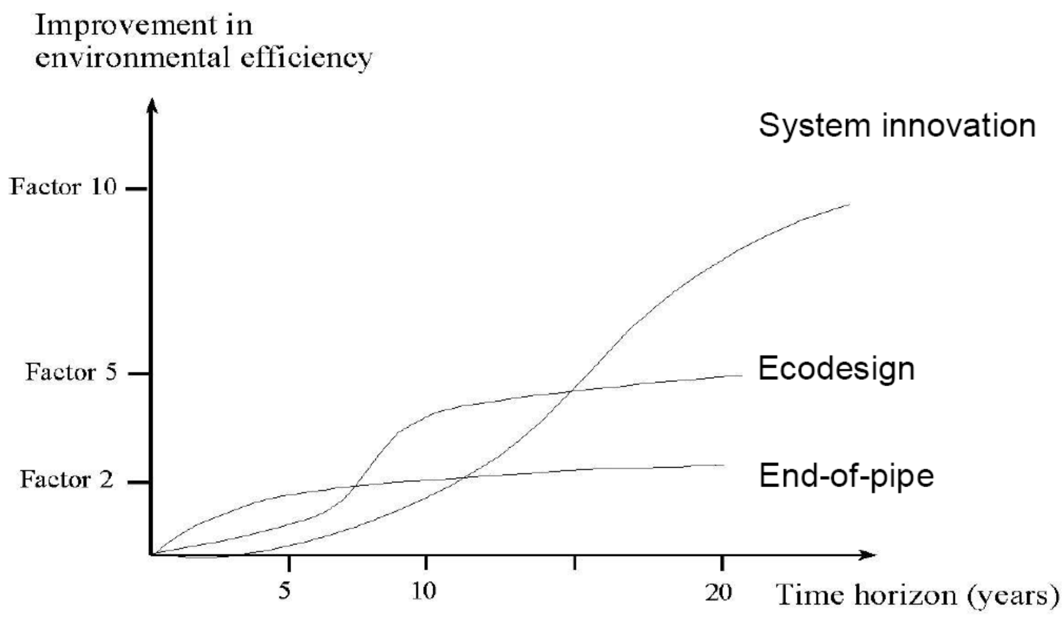


Figure 34: Division in end-of-pipe, ecodesign and system innovation (e.g. Weterings et al., 1997; Elzen et al., 2004).

In Figure 34, it is shown that system innovations have the potential to improve the environmental efficiency up to a Factor 10 or more, whereas system optimization and system redesign allow for an environmental improvement up to a Factor 2 or a Factor 5, respectively. According to OECD (2011), eco-innovation varies according to different degrees in relation to the implemented change provided. Table 15 frames these variations from incremental to disruptive and radical changes.

Incremental innovation	aims at modifying and improving existing technologies or processes to raise efficiency of resource and energy use, without fundamentally changing the underlying core technologies. Surveys of innovation in firms demonstrate that this is the dominant form of innovation and eco-innovation in industry.
Disruptive innovation	changes how things are done or specific functions are fulfilled, without necessarily changing the underlying technological regime itself. Examples include the move from manual typewriters to word processors, or the change from incandescent to fluorescent lighting.
Radical innovation	involves a shift in the technological regime of an economy and can lead to changes in the economy's enabling technologies. This type of innovation is often complex and is more likely to involve non-technological changes and mobilize diverse actors.

Table 15: Definition of eco-innovation (OECD, 2011)

As reported to EIO (2013), incremental innovation are generally "quick wins" for a company and do not lead to a systemic change alone. Over time, incremental innovations may accumulate and result in a substantial change, especially if they are applied on a large scale. In this case, an incremental system innovation is achieved. A system eco-innovation may be incremental, when it results in the adaptation of an existing system. On the other hand, system innovation may happen at the level of sub-systems and systems rather than individual components (e.g. individual products or services). As shown in Figure 35, disruptive eco-innovations lead to shifts in a paradigm or in the functioning of an entire system. They can lead to reconfiguring entire markets, consumer behaviour and technological systems.

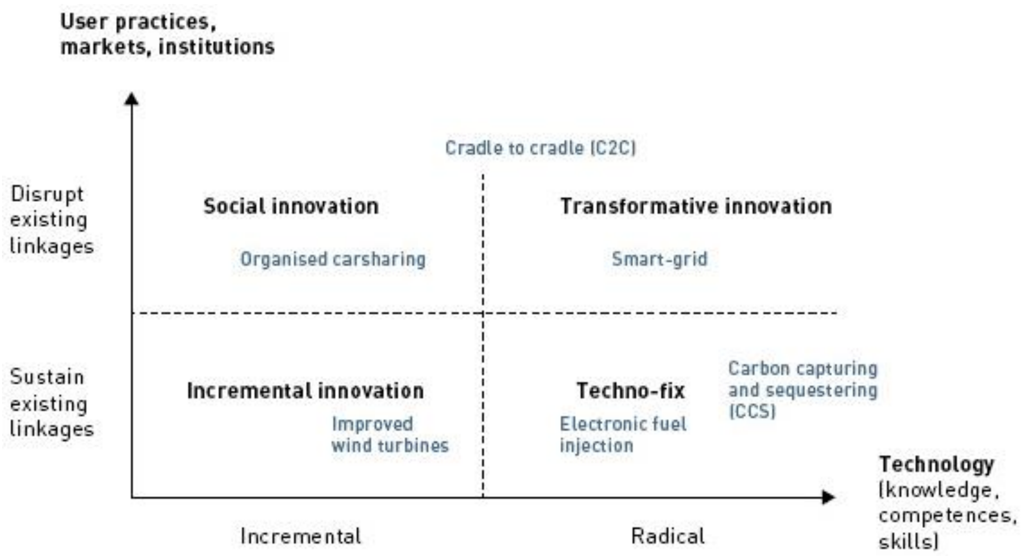


Figure 35: Classification of eco-innovation based on technology and market/user practices (Kemp, 2011)

As stated by Sterrenberg et al. (2013), radical systems innovations are "innovations directed to redesigning entire systems of practices and provisions, instead of individual products or processes". Therefore, a radical system innovation can be based on a radical redesign of established systems that leads to a transformative change. Radical rethink means for example on how to satisfy the needs of society while recognizing global social, economic and environmental challenges. In the following Figure 36, an overview of different types of eco-innovation based on the EU Eco-innovation observatory, is provided.

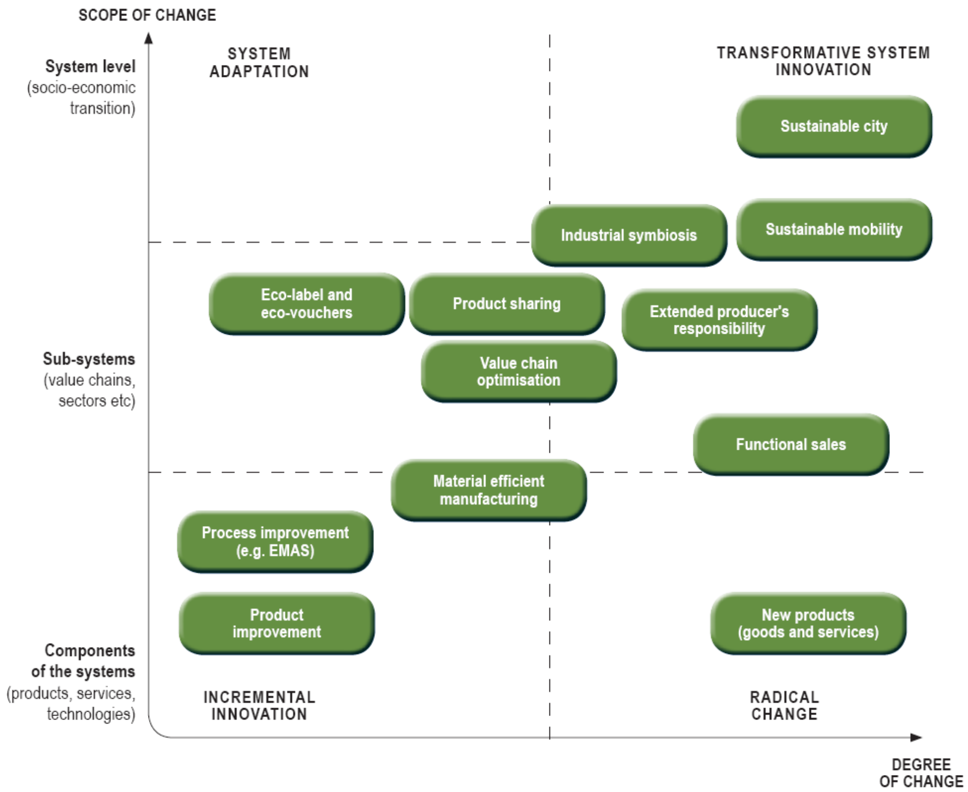


Figure 36: Overview of different types of eco-innovation based on two dimensions: target and degree of implemented change (EIO, 2013)

5.4 Trend of eco-innovation

In spite of a number of sustainable innovation frameworks and increasing eco-innovation initiatives, the effectiveness of innovation towards sustainability has not yet strong enough (EIO, 2013). According to Tukker et al. (2008), within specific portions of the production-consumption value chain, possible interventions and innovations have generally tended to be incremental. Although both incremental and disruptive changes are beneficial, eco-innovation activities have not yet spread enough or have not yet happened at an intensity large enough to realise a substantive reduction of material inputs at the macroeconomic level. In actual fact, there is a general trend towards more ‘environmentally-friendly’ products, particularly evident is the proliferation of eco-labels, but the trend toward increasing total consumption of natural resources has also continued. In Figure 37, it is reported the share of firms reporting reduced material use per unit and the output as a result of innovation (blue) and firms with any innovation activity (light blue) (Eurostat, 2010). As a result, a gap between incremental and radical eco-innovation has emerged.

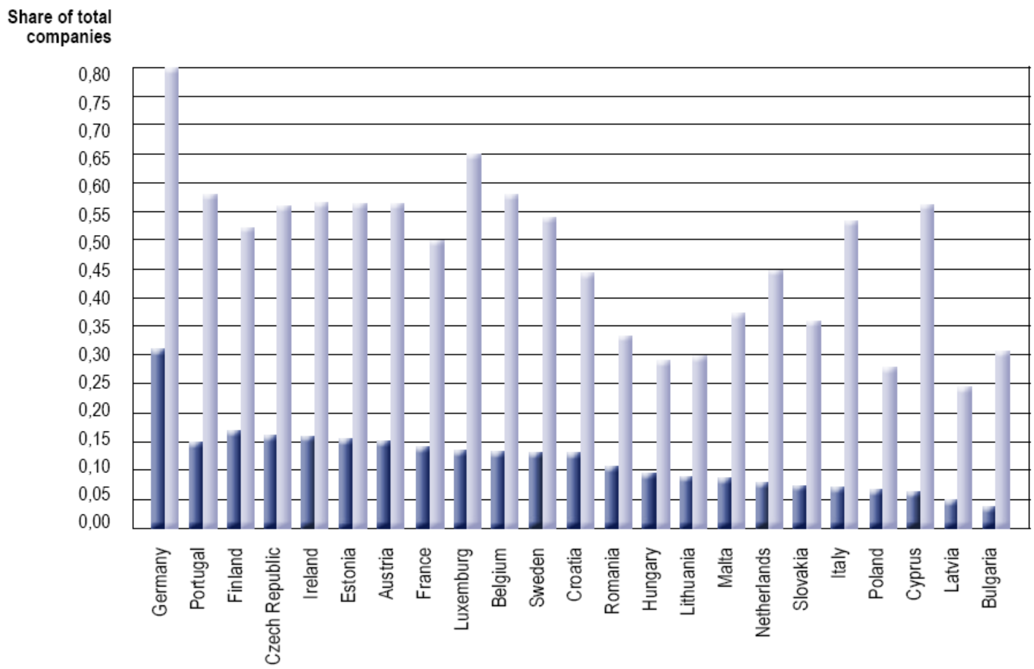


Figure 37: Share of firms reporting reduced material use per unit of output

Only radical and systemic change can mostly contribute to an absolute decrease of environmental pressures and impacts. Besides that, the recent global crisis has put in evidence systemic problems as systemic lock-ins and market failure which affects strategic operations and inhibit eco-innovation efforts in companies. In order to accelerate eco-innovation, it is crucial to identify factors which can help to steer and to create pervasive change. Structural barriers such as systemic lock-ins and market failure have a direct effect on the strategic operations of companies and may impede disruptive eco-innovation efforts. However the scope and urgency of the challenges call for eco-innovation which leads to system-wide change in the way society uses resources. As EU Environment Commissioner Potočnik stated in October 2012: "Eco-innovation should go beyond incremental environmental improvements and efficiency gains, and aim at 'breaking out of locked-in systems and thinking"'. As indicated by EIO (2013), eco-innovation will probably face structural barriers and resistance from dominant market players who benefit from the status quo (e.g. traditional versus renewable sources of energy). Such structural barriers may significantly reduce the positive impact or even prevent implementation of individual eco-innovations. System eco-innovation, on the other hand, addresses the barriers as an inherent innovation challenge in the design stage, and aims to implement the change on the level of a functional system, rather than on the level of an individual component of the system (e.g. product). Radical system eco-innovation is an investment for the future that provides a systemic response to grand societal challenges expected to grow in the medium to long term. It is not a “quick fix” strategy, but aims for long term wins. System eco-innovation offers frames and a direction for short-term investments. It could even support decisions to stop investments promising “quick wins” as they can become obsolete when system-level change is implemented.

According to Kemp (2011), different types of eco-innovation require different policies. In general, incremental improvements of commercial products do not require special support. Companies are perfectly capable of producing and funding these. Radical innovations and system innovations are much more in need of support, but the barriers to them and the level of support needed will differ. Radical innovations are transformative and require more support than technical fixes for problems of well-established regimes. Support for transformative innovation should go beyond the financial as it requires institutional change in the economic and social world. Comprehensive and long-term resource use targets are needed to set both an orientation for policy development and a direction for eco-innovation efforts at the macro-economic level. Operational targets and milestones are needed to promote change at different levels of society and in different sectors of the economy.

5.5 The need of radical change.

To sum up, system innovations are not only technical innovations but involve social and (infra) structural aspects (Sterrenberg et al., 2013). This is because - as sociological and governance studies demonstrated - many of today's 'institutions', such as financial arrangements, regulations, rules, actor configurations and the physical infrastructure, have been developed in co-production with the needs and practices of the past. Generally, institutions and infrastructures tend to rely on existing practices; this makes the past and present unsustainable practices persistent. Their persistency allows for incremental innovation rather than for radical innovation. For these reasons and as experiences shows, sustainability innovations often run into institutional barriers. As a matter of course, the institutional and physical heritage have to be considered, not as an unchangeable condition however, but as structural elements that might need innovation too. Changing the institutional and physical heritage often depends on managerial and political support and takes long time. Consequentially, major system innovations take one or two generations to accomplish. For this reason, a systemic approach allows for enhancing eco-innovation in order to shift toward sustainability in a coordinated way. Eco-innovation seeks more radical improvement and the role of sustainable innovation should go beyond stand-alone innovations combining product, process, organizational, marketing, and social eco-innovation towards a transformative system eco-innovation. In that way, innovative clean technologies or product-level eco-innovations can be considered as elements of the system. According to OECD (2012), transformative system eco-innovation aims at building up a shared understanding of how and why systems work in order to integrate all the components and to move the entire system towards sustainability. In order to achieve that, system innovations should be not only technology-driven, but involving socio and structural aspects. The ambition is to achieve innovation at level of *'socio-technical systems'*. Such systems consist of actors and networks (individuals, firms, and other organizations, collective actors) and institutions (societal and technical norms, regulations, behaviours, standards of good practice), as well as material technological artifacts and knowledge (Geels, 2004; Markard, 2011; Weber, 2003). The different elements of the system interact together providing specific trends in society. The systemic concept highlights the fact that a broad variety of elements are strongly interrelated and dependent on each other (cf. Finger et al., 2005; Hughes, 1987). This has crucial implications for the dynamics the systems exhibit, and especially for system transformation (Markard, 2011).

In summary, main features of an effective *socio-technical system innovation* towards sustainability can be summed up and in the following, a list is provided, based on Geels (2010) and Sterrenberg et al. (2013). The main features of socio-technical system innovation are:

- to be challenge-led, not technology-driven;
- to be dealt with in terms of systems of practice and provision, not-single innovations in products and processes;
- to be dealt with in terms of 'socio-technical innovation', including also, for example new rules, routines, new financial arrangements and possibly changes in physical infrastructure;
- needing a blending of a long-term strategy because of the long-term horizon and near-term implementation;
- needing changes at multi societal and multi-actor levels;
- acknowledging a significant role for entrepreneurial, financial and public actors in addition to universities and established businesses.

5.6 Towards the Sustainability Transitions framework

Over the past years, numerous conceptual frameworks have been developed for the study of system innovations. In this context, Sustainability Transitions (ST) has been recognized as a "*research field for long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption*" (Markard, Raven and Truffer, 2012). 'Transition' is often used interchangeably with the term 'systems innovation', either at the technology system or society-wide level. Kemp and Rotmans (2005), however, argue that "for the purposes of managing processes of change to sustainability it is useful to use the concept of a ‘transition’ rather than system innovations” since it brings into focus the new state, the path towards the end state; it focuses on the transition problems and the wide range of internal and external developments which shape the outcome. Rotmans (2001) has recognized that transitions have the following characteristics.

- to inhibit developments that take place within economic, technological, political, environmental, social, etc. spheres that affect each other;
- to involve a variety of actors from different groups;
- to constitute radical shifts (in scope) from one configuration to another;
- to have an inherent complexity and uncertainty due to the multiple developments that are intertwined, the multi-actor nature and the existence of radical shifts
- to entail long-term processes due to the complexity and uncertainty of the process.

The concept of ‘transitions’ was first coined by Alex de Tocqueville in the 19th century. He used this concept to describe changes in master-slave relationships and defined it as a period in history in which the ruling class no longer has the strength to stay in power on the basis of a well-established formula (Coenen-Huther, 1996). The term transition was also utilized in other research areas, especially disciplines that deal with evolutionary theories such as evolutionary biology, demography, economics and studies on power relations. With the fall of the Berlin Wall in 1989, which led to transitions of former communist countries towards market-based entities, social sciences witnessed the emergence of a new discipline called transition (Marody, 1996). This was connected to general theories, such as evolutionary economic theory (Nelson and Winter, 1982; van den Bergh and Gowdy, 2000). In the 1980s, the "transition" concept was introduced within the research on socio-technical research, which had gained an increase in attention in the 1990s. An example of one of the first concept of transition is outlined in the Box 4.1. This was partly given in by the momentum caused in 1987 by the World Commission of Environment and Development that coined the term ‘sustainable development’ and placed this term on the agenda as a global normative goal. This term stimulated an interest during the 1990s in particular towards transition research for sustainable futures. Around the turn of the millennium the 'governance' concept was thrown in the mix of 'transition studies' turning the attention towards the influence of governmental and non-governmental actors and as well as their policies towards processes of change, this especially after transition ontology was recognized by policy makers (van der Bosch, 2010).

Box 4.1 : Example of first concept of Transition

An example of *a transition* is the development in the Netherlands after the two world wars, of large scale agriculture. The desire to produce sufficient food at low prices was a major driving force. The transition went together with rationalization of production, mechanization and specialization. Small scale mixed farms disappeared and arable farming became separated from livestock farming. Within these categories some holdings specialized even more, for instance in poultry breeding or laying. Other structural changes added as well. For example, the Dutch government introduced product subsidies and started financing of university education, research and agricultural extension services to stimulate the development of knowledge and the application by farmers of the newest scientific insights. Land consolidation allowed for a more profitable use of land. Dutch banks granted loans to farmers to invest in the innovation and extension of their farms. Production increased enormously, and the Netherlands became an agricultural exporting country. During the transition, the authorities worked closely with organizations representing the farming community and agricultural experts in the Lower House of Parliament. The group was called the 'IJzeren Driehoek' or the Iron Triangle. This new actor configuration would only be broken through, when new structural changes were needed due to political pressure because of environmental concerns and the excessive government costs of the product subsidy system

5.7 Socio-technical transitions

In the framework of socio-technical research, 'transitions' generally refer to large-scale transformations within society or important subsystems, during which the structure of a societal system fundamentally changes (Rotmans et al., 2001). A *socio-technical transition* is a set of processes that lead to a fundamental shift of socio-technical systems (e.g., Geels and Schot, 2010a; Kemp, 1994). According to Markard et al. (2012), transition involves far-reaching changes along different dimensions: technological, material, organizational, institutional, political, economic, and socio-cultural. Transitions involve a broad range of actors and typically unfold over considerable time-spans (e.g., 50 years and more). In the course of such a transition, new products, services, business models, governance and organizations emerge, partly complementing and partly substituting existing ones. Technological and institutional structures change fundamentally, as well as the perceptions of consumers regarding what constitutes a particular service (or technology). Famous historical examples of socio-technical transitions include the introduction of pipe-based water supply (Geels, 2005a), the shift from cesspools to sewer systems (Geels, 2006), and the shift from carriages to automobiles (Geels, 2005b). Socio-technical transitions differ from technological transitions in that they include changes in user practices and institutional (e.g., regulatory and cultural) structures, in addition to the technological dimension. Moreover, socio-technical transitions typically encompass a series of complementary technological and non-technical innovations (e.g., complementary infrastructures). The emergence of a transportation system with the automobile technology at its core, for example, required a complementary development of road infrastructure, fuel supply systems, traffic rules, services (e.g., maintenance, insurance), user practices, etc. In fact, socio-technical transitions do not just change the very structures of existing systems, such as transportation, but they also affect related societal domains, such as living, housing and working, production and trade, and planning and policymaking. Transitions can be also defined as major shifts in ‘socio-technical regimes' or the dominant way in which social needs such as for example energy supply and mobility are fulfilled” (Rip and Kemp, 1998; Geels, 2002). Transition scholars emphasize that transitions are long-term and complex processes (often lasting several decades), regimes tend to be stable and resist to any fundamental change. According to Geels (2005c), Van der Vleuten and Raven (2006), Cowan and Hultén (1996), this lock-in occurs at three dimensions:

- **Institutional structures**: both formal (like laws, regulations and public financing schemes) and informal (like cultural values). Institutions are persisting to change, preventing the breakthrough of simple innovations.

- **Actors and social networks** represent incumbent organizational capital and institutionalized power. They have a key role in transition because they can be 'blind' for alternatives supporting an existing system even when alternatives have improved from social, environmental and economic characteristics.

- **Technological products and services**, production technologies and infrastructures also give certain 'hardness' to a regime and often represent large vested interests of incumbent actors. Thus, regimes tend to be institutionally, socially and technologically locked-in

As seen in Chapter 3, the concept of ‘regime’ refers to the rule-set embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artifacts and persons, ways of defining problems; all of them embedded in institutions and infrastructures. According to the regime concept, a definition of transition has been refined by Loorbach and Rotmans (2010). Transition is "a fundamental change in structure (e.g. organizations, institutions), culture (e.g. norms, behavior) and practices (e.g. routines, skills)". In other words, the dominant way in which a societal need (e.g. the need for transportation, energy, or agriculture) is satisfied, changes fundamentally; this can take roughly one or two generations (25-50 years) to achieve (Kemp and Loorbach, 2003; Alkemade et al., 2011).

5.8 Sustainability Transitions

Considering the crucial challenge for sustainable development, the starting point for sustainability transitions research is a recognition that many environmental problems, such as climate change, loss of biodiversity, resource depletion (clean water, oil, forests, fish stocks), are formidable societal challenges, whose solution requires deep structural changes in key areas of human activity, including our transport, energy, agri-food, housing, manufacturing, leisure and other systems. Environmental problems such as climate change can be categorized under the term "persistent problems". These are problems inherent in system structures and thus cannot be solved with end-of-pipe solutions (thus without fundamentally changing the structures). Environmental and global crisis is the result of the nature of current productions and consumption systems. According to Raven and Verbong, (2009), solving this problem requires a transition towards sustainable systems.

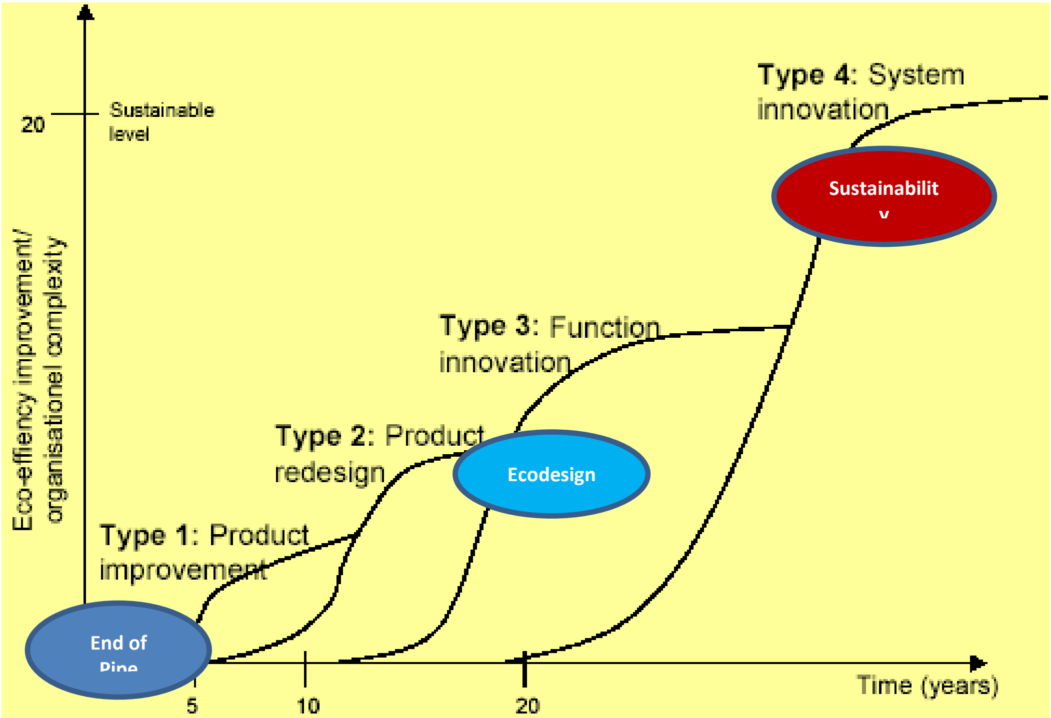


Figure 38: Evolution of approaches to sustainable development (Own source adapted by Stevels, 1996)

Embracing this goal, and attempting a distinction with previous transitions, the notion of "sustainability transition" was coined. Sustainability Transitions adopts a broader perspective than other approaches to sustainable development, which it can encompass and complement by shifting the focus to interactions between approaches in wide-scale system transformation (Figure 38). Each of the above approaches tends to focus its explanation of (un)sustainability around a limited set of dimensions. Transition research developed in *co-evolutionary approaches* highlights multi-dimensional interactions between industry, technology, markets, policy, culture and civil society. Transition research argues that transformative and structural changes derive from mutually (though not equally) influential changes to institutions, economics and practices. Wide-scale, path-breaking transitions to new food, energy, mobility and other systems requires us to encompass multiple approaches in ways that can understand them in interaction. Geels (2011), Kemp and van Lente (2011) refer to Sustainability Transition as "a change of systems towards environmental and social sustainable alternatives which is purposive/ objective-oriented in nature and can thus be controlled and directed to a certain extent". According to Lachman (2013), STs differ from historical transitions in significant ways. Many of the (newer) environmental problems will require from several years to decades before their full effect becomes apparent. As such, sustainability is not perceived as an urgent issue compared to other issues more related directly to sensitive environmental problems, such as pollution, acid rain, etc. Furthermore, STs involve multiple solutions rather than the so-called ‘silver bullets’ as was the case of historical transitions (Geels, 2010).

5.9 Theories of Sustainability Transitions

In theoretical terms, several frameworks have emerged from transition studies over the past 15 years (Markard, Raven and Truffer, 2012). Theories of Sustainability Transitions (TST) as analytical frameworks are detailed in Figure 39. It can be observed that TST arise from the study of Technological Innovation Systems, TIS, (Bergek et al., 2008; Jacobsson and Johnson, 2000; Hekkert et al., 2007). Correspondingly, the Multi-Level Perspective (MLP) on socio-technical transitions (Geels, 2002; Geels and Schot, 2007; Smith et al., 2010) has been a prominent analytical framework which has influenced TST. In parallel to the MLP, other frameworks are subsequently emerged as characterized by normative and governance orientated focus in view of supporting radical innovations and system transformations. One of those is the Strategic Niche Management, SNM (Kemp et al., 1998; Raven and Geels, 2010; Smith, 2007) that has deepen the concept of niche, introduced by the MLP, and emphasized the importance of transition experiments.

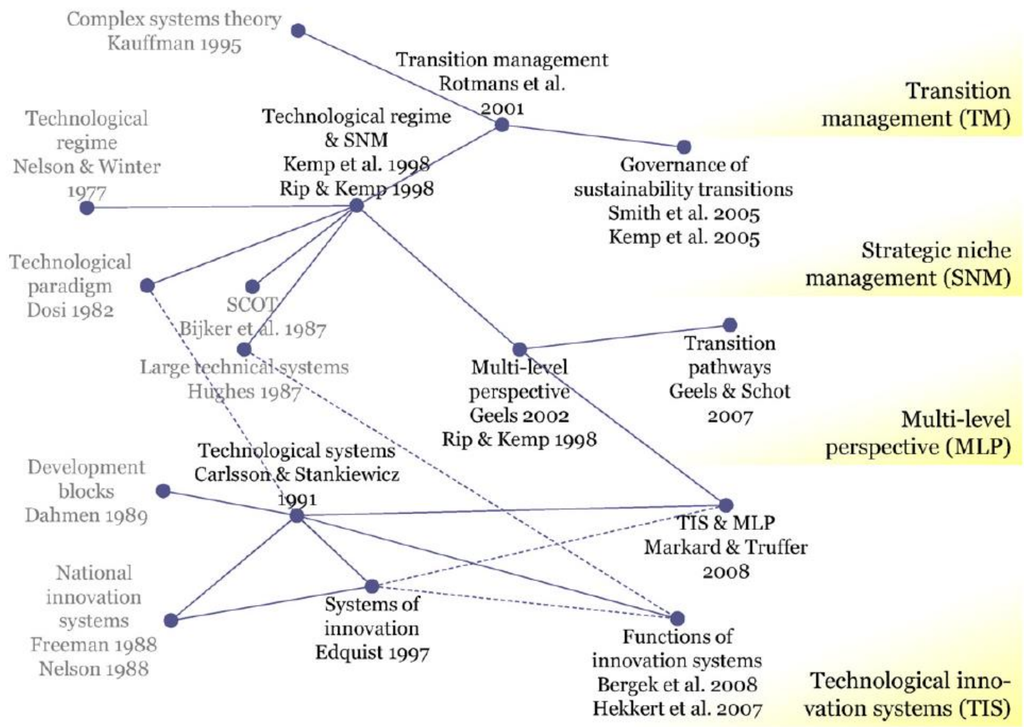


Figure 39: Map of key contributions and core research in the TST (Markard et al., 2012)

All these TST frameworks have the scope to analyze the transition dynamics, in other words they explain how the transitions originate, work and take place. Other frameworks aim to examine the management of the transformative change, viz. what influences the speed and the direction of change (Lachman, 2013). In this field, one of the most known frameworks is the Transition Management, TM (Kern and Smith, 2008; Loorbach, 2010; Rotman et al., 2001). Because this is an interesting aspect for the present PhD research, a comprehensive analysis of TST is provided in the following.

5.9.1 Technological innovation systems (TIS)

An influential theory analyzed is linked to transitions of technology and consists of Technological innovation systems (TIS). A TIS has been defined as “a dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion and utilization of a technology" (Carlsson and Stankiewicz 1991: 111). More recently, TIS researches have shifted the focus to radical innovations in an early stage of development showing the potential to challenge established socio-technical systems (Hekkert et al., 2007). The TIS framework focuses on a specific technology and seeks to understand its success or failure on the basis of the performance of the TIS. The detection and investigation of so-called system failures and the creation of appropriately targeted policy responses is a major theme of this framework. Therefore, TIS is concerned with 'functions' that are relevant for the diffusion of innovations. It can be used to identify barriers and potentials for the diffusion of new technologies and to achieve policy recommendations, in order to accelerate their diffusion and implementation.

5.9.2 Socio-technical transition approaches

As paragraph 4.4 has emphasized, technology plays an important role in all social functions, but innovations fulfill functions in association with social structures. One of the most central notions linked to transitions research is actually the *socio-technical* concept. According to Kemp et al. (1998), "socio-technical" means that scientific knowledge, engineering practices, and process technologies are strictly connected with the expectations and skills of technology users, with institutional structures and with the broader infrastructures that surround them. Socio-technical transitions have been conceptualized intensively by Dutch researchers (Elzen et al 2004; Kemp 1994 Geels 2005c; Rotmans et al 2000). In particular, Rip, Kemp, and Schot have contributed to research on socio-technical regime. The core idea behind the concept of regime is that it concerns established pathways of development through stages of incremental socio-technical change. Much of the early work on socio-technical transitions was related to the factors that lead to the destabilization of existing regimes and the emergence of new regimes. This has derived the assumption that the regime shifts constitutes transitions. In the framework of TST (Kemp, 1994; Kemp et al., 1998; Schot, 1992; Schot et al., 1994), one of the key questions was how to reorient regimes and manage transitions e.g. toward sustainability? In this framework, the concept of socio-technical transitions has posed the basis of a number of TST conceptual developments which include: the multi-level perspective (MLP) and the multi-phase models, the strategic niche management (SNM) and the transition management (TM). The paragraphs that follows explores these theories.

5.9.3 The Multi-level Perspective

The multi-level perspective (MLP) is centered on the concept of socio-technical regimes and describes the dynamics of transitions as the interactions between three different functional levels: the macro-, meso- and the micro-level. Especially, the perspective distinguishes three conceptual levels: socio-technical landscape, socio-technical regime and socio-technical niche, see Figure 40 and Table 16 (Rip and Kemp, 1998; Geels, 2002).

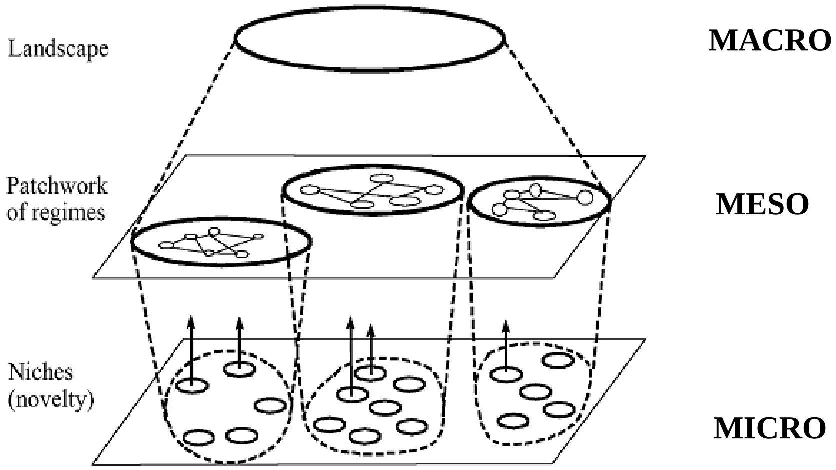


Figure 40: Multi-level perspective and its nested hierarchy (Geels, 2002)

Landscape	The whole set of impacts outside the level of niches and regimes (like autonomous trends and global events) which influences the levels below. Niches and regimes have little influence on the landscape level, but landscape factors can have significant impact, even resulting in systemic changes (rearranging the place of regimes and niches within the system).
Regimes	A patchwork of regimes are dominant segments of functions accepted and stable in society (rules, norms, institutions, physical structures). Regimes change by co-evolution of diverse segments with each other but also by pressure of the landscape. Four types of interactions among regimes have been identified, e.g. competition, symbiosis (opposite of competition), spill-over and integration (Raven and Verbong, 2009).
Niches	Niches are innovative activities that take place in a time-limited

	protection usually independently by dominant selection rules. Niches can deviate from regimes and might even replace the incumbent regime, by creating new trajectories. Another characteristic that sets niches apart from regimes is the fact that niches tend to be more flexible and less bounded by rules (Berkhout et al., 2010).

Table 16: Aspects of MLP different levels: landscape, regimes and niches

The **socio-technical landscape** is the macro-level of the Multi-level Perspective analysis, which refers to aspects of the wider exogenous environment that affects the socio-technical development. As Markard and Truffer (2008) state, landscape includes a set of factors that influence innovation or transition processes but are hardly (or only in the long run) affected by themselves. To this purpose, landscape is really hard to deviate.

The **patchwork of regime** forms the meso-level in the multi-level perspective. The Socio-technical regime accounts for the stability of an existing socio-technical system. The regime consists of three interlinked elements: (1) the set of formal and informal rules and institutions that reproduce and maintain the present socio-technical system; (2) the material and technical elements and (3) a network of actors and social groups, which can develop over time (Geels, 2004). A change in the regime level implies a systemic change. Actually, regimes tend to resist systemic change. As long as regimes themselves are stable, and the landscape is not unfavorable, regimes create a stronger alignment between different elements of the system in which it operates (thus increasing its momentum), thereby making the entire system path dependent/locked in (Raven and Verbong, 2007). Even change within regimes follows a dependent path and tends to be incremental. If however, change within a regime is drastic to such an extent that it leads to systemic change, one can speak of regime transformation or reconfiguration.

Niche is another key concept in transition studies, due to its pivotal role in the emergence of novel technologies. Niches have been conceptualized as protected spaces or application domains, in which radical innovations can develop without being subject to the selection pressure of the prevailing regime (Kemp et al., 1998). Initially, only technological and market niches were acknowledged; however, Geels (2007) maintained that the concept of “niche” has general relevance. Through processes of social learning across multiple experiments, articulating promising expectations and heterogeneous networking, niche innovations can gain momentum and can eventually compete established technologies (Geels and Raven, 2006). According to Rip and Kemp (1998) and Geels (2002), the MLP figures out interrelated dimensions important for the socio-technical transitions:

- socio-technical system: the tangible elements needed to fulfill social functions,
- rules: that guide and orient activities of actors and social groups
- social groups: who maintain and reproduce the elements and linkages of socio-technical systems.

In particular, the strength of the MLP framework is that transitions can be explained by the interplay of stabilizing mechanisms at the regime level, combined with destabilization of pressure from the landscape and radical innovations at the niches (Markard and Truffer 2008). In this context, actors and organizations are embedded in interdependent networks, which represent a kind of “organization capital” and create stability with their interactions. In the framework of MLP, these interactions have been explained with transition dynamics, which describe the interrelate action of the three levels in terms of four different stages: *pre-development*, *take-off*, *acceleration* and *stabilization*. In the following figure, a graphical interpretation of these dynamics is shown. In particular, it can be observed that the breakthrough of technological innovations is dependent on multiple processes in the wider context of regimes and landscape. In Figure 41, the performance of radical innovation is initially low and cannot immediately compete on mainstream markets in the regime. Niches act as “incubation room” for the radical innovation, nurturing their early development. Nevertheless, as figure suggests, landscapes influence change both on niches and regimes; in return, niches (may) change the regimes and a new regime changes the landscape in the longer term.

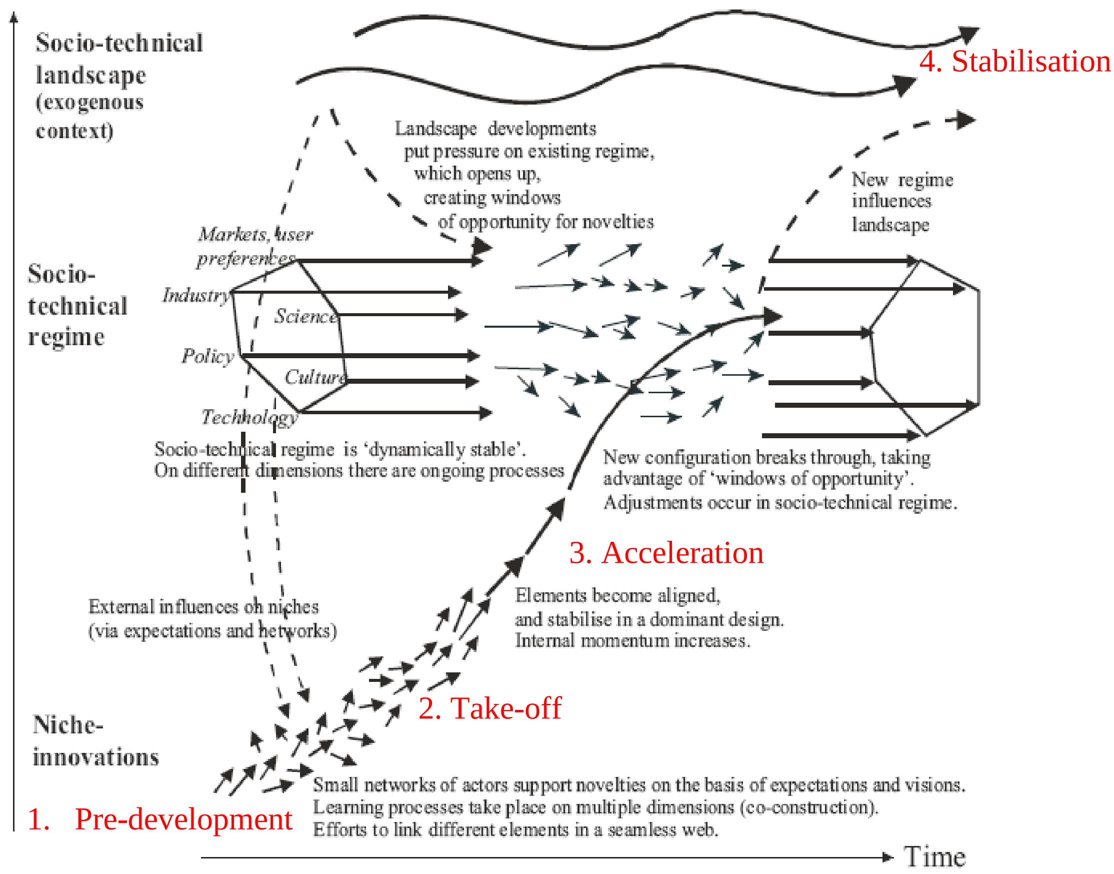


Figure 41: Transition dynamics according to Multi-Level concept (Schot and Geels 2008)

The socio-technical landscape in this model is relatively static, stands for the external context and represents the physical, technical and material setting supporting the society, and cannot be changed by the actors in the short term (Geels & Schot 2007). Landscapes are constituted by rapid external shocks, long-term changes and factors that do not change or change only very slowly (Van Driel & Schot 2005).

5.9.4 Strategic Niche Management

As transition dynamics has shown above, niche is a key concept in the transition studies. The creation of 'protected spaces' has been further investigated as a core element of Strategic Niche Management (SNM). SNM can be seen as a framework focusing on the niche level of the MLP framework previously discussed. The aim is to create transitions pathways which are able to penetrate the prevailing regime so as to replace unsustainable technologies as part of the dominant regime (Kemp et al 1998). The framework was partly inspired by historical studies of technology and economics showing that many successful innovations started as a technological niche and only gradually overturned a dominant regime (e.g. Geels and Schot 2007). Historical studies have also shown that potentially valuable sustainable technologies have often failed to develop fully, or to catch on in the market, even though they may had superior performance characteristics. Thus the approach attempts to purposefully craft and guide such niches to give promising technologies time to develop. Furthermore, SNM is a process-orientated framework with a focus on experimenting and learning. In order to gain insights regarding the breakthrough of niches in to the mainstream of incumbent regime (Raven and Geels, 2010), the core idea behind SNM is that niche management depends by learning-by-doing and doing-by-learning. The objective of transformative niches is not just to achieve a particular technological result but how users will make use of it, since the desirability of a new technology is shaped in social practice. The major concern with SNM is to establish processes by which experiments can evolve into viable market niches and ultimately can contribute to a shift towards a radical system shift e.g. to a more sustainable socio-economic systems. According to Schot and Geels, (2008), SNM is also a policy tool. Especially, the process for creating niches is not exclusively governed by top-down approach. Rather, the niche creation can be steered by a range of actors, including users and societal groups that can redefined the system of governance. Through processes of social learning across multiple experiments, articulating promising expectations and heterogeneous networking, niche innovations gain momentum and can eventually compete with established technologies (Geels and Raven, 2006). SNM scholars have distinguished largely bottom-up perspective by investigating how niches grow, stabilize, or decline by interaction with prevailing regimes (Raven, 2006) by developments over longer periods over time (Geels and Raven, 2006; Schot and Geels, 2008; Smith, 2007). As niches are considered a way to trigger regime shifts, strategic niche management (SNM) research focuses on the creation and the evolution of such niches (Hoogma et al., 2002; Kemp et al., 1998) (Figure 42).

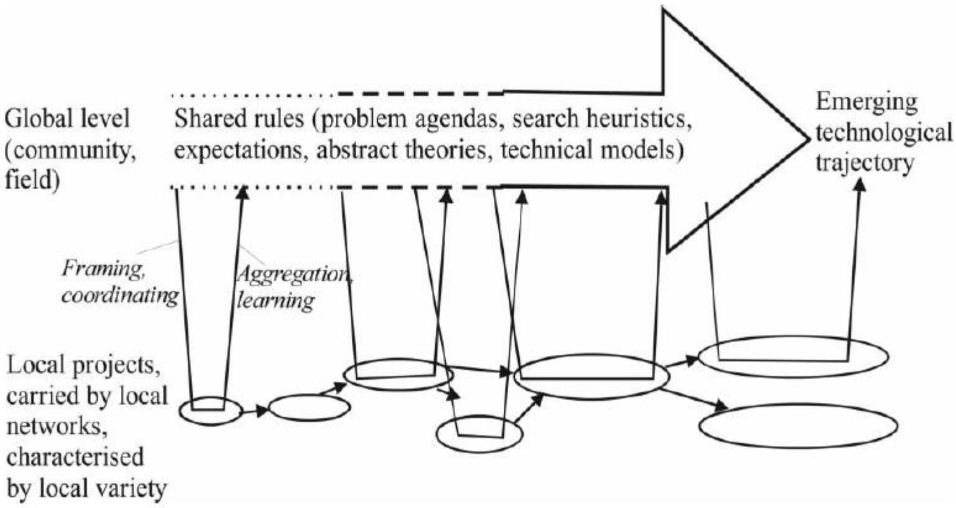


Figure 42: Emerging technical trajectory carried by local projects (Geels and Raven 2006).

According to Sterrenberg (2013), SNM has delivered other useful insights. SNM research establishes that experimenting niches and especially developing **niche experiments**, is crucial for system innovations. Indeed, niche experiments potentially contribute to system innovations. From a SNM perspective, the question is how niches could become as strong as possible providing (sufficient) opportunities for system innovations. To this purpose, SNM research has moreover emphasized the importance of **actor network**. A network analysis is useful to learn about expectations, i.e. the basic drivers in social interactions. SNM underlines that innovators should explore the expectations of actors; articulate these expectations; and negotiate them with others. SNM specifically suggests actors to articulate and negotiate their expectations and interests in relation to sustainability and the regime shift in need as well as in terms of landscape pressures. Therefore network analysis can help to establish and strengthen the systemic social dimension of sustainable innovations. Furthermore, SNM research has stressed **the role of learning** within and among the various niche experiments that can be developed around a certain technology. This is especially useful when a niche-experiment is an experiment that crosses sectorial borders (e.g. energy, mobility, environment, urban settlements). Besides, the SNM perspective attempts to elaborate existing learning theories in social sciences and planning, also recognizing the importance of two different types of learning:

- First-order learning. The leading question is: are we doing the things we have planned in the right way? In a project setting, this is, for example, about 'answering the questions we asked at the start of the project'.
- Second-order or 'reflexive' learning. The leading question is: are we (still) doing the right things? This is the sort of learning that is critical about dominant knowledge, insights, arrangements and systemic learning. This second-order learning is essential for system innovations, because of its radical character. In a project setting, this is for example about 'answering if we were actually asking the right questions at the start of the project'.

To increase the chances of success, learning processes should be deepened. Namely, learning about the innovation and the direct context of the niche experiment in terms of regime and landscape, and what changes would be needed for the niche to become mainstream practice. Then learning need to be broadened. Specifically, learning between niches and about how they could be linked. For example a niche within the building industry within the experimentation of practice with novel small scale infrastructure. As a final point, learning is about how niches can scale-up and influence the regime level and thus develop mainstream practice. Last but not least, SNM research highlights the relevance of temporarily shielding niche experiments to protect them from mainstream selection pressures and prevent premature failure. This requires that niche need to be simultaneously nurtured (e.g. improving technical or economic performance) and empowered to break in view of system innovations. Such managing protection could be operationalized in terms of several different aspects, for example financially (e.g. subsidies); geographically (e.g. specific location); institutionally (e.g. regulatory exemptions); socio-cognitive (e.g. attractive visions) and politically (e.g. ministerial commitments).

To sum up, in the SNM framework, the process of niche experiments is crucial and often includes different phases and instruments (Kemp et al 1998; Kemp et al

2001; Weber et al 1999), such as network analysis, the selection and the set up of new experiments, the learning process (deepening, broadening and scaling up) and finally the breakdown of regimes.

5.10 Transition management

Another theory principally intended for investigating how to steer future directions instead is the transition management (TM) approach. According to Loorbach, (2007), *Transition Management is a new mode of governance for sustainable development that is aimed at enabling, facilitating and guiding transitions to sustainability.* Therefore, TM is a framework to steer future change. TM is based on a different process-oriented driving that attempts to mediate uncertainty and complexity with the management intervention. One of distinctive feature of TM is that transitions towards socially here are seen in a perspective of steering (Schot et al., 1994; Kemp et al., 1998; Van der Laak et al., 2007; Kemp and Loorbach, 2006, Loorbach, 2007). According to Lachman (2013), key elements of TM can be summarized as follows:

- experimenting and learning to guide variation and selection (learning-by-doing and doing-by-learning) in order to keep all options in consideration and the playing field open;
- inclusion of multiple stakeholders (from multiple domains and levels) input through inclusion and involvement;
- complementing conventional policies (which has a short-term focus) with long-term goals with the aim to sustainable development;
- continuous reflection (monitoring, evaluating, improving) on all levels;
- bringing system innovations alongside system improvement.

Currently, TM is broadly applied to stimulate sustainability transitions on the scale of regions, cities and community as well as to initiate transformations in socio-technological systems (Rotmans and Loorbach, 2008, Loorbach, 2010). However, the aim of the transition management is not the realization of a specific transition, but it is a "*basket of objectives"* formed by the sharing visions of those participating. This is a social vision and thus not only comprehensible for individuals with expert scientific knowledge. Particularly, TM combines bottom-up and top-down framework for a goal-oriented modulation. To achieve this goal, TM is executed on three levels (Loorbach and Rotmans, 2006; Loorbach, 2010):

- **Strategic**: activities at the level of a societal system that take into account a long time perspective; that relate to structuring a complex societal problem and creating alternative futures;

- **Tactical**: activities at the level of sub-systems that relate to build-up and break-down of system structures (institutions, regulation, physical infrastructures, financial infrastructures and so on);

- **Operational**: activities that relate to short-term and everyday decisions and action. At this level actors either recreate system structures or they choose to restructure or change them;

According to Loorbach and Rotmans, (2006), the Transition Management consist of a cyclic process with four phases implemented at different levels: problem structuring and envisioning (strategic level), agenda building and networking (tactical level), experimenting and diffusing (operational level). Its operationalized depends on continuous monitoring, evaluating and adjusting on all levels. The three level of TM can be combined to the other TST frameworks such as the multi-level perspectives and SNM. In particular, TM can be considered as a multi-level governance scheme in which managing is operated through improving the interaction between the different levels of MLP. Especially, operational sphere act at niche level, the tactical sphere within the regime and finally strategic sphere tends to influence the landscape through long-term goals. Therefore TM focuses on the management action strategically connecting problems and solutions at different levels. Figure 43 shows the four phases of the Transition Management cycle in relation to the three different level of multi-level perspectives.

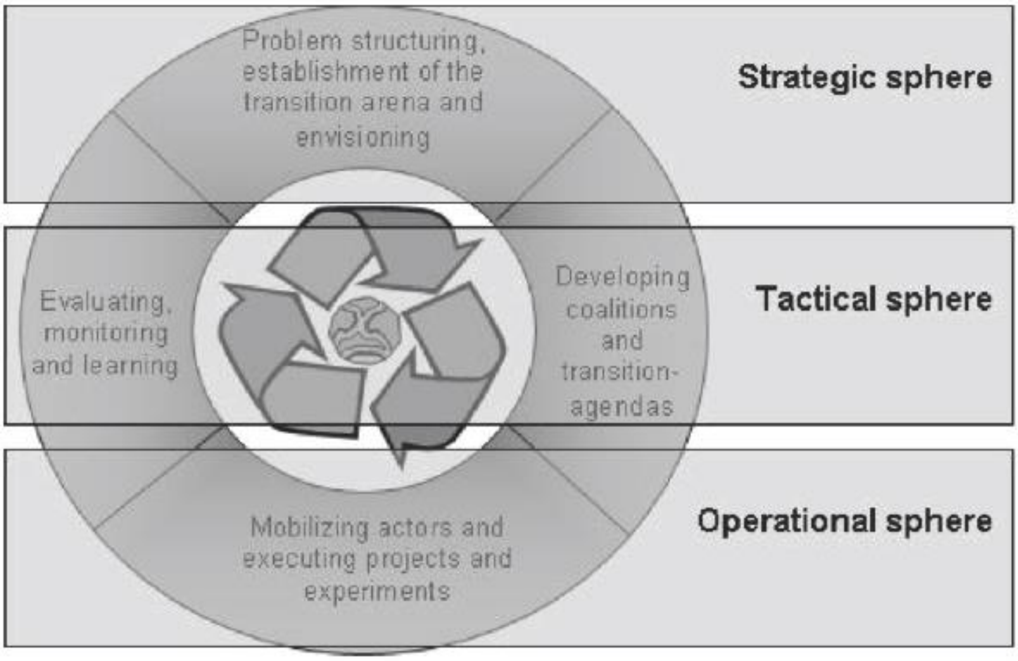


Figure 43: Transition Management Cycle (Loorbach and Rootmans, 2006)

Instead of three levels, a fourth level has been recognized as the basis of theoretical explorations and practical experiences: reflexivity (Lissandrello and Grin, 201; Sterrenberg, 2013; Loorbach, 2008). In Figure 44, a revision of TM cycle is proposed adding reflexive level. Grin and Weterings (2005) have identified reflexive monitoring as "a participatory process of describing, evaluating, and reflecting on ongoing activities, designed to strengthen both the quality and impact of a project, concurrently, by feeding back into the project an understanding of its proceedings". However, to move transitions ahead we just do not need of managers that know the present and know how to design the process, but also planning and in particular 'reflexive planning'. According to Lissandrello and Grin (2011) reflexivity concerns both how the design of new practices takes place and also how planners' actions inevitably cause a confrontation between the emerging, exigent present problems and the persistence of existing approaches, structures, and systems. Transitions require 'reflexive planning' therefore a capacity of agency that entails a change in the habits, imagination, and judgment of the actors involved in relation to different structural and temporal orientations (in relation to the past, in the possibility of the present and in the visions of the future). A reflexive phase is then crucial for moving transition processes ahead.

Indeed, reflexivity allows to identify weaknesses and strengths in view of possible of sustainability paths along the various phases of the planning process and to explore new ways to overcome them. In practical terms, reflexive activities are not just related to the evaluation of the experiments and learning, but also by shaping the future through learning.

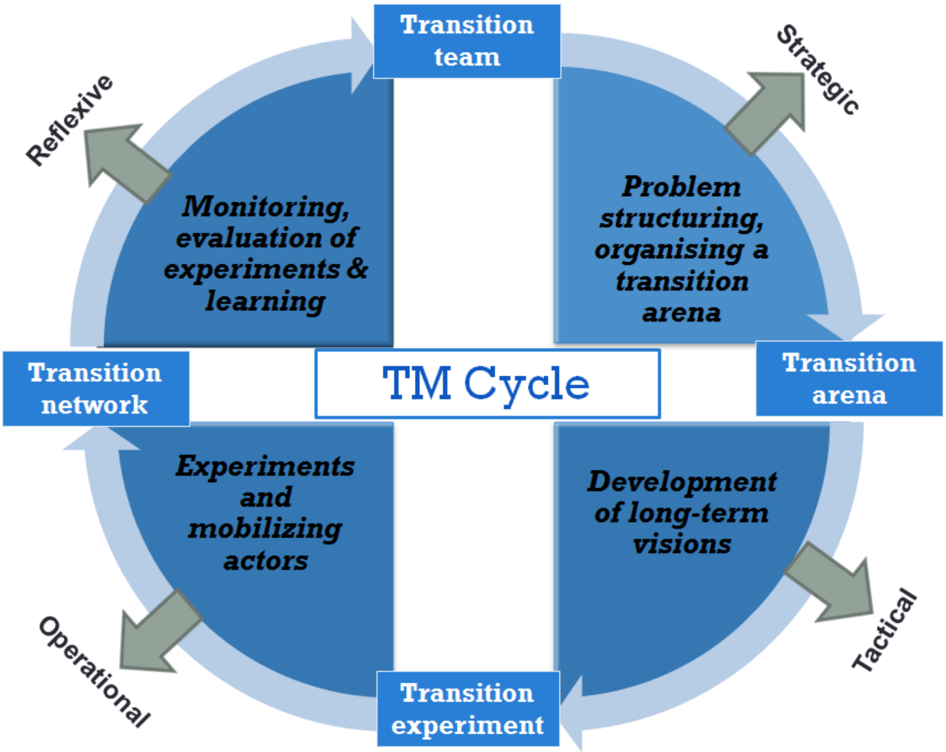


Figure 44: Four Levels of Transition Management Cycle (Adapted by the author from Rootmans and Loorbach, 2008)

Level	**Phase**	**Systemic instrument**	**Actions**
Strategic	Problem structuring Establishing a transition arena	Transition Team Transition Arena	Investigating the context Community engagement visioning Strategic discussions long-term goal formulation
Tactical	Development of long-term visions Framing the transition challenge	Transition Agenda	Agenda-building, Backcasting Negotiating, Networking, Coalition building
Operational	Experiments and mobilizing actors	Transition experiments Transition network	Operational activities Processes of experimenting, implementation Projects development
Reflexive	Monitoring, evaluation and developing knowledge		Evaluating experiments Analysis and interpretation of results Imagine and understand Alternative trajectories for future action Evaluation and learning

Table 17: Transition Management Process Description

5.10.1 The Transition Management process

Beside the conceptually notions of TM mainly based on complex systems theory and new forms of governance, TM has been practically implemented. The most remarkable process of TM have been developed by Rotmans and Loorbach (2006) and include four phases and different systemic instruments. The TM process is described by connecting levels, phases to systemic instruments and illustrating actions. As outlined in Table 17, in the implementation of the process different phases and key instruments are distinguished. Primarily, a transition team is formed to drive the process and embed it in the local context. The transition team starts to explore the context, conducting interviews and doing research, and working towards a system analysis and actor analysis. Based on the actor analysis, diverse groups of people are invited to engage in a series of meetings as a transition arena. According to Fink (1996 in Jorgesen), the term 'arena' is a metaphor taken from political and social theory. In the framework of TST, the approach of arena of development, AOD, has been developed by Jørgensen and Sørensen (2002) who has proposed a flat approach inspired by the actor-network theory instead of the hierarchal framework of MLP. In this context, it is referred to the word's original meaning in Arabic – '*sand on sand*' – to indicate the spatial and relational temporality and fluidity of the phenomena for which the approach provides the analytical framework. Transition arena emphasizes the temporary and actor-dependent character of the fields that hold social ordering and in which change and transitions take place. In the transition arena, the actors-group are the change agents which explore the transition challenges and create a shared problem framing. According to Roorda (2014), change agents are individuals willing to go beyond 'business-as-usual', who are intrinsically connected to the issue at hand and are open to other perspectives. Subsequently, they exchange and elaborate perspectives on a possible future, thereby creating visionary images for the future of the city. As a final step in the transition arena setting, the change agents elaborate transition pathways, indicating fundamental changes and corresponding actions needed to reach the envisioned future. The ideas brought forward by the transition arena are summarized and published in a transition agenda. Actions are undertaken to make the transition agenda public and give others a chance to adopt and adapt it, and relate it to their own agenda and practices. A shared transition agenda provides a starting point for involving a wider group and instigating new activities, networks and collaborations. In this context, transition experiments are the main instruments for actors engagements. Through these radical short-term actions in line with the transition agenda, are initiated or adapted. Transition experiments give an impulse provide agents with an opportunity to involve other actors and engage a broader audience. As a result, insights from these experiments can be taken to a more strategic level. One of the consequences of TM process is to create a supportive network of policy officers and representatives of companies and other organizations for these bottom-up sustainability initiatives.

To sum up, Transition Management is based on the empirical and theoretical understandings of transition studies. Therefore TM can influence the direction and pace of societal change dynamics towards sustainability. According to Roorda et al. (2014), TM is characterized by six principles which can influence transitions process:

- **Acknowledge the complexity of the challenges**. TM understands the dynamics and interlinkages of multiple domains, actors, and scales. This can be done by thoroughly examining the existing situation, as well as by questioning assumptions, problem perceptions, and dominant solutions.

- **Recognize the difference between system optimisation and system innovation**. The latter requires taking small but radical steps, guided by a long-term perspective, which can be acquired by questioning mindsets and being open to unorthodox ideas and actions.

- **Give room to diversity and flexibility**. The future can neither be predicted nor planned. Options should therefore be kept open by exploring multiple pathways when working on strategies and actions. Resistance and barriers should be anticipated, and diversity fostered. Involving a variety of perspectives will enable cross-fertilisation and prevent ‘tunnel vision’.

- **Co-create**. Neither local government, nor any other single actor can address sustainability challenges on its own. A variety of people and organizations make decisions that influence the future on a daily basis. As a local government, it is important to engage multiple stakeholders beyond simply providing input – everyone can be considered a decision maker, contributing their positions and perspectives.

- **Systemic thinking**. Achieving ambitious targets is difficult when vested interests and positions are taken as a starting point. Therefore, actors who are already adopting new or alternative ways of thinking and doing (change agents) should be found, as they can be influential in mediating and triggering transitions. They should be actively engaged and supported with the resources and opportunities needed to realize innovation.

- **Facilitate social and institutional learning**. Learning is essential for societal change. Opening up to actors with different backgrounds provides better insights into the challenges of and opportunities for change. The aim is short-term action aligned with a long-term vision to learn about new practices and current constraints. Learning processes should be supported by providing time for reflection and creating a setting that supports mutual trust and openness.

5.11 Investigating key instruments of TM

With the aim to stimulate sustainability transitions and to initiate radical transformations in socio-technical systems, several project has yet applied TM approach in different contexts such as regions, cities and neighborhoods and different domains such as energy, water, and mobility (Roorda et al., 2014). Also for the purpose of this thesis, TM has been recognized as the most effective approach that can steer the system innovation towards sustainability. In the following, key instruments of TM are identified with the purpose of applying them in the empirical part of this research project.

Beforehand, it has been seen that TM proposes a number of systemic instruments for stimulating transitions towards sustainability: Transition Team, Arena, Experiments and Network (Figure 45). For the purpose of this thesis, a deep investigation of these instruments is carried out. The aim is to understand the instruments and their features in order to drive a radical innovation at system level.

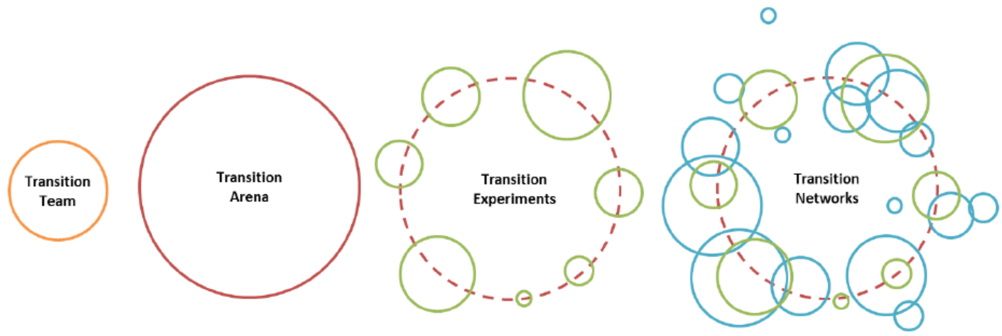


Figure 45: Key Instruments of Transition Management (Roorda et al., 2014)

5.11.1 Transition team

The first instrument of TM is the transition team, the core team which manages and facilitates the TM process in a multifunctional and transdisciplinary way. A transition team is a group of person that avails the Transition Management approach for steering transitions towards socially needed directions. A multidisciplinary framework is required to ensure that all relevant actors can contribute and commit to sustainability improvement in the earliest stages of the TM process and stay involved throughout the practical stage, up to and including communication phase and final evaluation. Given on the focus of the transition process and its desired outputs, a transition team is formed by the initiating agency of the process. Commonly, the transition team consists of 3 to 5 people and is a strategic and content based mix of employees of the initiating organization, plus possibly external experts in the field under study (e.g. policy experts), transition management experts, and/or a process facilitator. The transition team manages and facilitates the TM process, organizes the internal and external communications, and relates the TM process to ongoing (policy) processes. Moreover, the transition team co-ordinates the logistics, process facilitation as well as the substantive input for transition arena meetings and also takes the outcomes forward. All of these are demanding and time-consuming tasks. It is therefore important to clarify the roles, responsibilities and time investment of every team member at early stages of team formation. In addition, the team should have a cross-functional nature, involving members with different areas of expertise. To this purpose, the transition team performs a *system analysis* to get an integrated overview and understanding of the topic; and an *actor analysis* to map the actors relevant to the topic at hand. The actor analysis is related to the system analysis: the system analysis provides a starting point for exploring which actors are relevant to the issue, the actor analysis indicates which actors could be interviewed to explore perspectives as part of the systems analysis. This may involve desk research, interviews and expert discussions. Moreover, a system analysis encourages holistic thinking and views a chosen change issue from a long-term perspective. It supports those involved in looking beyond their own expertise, questioning their beliefs and value frameworks, making different perceptions explicit. System analysis and problem structuring require competence such as concepts, tools and skills that provide insight in dominant patterns and structures of social subsystems. As such a system analysis is important for preparing the transition team for the participatory framing of the transition challenge and the collective envisioning process. In addition, systems analysis provides participants who have different backgrounds and knowledge with a common information base and enables mutual understanding of the system under analysis and examination. A crucial activities for the Transition Team is also networking with other actors. Networking is needed, not only to create a positive attitude towards and support for the process, but also to find links to other similar initiatives. The transition team can also aim for commitment from relevant peers who can contribute with expertise, time, communication channels and/or contacts. After the preparation and exploration of the first phases of the Transition Management processes, a broader group can be identified and the transition arena start to settle. The arena group consists of about 10-15 change agents who are selected and invited by the transition team on the basis of the systems and actor analysis. The transition team will not approach parties as stakeholders, but instead invites people on personal title. They look for individuals who they consider to be change-agents because of their willingness to go beyond business-as-usual. Further requirements are that individuals are intrinsically connected to the issue and have the openness to appreciate other perspectives. The key for a fruitful arena group is diversity. Therefore the group should consist of people from various backgrounds (e.g. businesses, government, research institutes, citizens), domains (e.g. energy, culture, education, mobility, youth work, industry) and with various competencies (e.g. leadership, creativity, analytical skills, coalition building skills).

5.11.2 Transition arena

Transition arena is a small network of various frontrunners who develop vision, goal formulation, roadmaps and milestones. Particularly, transition arena is a setting in which different perspectives, expectations and agendas are confronted, discussed and aligned. As stated by Jørgensen and Sørensen (2002), arena is a spatial imagery that brings together heterogeneous elements that seem distant in geographical and conventional cultural space. It resembles the idea of the 'patchwork' of technology stories. It uses the idea of partial connections and multiple stories. In addition, it specifically addresses conflicting interests and contention about the space. Arena is characterized by adopting a 'flat' approach, as it does not operate with pre-classifications of social structures and institutions into levels and hierarchies. Therefore, actors on an arena take into consideration a heterogeneous set of elements, which include humans, technologies, institutions, visions and practices provided with their specific meaning, position and identity through their inter-connectedness in networked relations. Transition arena is a temporary setting that provides an informal and well-structured space to a small group of change agents from diverse backgrounds (businesses, government, research institutes, NGOs, and citizens). The group engages in a series of meetings, jointly elaborates a transition challenge, drafts a long-term vision, and develops transition pathways to realize this vision. The transition arena gathers a group of ambassadors inspired to go beyond current interests and daily routines. The result is the implementation of inclusive and fluid transformation processes.

In fact, a transition management process does not replace the need for other policy interventions, but can inspire policy formulation. Moreover, any application of transition management is complementary to other governance activities and influences but does not replace them; outcomes can for example serve as inspiration for strategic planning and regulation formulation. Thanks to several meetings and events, the transition arena is subsequently involved in the TM phases such as structures the transition challenge, drafts visionary images, and develops transition paths and a transition agenda. The formulation of the transition challenge is based on the system and actors analysis and they analyse clear challenges by dissecting them from their societal context, define clear targets aiming at incremental improvement on the short term and implement clearly laid out plans with milestones and goals. It can be initially characterised by diverging and exploratory discussion, but finally it requires a convergence of ideas. If the discussion is spread over multiple meetings, the transition team can use the insights of each arena meeting to further elaborate the systems analysis and present it again at the next meeting. The participating change agents engage in a series of meetings to jointly develop a new and shared visionary story which they can directly link to their own everyday practice. Envisioning concerns new innovation trajectories from a long term perspective on sustainability. The outcome is the identification of a long term vision, needed as an anchor point for strategies and short term action. It is also needed as a storyline that can instill a degree of credibility and aspiration amongst participants, as well as mobilize individuals outside the process. In particular, the story line that emerged from the arena meetings is called “transition narrative” and comprises the ideas from system analysis, the visionary images, the pathways, and the short-term actions. The transition paths include goals and interventions on the short-, mid- and long-term. The process of envisioning is as important as the vision itself, since it contributes to positive group dynamics and a common ‘language’ and therewith the alignment of perspectives. At the individual level, the vision allows actors to envision themselves as being part of or contributing to solutions. Finally, it is necessary bridging a long term imagined sustainable future with the present. Several transition paths are developed that each describe a possible route from the present towards the envisioned future. Finally, the transition narrative is consolidated in a publication, the transition agenda. In the transition agenda, the transition paths are prioritized and then operationalized by indicating short-term actions. Subgroups of the arena emerge that take the responsibility for implementation of some of these actions. Therefore, transition agenda is useful to implement the desired goal with the consent of regimes, by aligning them with the long-term goal. Furthermore, a shared transition agenda, which provides a starting point for involving a wider group and instigating new activities, networks and collaborations.

5.11.3 Transition Experiments and learning process

Transition experiments are short-term actions through which alternative structures, culture, and practices are explored. A transition experiment is therefore both a goal in itself and an instrument to explore and learn about radically different ways of meeting societal needs – now and in the future. Within the model of TM, transition experiments have been defined and implemented as one of the key instruments for stimulating transitions towards sustainability. What differentiates these from other innovation projects is that they take societal challenges rather than specific innovation (i.e. a solution) as a starting point. In Table 18, the difference between Traditional Innovation Experiments and Transition Experiments are outlined. Essentially transition experiments are innovation projects with a societal challenge as a starting point for learning aimed at contributing to a transition. As stated by Raven et al. (2010), the contribution of small-scale experiments is essential to transitions towards a more sustainable society. Therefore, on one hand, transitions experiments have a high potential to contribute to transitions (Raven et al., 2010). On the other hand, they are characterized by a high risk (Rotmans, 2005). Indeed, the implementation of transitions experiments in various application domains can provide a fruitful support to the urgent need of making sustainability transitions happen. The final scope is not only the success of the single initiative, rather the learning process associated to transition experiments.

	Classical Innovation Experiment	**Transition Experiment**
Starting point	Possible solution (to make innovation ready for market)	Societal challenge (to solve persistent societal problem)
Nature of problem	A priori defined and well-structured	Uncertain and complex
Objective	Identifying satisfactory solution (innovation)	Contributing to societal change (transition)
Perspective	Short and medium term	Medium and long-term
Method	Testing and demonstration	Exploring, searching and learning
Learning	first order, single domain and individual	second order (reflexive), multiple domains (broad) and collective (social learning)
Actors	Specialized staff (researchers, engineers, professionals, etc.)	Multi-actor alliance (across society)
Experiment context	(partly) controlled context	Real-life societal context
Management context	Classical project management (focused on project goals)	Transition management (focused on societal 'transition' goals)

Table 18: Difference between Traditional Innovation Experiments and Transition Experiments

In general, learning can be understood as an (inter)active process of obtaining and developing new knowledge, competences or norms and values . The aim of learning in transition experiments is to contribute to a transition, e.g. a fundamental change in dominant culture, practices and structure. The learning process in transition experiments is therefore characterized by a process in which multiple actors across society develop new ways of thinking (culture), doing (practices) and organizing (structure). Characteristic for a transition experiment is that the experiment does not take place in a laboratory environment, but in a real-life societal context that enables high quality learning. From research on transitions to sustainability, three characteristics of a high quality learning process can be identified. Research within SNM (Raven, 2005) explains that successful experiments have learning processes that are primarily broad. Namely, learning is about many dimensions of a problem (e.g. institutional, technological, socio-cultural, environmental, economical) and the alignment between these dimensions. Furthermore learning is also a *reflexive process*. Definitely there is attention for questioning underlying assumptions such as social values, and the willingness to change course if the innovation does not match these assumptions. Furthermore, literature on transitions to sustainability emphasizes the importance of social learning, a process in which multiple actors interact and develop different perspectives on reality (Leeuwis, 2003). In transition processes social learning is specifically aimed at `reframing; changing the 'frame of reference' (Schon and Rein, 1994) and perspective of actors involved (Rotmans and Loorbach, 2006). An adequate learning process in transition experiments facilitates broad learning about different dimensions of a broad societal challenge; reflexive learning that questions existing ways of thinking, doing and organizing; and social learning to develop an alternative perspective on reality through interaction in heterogeneous groups.

5.11.4 Transition Network

TM instruments as Transition Team and Transition Arena are effective instruments to shape a participatory process. On one hand the Transition Team is the core team that manages and facilitates the TM process in a multifunctional and transdisciplinary way. On the other hand the Transition Arena is one of the main result of TM process and provide the framework where to put into practice transition experiments. According to Roorda et al. (2014), four types of follow up activities are sketched below.

- Engaging is about getting more people, organizations and initiatives to work towards sustainability transitions.
- Internalizing is about anchoring the insights from the transition narrative and the transition experiments in policy processes of various domains and organizations.
- Opening up is about creating space for and building upon emerging initiatives.
- Igniting is about creating new impulses that inspire people and make them think beyond their own stakes, routines and perspectives.

The result is the creation of a network in which people involved strategically disseminate the ideas of the transition arena to make organizations adapt their initiatives and strategies in line with the transition narrative and search for people to contribute to the transition experiments or adopt specific parts of the transition agenda. Similarly to the transition experiments, the network is based on learning. People in strategic positions discuss the new practices started with the transition experiments and the current barriers they reveal, with regard to for example financing structure or regulations. In addition, transition network connect people and organizations which do not yet have robust experiences of sustainability initiatives and search for opportunities to link their work to the envisioned future. In this context, it could be useful to create a supportive network of policy officers and representatives of companies and other organizations. The formalization of a structure which helps revealing promising ideas and support in transforming ideas into promising projects could be a way to facilitate transition experiments and to arise other bottom-up sustainable initiatives. Thanks to the adoption of a monitoring approach and mapping, an overview of emerging initiatives can be achieved, especially to link bottom-up sustainability initiatives. Subsequently, the network can be enhanced through meetings where participants can inspire and learn from each other while working on elaborating certain aspects of the narrative, exchanging experiences from ongoing initiatives or identifying challenges and opportunities for upcoming trends. As a result, new transition arena trajectory with a more specific focus can be initiated.

5.11.5 Co-evolutionary approach of TM instruments

With the purpose to identify key instruments for steering system innovation towards sustainability, the TM is primarily considered as a process providing valid support for implementing transitions. According to several experiences of TM (Roorda et al., 2014), an important notion emerged from TM is the mutual interaction among the systemic instruments. For example, transition experiments are derived from the sustainability vision developed by the transition arena and fit within identified transition pathways. Another instruments is transition agenda useful to implement the desired goal with the consent of regimes, by aligning them with the long-term goal. Practically, transition experiments are short-term initiatives to explore and learn about the shifts in structures, culture and practices as depicted in the transition pathways. Furthermore, monitoring and evaluation of transition experiments include learning-by-doing and doing-by-learning, learning from others, and from one's own experiments. Monitoring and reflection can lead to adaptations in the vision or in the coalitions and networks. Finally the formation of coalition and transition network are instruments which demonstrate the extension and the iterative nature of the process. In the transition management cycle, the different instruments for TM are therefore integrated. In practice the transition management activities are carried out partially and completely in sequence otherwise in parallel and in a random sequence. Consequently he transition management cycle is characterized as a co-evolutionary approach in terms of joint searching and learning process, focused on long-term sustainable solutions.

5.12 Discussion and conclusion

This chapter has investigating different frameworks pursuing system innovation towards sustainability. Systemic transformation is effectively the mainly opportunity to answer systemic problems as systemic lock-ins, the recent market failure and the growing pressures on our environment. In particular, system innovation can range from the incremental to the radical degree of produced technological change and the level of impacts to the system. Considering the current systemic problems, several international studies has emphasized that there is the growing urgency of a radical system innovation to pursue sustainable development goals. Radical system eco-innovation is an investment in the future that provides a systemic response to grand societal challenges expected to grow in the medium to long term. It is not a "quick fix" strategy, but aims for long term wins. In this context, Sustainability Transitions is emerged as a research field providing a support to move towards more sustainable systems. Definitely, ST are directed to redesigning entire systems of practice and provisions. Sustainability Transition goes beyond incremental environmental improvements and efficiency gains, and aim at 'breaking out' of locked-in systems and thinking. Several eco-innovations can take the form of improved products and processes, new technologies and services, and new ways of doing things, but key to the transition is the combination of technologies, new business models and sustainable behaviors. ST adopts a systemic approach with the aim to steer and to create pervasive change. The chapter has explored the different frameworks emerged from the Theories of Sustainability Transitions aimed at developing a co-evolutionary approaches that highlight the multi-dimensional inter-connection of actors and socio-technical regimes. TST are actually directed at explaining a specific type of social change. Therefore *transition* is mainly defined as a fundamental change in the dominant way a societal need such as the need for energy, health care, mobility, housing and agriculture is fulfilled. Transitions are characterized by their long time frame. Especially, the chapter has described the different researches theories which analyze the propriety of these long-term structural societal changes. In this framework, Technological Innovation Systems (TIS) has been initially developed with a focus on analysis and dynamics of a particular innovation. TIS is especially concerned with successful diffusion of a particular technology or product. But the most widespread analytical transitions theory is the Multi-Level Perspective MLP. MLP is based on the multi-phase concept and provides a way to describe the dynamics of transitions in terms of different stages. In particular, the MLP analyzes the interlinked patterns between dynamics at three levels of a societal system: niches, regimes and landscape. The focus is on the analysis and the dynamics of broader transition processes and variety of innovation. Subsequently, different patterns of transitions has been distinguished. In the beginning they were only focused on technological substitution, but recent patterns also distinguish other types of interaction and more differentiated transition pathways (e.g. de-alignment and re-alignment, reconfiguration, transformation). In the analysis of transition pathways, several studies have investigated the process in which niches grow, stabilize, or decline in interaction with the dynamics of prevailing regimes. Since niches are small-scale protective spaces where actors experiment with radical innovations that may challenge and break through into the prevailing regime. In these protective spaces, innovations are shielded from the mainstream selection pressures and are developed further, in spite of their poor technical or economic performance. Therefore niche have potentially path-breaking consequences when they become widely diffused and adopted. A theory which highlights the importance of protected spaces and of user involvement in early technological development is Strategic niche management (SNM). SNM aims to create new transition pathways which are able to penetrate the prevailing regime (or be part of a realignment of the regime) so as to replace unsustainable technologies as part of the dominant regime. As a result, Strategic Niche Management stimulates a learning processes and processes of societal embedding of socio-technical innovations. A core element of SNM is therefore to experiment in practice in (partly) protected niches. The characteristics of niches enable experimenting and learning about novel or deviant culture, practices and structures . On the other hand, niches are also shaped by learning experiences that become aggregated and embedded in new or deviant constellations of culture, practices, structure. Therefore, experimenting is crucial for learning about social challenges and stimulating transitions. Another framework in which the notions of experimenting and learning has been also developed and applied, is Transition Management (TM). TM is aimed at developing instruments for governing transitions into socially desirable directions. The governance approach of Transition Management (TM) deals with influencing transitions towards sustainable directions. TM is characterized by a prescriptive cyclical framework of co-evolving activities. This chapter has identified TM instruments that can contribute in effective way to steer sustainability transition process. For example, the Transition Team and the Transition Arena are effective instruments to shape a participatory process. On one hand the Transition Team is the core team that manages and facilitates the TM process in a multifunctional and transdisciplinary way. On the other hand the Transition Arena is one of the main result of TM process and provide the framework where to put into practice transition experiments. Really, experimenting in practice to learn about possible and desirable transition pathways is an another important TM instrument. Learning is also part of the reflexive phase in order to evaluate all the process, to identify new problems and challenges and to define future trajectories and actions.. Consequently, transition experiments are crucial instruments in order to stimulate learning and thereby guide variation and selection. This has resulted in both theoretical and empirical studies on the importance of conducting multiple experiments in the niche level and combining experiments with tactical and strategic activities. Consequently, the duality of niches emerges: niches make transition experiments possible and at the same time experiments also create or reinforce niches. As final consideration of this chapter, an effective approach for system innovation towards sustainability has been identified and it consists in Sustainability Transitions. Especially, in case of initial process Transition Management is recognized as a promising instrument. On the other hand, due to the inherent complexity, transitions cannot be designed, blueprinted or imposed from the outside, in other words, transitions cannot be managed in a controlling sense. Rather, transitions can be steered, triggered, and stimulated with respect to their dimensions. In this context, an important role for transition experiments has been highlighted, which refers to innovation projects in which actors and society contribute to make transitions happened. In the following chapter, the experimentation of transition practices will be demonstrated in bottom-up and top-down-initiatives. The aim is a wider engagement and awareness of sustainability visions in order to prepare and to mobilize actors for radical change at system level.

6 Transition into Practice: Methods, Case Studies and Models for steering Sustainability Transitions.

Act as if what you do makes a difference. It does.
William James

This Chapter intends to highlight the importance of conducting transition experiments. With this purpose, methods and recognizable examples of successful transition initiatives are investigated. The final aim is to demonstrate which mechanisms, strategies and tools allow to trigger an effective transition process. At the end, considerations on the role of the research in the sustainability transitions process are explored. The intention is to meet both the requirements posed by real-world problems as well as the goals of sustainability science as a transformational scientific field.

6.1 Why to experiment transitions

The challenges of sustainability require radical innovations in socio-technical systems, such as mobility, energy networks and household living in cities and regions. This means a change in the traditional paradigm of how to deal with sustainability and innovation, towards a socio-technical system approach. In this context, the development of ‘transition theory’ is directed at explaining a specific approach for socio-technical change, transitions, which are structural transformations in the dominant way social needs such as energy, health care, mobility, housing and agriculture are fulfilled. Historical researches into transitions theories and system innovation have revealed the importance of transition experiments. In accordance with the Multi-Level perspective and Strategic Niche Management, experiments are connected with the developments at landscape level and with the changes to be brought about in the regime. The emphasis on experimenting derives further from the recognition that transitions involve uncertain, complex and dynamic processes. Many, diverse actors are involved in the transitions, from the different levels distinguished in the MLP, and often from different sectors and domains: from civil society (which include citizens and NGOs among others), the private sector, public authorities, the education and the science community. In a similar way, the Transition Management approach also recognizes transition experiment as one of the key instruments for steering the transition process. As seen in chapter 5, there is emerged a strong relationship between niche and experimentation (Figure 46) .

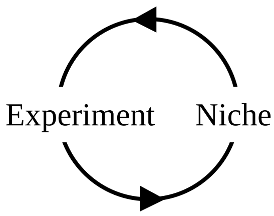


Figure 46: Duality between transition experiments and niches (Raven et al., 2010)

The niches, in which the innovation is generated in a protected environment, without it is subjected to external pressures, make feasible the experiment transition, but at the same time the experimentation creates and reinforces niches.

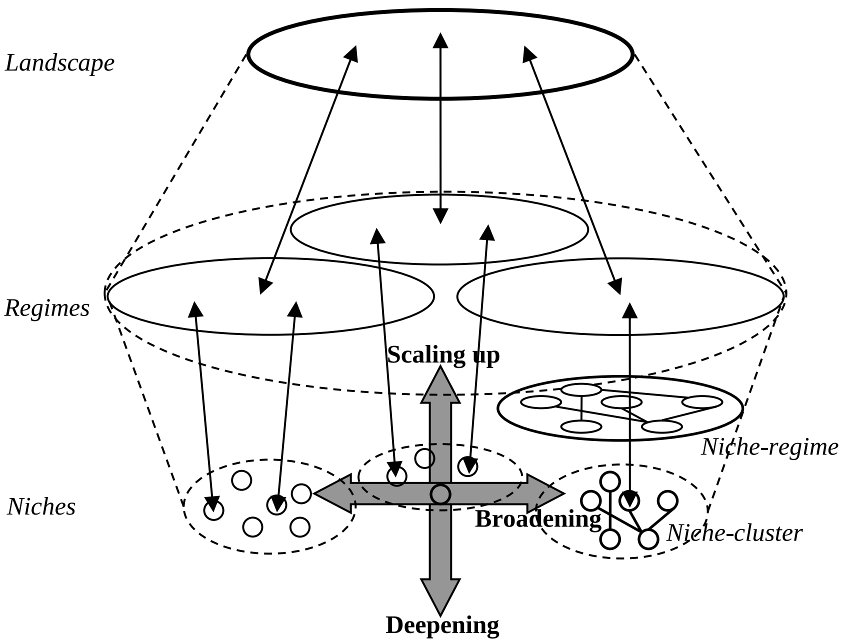


Figure 47: Deepening, Broadening & Scaling up transition experiments in niches (Based on Raven et al, 2010, Geels and Kemp 2000, De Haan and Rotmans, 2008)

In order to describe how, what and when experiments contribute to transitions, the frameworks relates the mechanisms deepening, broadening and scaling up to desired results or changes in established ways of thinking (culture), doing (practices) and organizing (structure), and distinguishes the conditions for change (see Figure 47). The mechanism of *deepening* is defined as a learning process through which the actors can learn as much as possible on an experiment of transition within a specific context. In particular, a deepening-process consists to transform an innovation project to a transition experiment, by creating the conditions for an open search and learning process in which a societal challenge is a starting point. The deepening-substance concerns the explicit formulate explicit learning goals that are connected to social (transition-)goals in order to develop new ways of thinking, doing and organizing.

- **Broadening-process:** This strategy is directed at linking the innovation project to a broader context, by interacting with new domains and partners.
- **Broadening-substance**: The essence of this strategy is assigning new functions to the innovation and adapting to other contexts.
- **Scaling up-process**: Essential is strategic management, which involves key actors (with power and willingness to change) at a strategic level from the outset of the process.
- **Scaling up-substance**: This strategy is aimed at changing dominant ways of thinking, doing and organizing, by stimulating structural support and resources for the innovation.

The mechanism of *broadening* is defined as the repetition of a transition experiment in different contexts and as the connection of this to other functions or domains. The *scaling-up* mechanism is defined as the integration of a transition experiment in the dominant ways of thinking (culture), doing (practice) and organizing (structure), at the level of a social system. Since the crucial role of experimentation, there is the need to create a portfolio of transition experiments that reinforce each other and contribute to the sustainability objectives in significant and measurable ways. In the TM framework, Transition experiments provide practical way to interact with other instruments such Transition Team, Transition Arena and Transition Network. In addition, experiments need to bring together diverse kinds of knowledge and skills and review their mutual relationship. In these circumstances experiments offer a good opportunity of developing transition practices. Transition practice is pioneering because it is about radical and uncertain innovations in the long term. There are no ready-made blueprints or protocols. Besides experimenting the literature pays a lot of attention to learning. Similarly, for transition practices a great emphasis is placed on learning. Learning is important for two reasons. This first is connected with the dynamics, risks and uncertainties inherent to transition practices and their long-term objective. It is therefore useful to learn about the preconditions for transition and potential paths to solutions from successful initiatives, but equally from ‘failed' initiatives. A transition can only take place if the actors involved change their roles and aims in conjunction. Thus, actors will have to learn to see structural bottlenecks not as given facts but as challenges. A second reason why learning is crucial, is that transition practices are influenced by how stakeholders define problems and their assumptions, knowledge, values and identities. Analyzing these, and critically assessing them, can help to prevent lock in and widen the scope for sustainable solutions. Therefore, practicing transition is uncertain and for this reason special competences for conducting transition practice are required.

6.2 How to experiment transitions

With the aim at providing guidance for practitioners who are conducting transition practices, the identification of useful skills, tools and best practices are presented in the following. In particular, the Dutch Competence Centre for Transitions (KSI, Link) has done research into competences, skills and roles that are needed for transition practice.

Key Elements of Transition process	**Competences**
System analysis and problem structuring	Concepts, tools and skills that provide insight in dominant patterns and structures of social

	subsystems
Re-orientation and visioning	Envisioning new, innovation trajectories from a long term perspective on sustainability
Establishing and executing transition experiments	Building of coalitions of actors that recognize the benefit of joining forces in performing innovative experiments
Broadening and scaling up transition experiments	Broader social embedding of transition experiments through interaction with other experiments, initiating similar experiments in other contexts and anticipating favorable conditions for scaling up
Monitoring, evaluating and learning	Concepts and tools for monitoring and evaluation of ongoing innovation processes and reflexive abilities of transition professionals
Transition management	Cluster of competences, enabling the transition professional to do what is necessary at the right time, in the right place with the right partners.

Table 19: Elements of Transition process

6.3 Which skills to experiment transitions

Especially, it can be distinguished two kind of skills. Process skills are about the quality of the project management, substance skills are about the quality of the explored solutions. Basic skills proved to be networking, great communicative capacity and powers of persuasion and ability to mobilize. Other specific skills include the ability to think in terms of systems, visionary power, observational skills, creative skills, sense of timing and persuasiveness.

	Transition Phase Action	Process skills	Substance skills
Strategic	• Investigating the context • Problem structuring • Community engagement • Visioning • Strategic discussions • Long-term goal formulation	• Networking skills • Communication skills • Decisiveness • Determination • Leadership • Vision	• Systems thinking • Creativity and imagination • Problem structuring skills • General knowledge • Large network • Abstract thinking
Tactical	• Agenda-building • Backcasting • Negotiating • Networking • Coalition building	• Negotiation skills • Communication and consensus building • Thinking in terms of co-production • Open to new combinations • Coalition building skills	• Strategic thinking • Analytic ability • Specific knowledge • Innovative ideas
Operational	• Operational activities • Processes of experimenting • Implementation plans • Projects executing	• Mobilizing skills • Organizational talent • Anticipatory skills • Entrepreneurial skills • Powers of persuasion • Networking and lobbying	• Second-order learning • Systems thinking • Insight and a sense of timing • Ability to balance substance, process and results
Reflexive	• Evaluating experiments • Analysis and interpretation of results • Imagine and understanding • Alternative trajectories for future action • Learning	• Observational skills • Reflective skills • Self-aware and independent	• Integrated thinking • Questioning with an open mind • Analytical thinking • Conceptual thinking

Table 20: Skills for conducting Transition Practices (Roorda et al., 2014, Raven et al., 2010)

In the framework of Transition Management process (Roorda et al., 2014), diverse skills are required in the different TM phases at strategic, tactical, operational and refelexive level. Research into transitions has furthermore led to the following skills for each phase of transition process (see Table 20).The relevance of the skills depends on the phase of the transition process. In the strategic phase (problem structuring and envisioning) actors with other skills are required than in the tactical (backcasting, agenda building) or operational phase (experimenting and implementing). According to Roorda (2014), an interesting category of actors who can facilitate the transition management process are the *frontrunners*. Other designations for frontrunner would be change agent, engaged citizen, unorthodox thinker or "out of the box thinker". The two most important characteristics of a frontrunner are that he/she is intrinsically connected to the issue - has "sparkling eyes" when talking about it - and thinks beyond own expertise, worldview or interests. Frontrunners can be categorized according to their background, their competences and their interest profile. To be a frontrunner an individual actor does not have to fit in all background and skill categories but the participants of the transition process as a group should be a good mix of these categories.

6.4 Transition Practices Methods

In the following, there are provided several examples of methods that can be used in transition practices in order to facilitate the execution of different phases of transition process. The methods are selected by the Dutch website www.transitiepraktijk.nl developed by KSI and the Dutch Competence Centre of Transitions, by the Dutch Research Institute For Transitions (DRIFT) in the framework of MUSIC Project, http://www.themusicproject.eu) and by the Transition Network movement, https://www.transitionnetwork.org . Methods enable transition professionals to develop and transmit their competences in managing successfully transition practices.

6.4.1 Methods for System analysis and problem structuring

The strategic phase is focused on creating a common understanding of the context and of the persistent sustainability problems, includes the structural roots .

In Annex I, there are provided two methods (Multi-Level-Perspective Analysis and SWOT Analysis) which can help to identify the systemic problems (the systemic aspects that make the sustainability problems persistent), and from there, the associated transitional challenge. The result is to generate a shared sense of urgency and a shared direction and ambition.

6.4.2 Methods for Re-orientation, visioning and backcasting

Development of a vision or a long-term perspective is through a joint process that those involved can learn about each other's mental models and become able to make adjustments to their deep convictions. The collective creation of a vision therefore supports more radical innovation rather than incremental renewal. The collective creation of a vision also helps in a practical sense because it can contribute to coordinating agendas and the strategies of those involved (convergent learning). Subsequently, it is necessary to identify the steps needed to attain it, it is easier to achieve a transition. Thinking in terms of the present you are more likely to remain caught up in familiar thought patterns Backcasting essentially involves defining one or more future scenarios for a sustainable future and then identifying the steps needed to achieve them from the present situation (Figure 48). Backcasting produces a strategy for achieving a sustainable future scenario. A series of specific activities can be suggested with a relatively short time horizon for implementing that long-term strategy. These activities can be grouped in a programme.

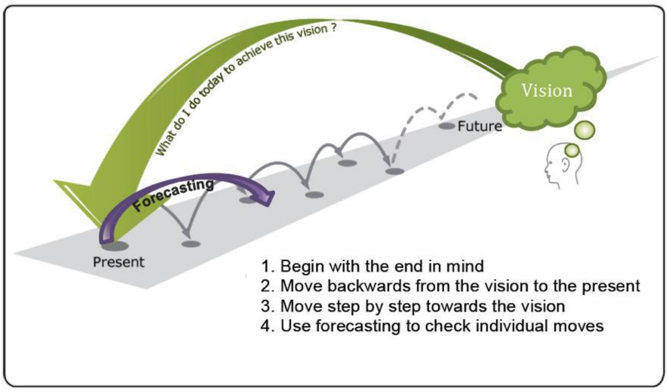


Figure 48: The process of backcasting

6.4.3 Methods for agenda building and creating an action plan

In the agenda building is crucial to create a large participatory process. The involvement of regime players is desirable, both for the legitimacy of the radical changes involved in transitions, but also because of the power and resources that are needed for change. An example reported in Annex I is the Open Space Technology (OST). OST is a powerful group process that supports positive transformation in organizations, increases productivity, inspires creative solutions, improves communication and enhances collaboration. Subsequently, a planning activity is required. Action plan is about the forms of suitable coalitions for renewal, coalitions whose composition will have to change in the course of time and according to need. In the Appendix I, example for building action plan are described (i.e. Dragon Dreaming, see also Figure 49)

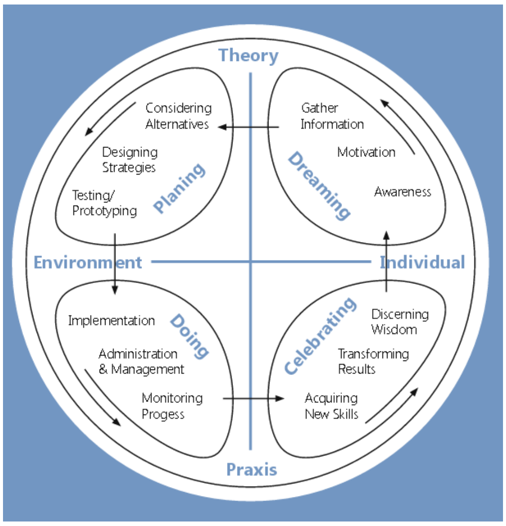


Figure 49: The Project Wheel of Dragon Dreaming

6.4.4 Methods for reflexive phase

In Annex I, Permaculture (Figure 50) is provided as an example of method for reflecting and learning. The twelve principles provide a design framework but also a way to verify if the systemic approach was fully adopted in the experimentation phase.

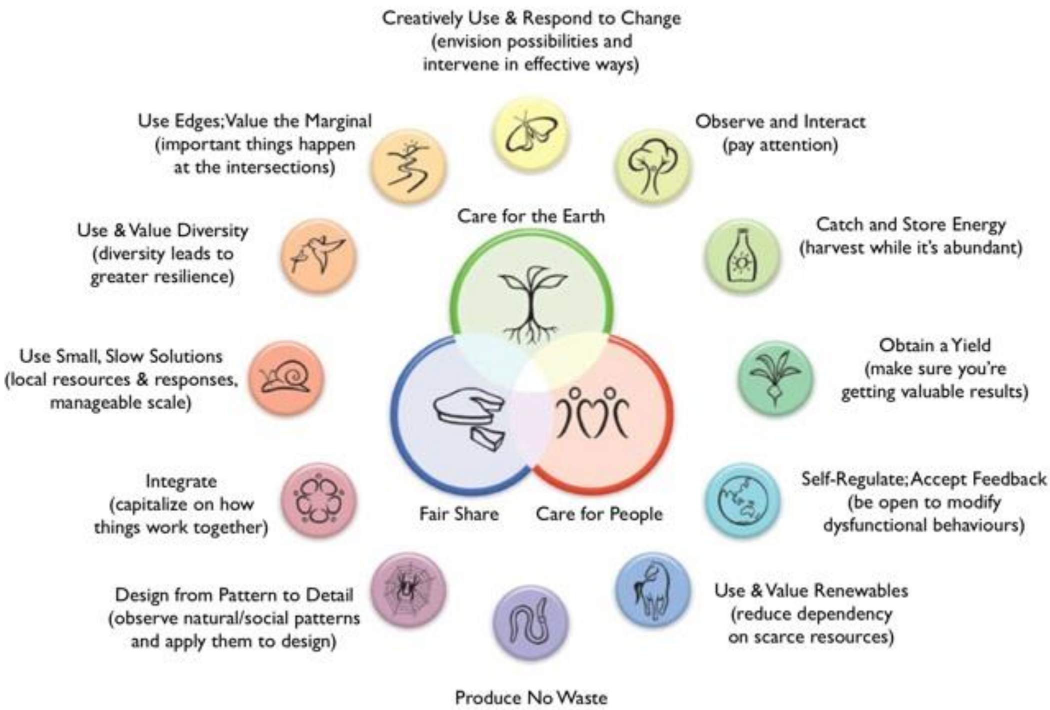


Figure 50: Permaculture design framework principles

6.5 Investigating frontrunner initiatives of Transition Practices

6.5.1 Dutch origins of Transition

Transition thinking had begun to develop in academic circles in the Netherlands by the beginning of the 1990's, and was lightly institutionalized in 2001 by the Dutch Knowledge network and research programme for System Innovations and Transitions (KSI). KSI aimed at improving understanding, identifying and influencing the process of sustainability innovation. To this end, knowledge from relevant scientific disciplines and insights, such as ecology, complexity theory, sociology, history, governance and innovation studies, were integrated. The programme also encompassed the performance of practice-oriented research and the participation in testing grounds, in such diverse sectors as energy, manufacturing, transport, housing and spatial planning, health care and water management. From the Dutch KSI network research activities and transition practices have spread. KSI has developed into the international Research network Sustainability Transitions Research Network (STRN). Simultaneously and in co-production with these initiatives, several scientists have developed a research agenda for an understanding of sustainability transitions through a program of networking, research coordination and synthesis activities.

6.5.2 European Programme Climate-KIC

Another effective initiative which promotes the experimentation of transition thinking is the European Programme Climate-KIC (http://www.climate-kic.org). Climate KIC is an European initiative supported by the EIT (European Institute of Innovation and Technology) and aimed at providing the innovations, entrepreneurship, education and expert guidance in order to shape Europe's ambitious climate change agenda. In the framework of Climate-KIC, a bottom-up regional programme is endorsed: Pioneers into Practice (PiP). PiP aims at developing regionally based transition platforms on low-carbon innovations. Thanks to a learning-by-doing programme, the PiP participants, called pioneers, have the opportunity to develop their knowledge and understanding on transition thinking in a variety of environments from business to government and research. With this intention, PiP provides transition practitioners with a guidance of competences developed through a mentoring programme. Particularly, pioneers are supported by leading European experts on transition and systems thinking. The core of the PiP programme is the placement, a working period during which the pioneers can develop experience of low carbon innovations within the host organizations. Definitely, PiP programme promotes the experimentation of transition towards low-carbon transformative innovations.

6.5.3 Regional and National Transitions Programmes

Besides, many local transition experiments have started in several sectors as the energy sector, health care, building, transport and agriculture. Currently, various policy domains are applying small-scale experiments as a key instrument for stimulating ‘transitions’ towards a more sustainable fulfillment of societal needs. Examples of these so called ‘transition programs’ are: the Energy Transition (initiated by the Ministry of Economic Affairs) and the Transition Program in the Care (initiated by the Ministry of Health, Welfare and Sports) , Urgenda, a Dutch private initiative, aiming at speeding up the transition towards a sustainable Dutch society, by connecting actors and initiatives and taking away barriers to sustainability innovation (www.urgenda.nl).

BOX 5.1: The MUSIC programme

Mitigation actions to reduce CO_2 emissions in Urban areas and the creation of Solutions for Innovative Cities

Transition Management has been successful applied to the urban context within an important European project named MUSIC (Mitigation in Urban Context, Solutions for Innovative Cities). This Interreg-funded project is a co-operation between five cities in north-western Europe and two research institutes – the Dutch Research Institute For Transitions (DRIFT), Erasmus University, Netherlands, and Public Research Centre Henri Tudor (Luxembourg). The overall aim of the MUSIC project is to catalyze and mainstream carbon and energy reduction in urban policies, activities and the built environment. The MUSIC cities will use the Transition Management method developed by DRIFT to guide this process. This project includes a series of workshops with several stakeholders (businesses, government, research institutes, citizens) resulting in a local sustainability vision and action plan. The local action plans and energy planning tools being tested in pilot projects include:

• Aberdeen: renovation of a school to become more energy efficient and at the same time increasing the energy efficiency awareness of students and parents

• Rotterdam: development of new cooperation models between public and private sectors to make public buildings less energy consuming. These models will be applied to swimming pools and smart roofs

• Ludwigsburg: building of an energy neutral community centre in a socially and economic weak district, where local residents will be informed on energy reductive measures

• Montreuil: building of an energy generating school building. Local residents and students will be involved and informed during the whole building process

• Ghent: developing a participation project to receive support from the users and inhabitants of the city. Also, Ghent will do a major pilot of a GIS support tool by proclaiming the energy saving message during several events.

(http://www.themusicproject.eu)

Further examples of transition programme implemented in other countries are: Sustrans in Denmark, sustainability experiments in Asia, the transition programmes - Housing and Building, and Materials in Belgium, and transition activities in other countries, for instance Sweden, Switzerland, Australia, India, Canada and the USA.

6.5.4 Grassroot movement of Transition Towns

Other remarkable transition experiences are implemented by the movement of Transition Towns. The Transition movement is a bottom-up network of active citizens who are trying to find practical solutions on a local level to the global problems of climate change and peak oil. The first Transition group started in Totnes (UK) in 2006 (see Box) and since then Transition initiatives have sprung up in communities across 30 different countries, including 11 in the EU: the UK, Sweden, Spain, Portugal, the Netherlands, Italy, Ireland, Germany, France, Denmark and Belgium. There are currently over 1000 groups officially registered as Transition initiatives, located in cities, towns, villages and rural areas, and the number is growing all the time. It is estimated that there is also a similar number of unregistered groups, also pursuing the Transition approach. In the 13 countries surveyed, there were an estimated 898 groups officially or unofficially pursuing the Transition approach at the beginning of 2013 (see Figure 51).

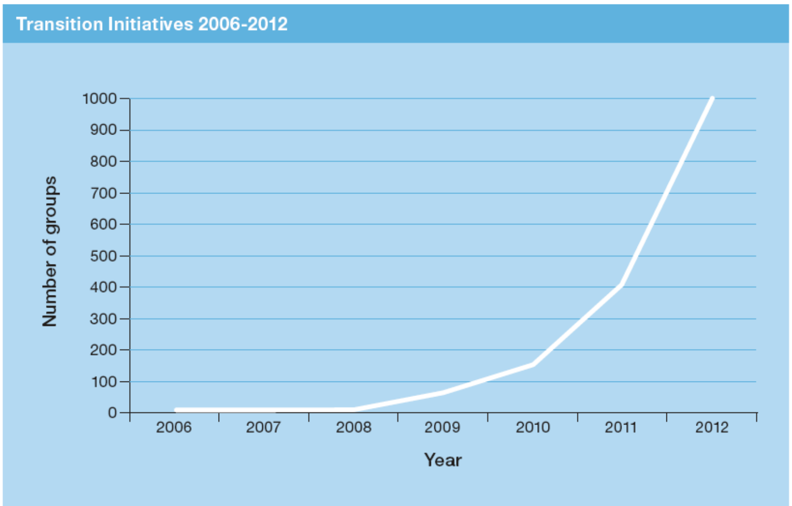


Figure 51: Transition Towns Initiatives (2006-2012)

These groups all share a concern with regard to decreasing supplies of fossil fuels (peak oil), climate change and, increasingly, the economic downturn, and all have adopted a community-led approach to addressing these issues within their own local areas. A common thread between these groups is the focus on practical, action-oriented projects, which cover a wide range of activities, from community gardens, to energy saving clubs, shared transport and recycling and repair schemes, to more investment intensive projects in areas such as community supported agriculture and community energy production. Most groups start small, but through their engagement in projects they gradually draw in more and more people from within their catchment areas.

BOX 5.2: Transition Town Totnes (TTT)

Established in 2006, Transition Town Totnes (TTT) is a dynamic, community-led charity, which acts as an umbrella for different thematic groups developing projects in and around Totnes, in areas such as sustainable construction, food production, business and livelihoods. There are currently around 20 ongoing projects, all of which have been developed by interested members of the community, with the support of the TTT office. One award winning TTT project, which ran from January 2010 to July 2011, was Transition Streets, which aimed to engage the wider community in Totnes in living more sustainably. Nearly 500 households participated in the project. These were organized into 56 different groups of neighbors. The projects saw households save an average of £570 and 1.3 tonnes of CO_2 per annum. New social ties were also created and the vast majority of groups vowed to continue their activities beyond the life of the project. TTT activities are mainly carried out by volunteers, but it also has a full-time manager and a part-time office coordinator. (http: //www.transitiontowntotnes.org)

6.5.5 Transition Training Initiatives

With the aim to set up and run successful Transition Initiatives, Transition Network organize different Transition Training courses that a valid support in order to have a first experience of Transition. The main outcomes of the courses are providing the basics for setting up, running and maintaining a Transition initiative. Consequences are learning about the stages of Transition, experiencing a personally deepening journey into the inner dimension of Transition and meeting other people involved in Transition initiatives in order to share experiences, difficulties and successes (Figure 52). Different training courses introduce and develop the idea of a Transition initiative:

- **Transition Talk** is a 1-day course that enables participants to give a Transition presentation.

- **Transition Launch** is packed with imaginative ways to delve into the practice of Transition showing you how to set up, run and grow a Transition Initiative. It is also useful for people who have recently become involved in Transition and want to develop the essential skills and insights to help their Transition initiative become a success.

- **Transition Thrive** is an advanced exploration of the Transition model and process. It help to explore how to sustain momentum in a Transition Initiative, and what will help to thrive as you deepen into the process. Each person can learn specific and attainable ways to either get their Transition Initiative back on its feet or onto the next level.

Transition training is based on the "head, heart and hands" approach and on the importance of maintaining a balance between these three components. The "head" refers to scientific and mental conclusions and facts that inspired Hopkins and his collaborators to establish the first Transition Town in Totnes. It includes the insight that the present lifestyle is not sustainable. Rather than preaching a doomsday scenario, the Transition movement considers these negative developments to be an opportunity by transitioning to a better way of life based on greater sharing of resource use and better cooperation.

Figure 52: Transition group in San Lazzaro di Savena , Bologna

Another element part of the Transition process is the “heart,” or the so-called “inner Transition.” For example, in an “inner Transition” group people might investigate together which of our “inner mechanisms” actually encourage us to create our external industrial growth model, which so often inflicts harm on our environment and our inner well-being. Another aspect of this work might be to examine how one’s group can collaborate well and deal constructively with feelings of desperation and powerlessness, posed by overwhelming, “big” challenges. A first, important step might be simply to recognize those emotions and then to find wise and appropriate ways of dealing with them. Finally, the “hands” which means Transition initiatives. In this initiatives is equally important to anchor both the “head” and the “heart” as concretely as possible in actions on the ground, be they neighborhood meetings, art or food projects, a reskilling workshop or regional currencies. The “head,” “heart” and the “hands” of the Transition movement draw further upon deep ecology approaches developed by Joanna Macy (“the work that reconnects”) as well as the theories and practice of permaculture. Transition Network is run from Totnes and has a small core staff that helps to deliver its support services, which includes maintaining a network website (https://www.transitionnetwork.org). In addition to providing access to various guides and other resources, the website also hosts a database of registered groups and a project directory that describes over 300 projects.

6.6 Case Studies of city as "platform for Transition Practices"

As a number of transition initiatives have shown, the city has become in the last years a relevant subject as a context for study and practice the transition towards sustainable development. In modern societies, cities are centers of social and economic activity and are the places where the majority of the population lives. Cities are actually at the center of the sustainability debate as the sites where many sustainability problems become apparent. Many discussions are taking place in relation to negative consequences of urbanization and low-density cities as well as energy efficiency buildings, means and infrastructures of mobility. Discourses on low-carbon and environmental sustainable society are populating the public sphere and reports, policy documents and academic scholarly works. While emerging 'warnings' are advised by experts, the urgency to provide policy change in view of sustainable 'objectives' for urban areas seems a norm today. Moreover, accelerating processes of urban globalization has having consequences as cities often are quoted as places where problems tend to accumulate and concentrate. Practice for urban sustainability is therefore a tangible challenge with effects from suburban initiatives to national scale and global level. Cities have a global impact and meaning. (Bulkeley & Betsill, 2005) In the following the analysis of two transition practices fulfilled at urban level is described. Both experiences are investigated under the lens of transition. The former is about an initiative promoted by the City of Bologna public administration in the framework of Covenant of Mayors (Lissandrello et al, 2014). This mainstream European movement involves local and regional authorities, voluntarily committed to increasing energy efficiency and the use of renewable energy sources on their territories with the aim of a 20% CO_2 reduction by 2020. The case of Bologna is focuses on the role of local authorities to pursue the challenge of a urban sustainability. The latter concerns a series of bottom-up initiatives realized in the framework of Transition Towns movement. In this case the emphases is on the role of grassroot initiatives in the achievement of sustainable transition. The experimentation of transition approach at urban level can help to demonstrate what characterize transition practices so that sustainability challenges can be addressed most efficiently.

6.6.1 Covenant of Mayors in the City of Bologna: a transition analysis

Local authorities can have a high degree of influence and impact generated by consumption and production issues. Actually, urban planning has an essential role in bringing about new directions on the long-term future actions beside environmental impacts (Shapiro, 2005). Moreover, local authorities can potentially act as a driver for the promotion of urban practice focused on shaping spaces where environmental, economic and social goals can all be achieved simultaneously. This seems one of the focuses of the Covenant of Mayors, an European initiative in which local public authorities are committed to increase renewable energy and to reduce CO_2 emissions and energy use in cities. This European initiative has gathered a growing interest, reached currently about 4500 signatories cities. Cities have started to transform, sometimes new urban lifestyles are emerging giving much attention to not-motorised transportations as well as 'green' initiatives and citizens' engagements. In the following there are investigated how some of these 'urban' initiatives have taken form in Bologna, Italy, in relation to the process of the Sustainable Energy Action Plan (hereafter SEAP) here considered as a potential tool for transitions towards a sustainable urban context. In order to translate local political commitment into concrete measures and projects, covenant signatories of Mayors has to fulfill different actions as the creation of adequate administrative structures and a baseline emission inventory as a preparatory document for the sustainable energy action plan (SEAP) which is itself a process which follows a first part of implementation and a second part of monitoring. The process consists also of a regular submission of implementation reports. The signatories represent the local authorities as cities, which include both small villages or major metropolitan areas, engaged in energy efficiency and renewable energy sources. A Baseline Emission Inventory is a quantification of the total amount of CO_2 referred to the urban area within a given period of time – the recommended base year being 1990. It aims to identify the principal sources of CO_2 emissions and their respective reduction potentials. The SEAP is the key document in which each covenant signatory outlines how to realize the goals and the fulfillment of EU objectives. It defines the activities, measures, time frames and assigned responsibilities. Covenant signatories are free to choose the form of their SEAP, as long as it is in line with the general principles set out in the covenant SEAP guidelines. Basically, SEAP is a planning document that details concrete activities and emission reduction measure that enable more resilient and sustainable local energy systems. In order to translate this political commitment into concrete measures and projects, Covenant signatories notably undertake to prepare a Baseline Emission Inventory and submit, within the year following their signature, the SEAP. Sustainable Energy Action Plans usually consists in a series of objectives and key measures and relevant examples as local initiatives which local authorities collect in a database of best practices called "Benchmarks of Excellence". The Benchmarks of Excellence endorses as useful actions for other local authorities, provinces, regions or networks to possibly transfer these practice in other contexts. Beyond energy savings, the results of signatories' actions are manifold: creation of skilled and stable jobs; healthier environment and quality of life; enhanced economic competitiveness and greater energy independence. These actions serve as examples for other urban contexts to follow. From the 'local authorities' point of view these initiatives seem to work by an increasing number of municipalities involved politically on the aim. In the following figure, the state of SEAP adoption undertaken by Emilia-Romagna Region is outlined (see Figure 53).

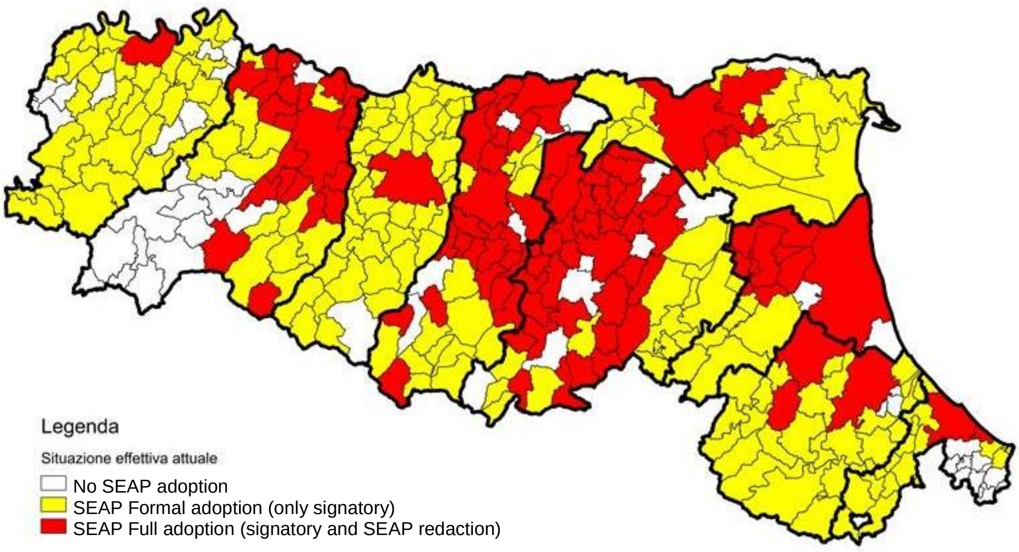


Figure 53: SEAP adoption in Emilia Romagna Region (source Emilia Romagna Region, January 2015)

The City of Bologna has a population of 384.089 inhabitants (900.000 in metropolitan area) and it is the capital of Emilia-Romagna Region in center of Italy. The urban area extends for about 140,846 Km2. Bologna is a crucial railway and motorway junction in Italy due to its central geographical position. Bologna's industry sector is characterized by a strong presence of small and medium enterprises and it is also well-known for its historical University with a presence of almost 100.000 students. The City of Bologna signed the Covenant of Mayors in December 2008. The first version of the Sustainable Energy Action Plan (hereafter SEAP) was realized in May 2012. Bologna's office of the Covenant of Mayors, includes both long and interim-term objectives. The baseline emission inventory, which is the foundation for sectors distribution of the most important emissions of Bologna is based on 2005 sources (Figure 54).

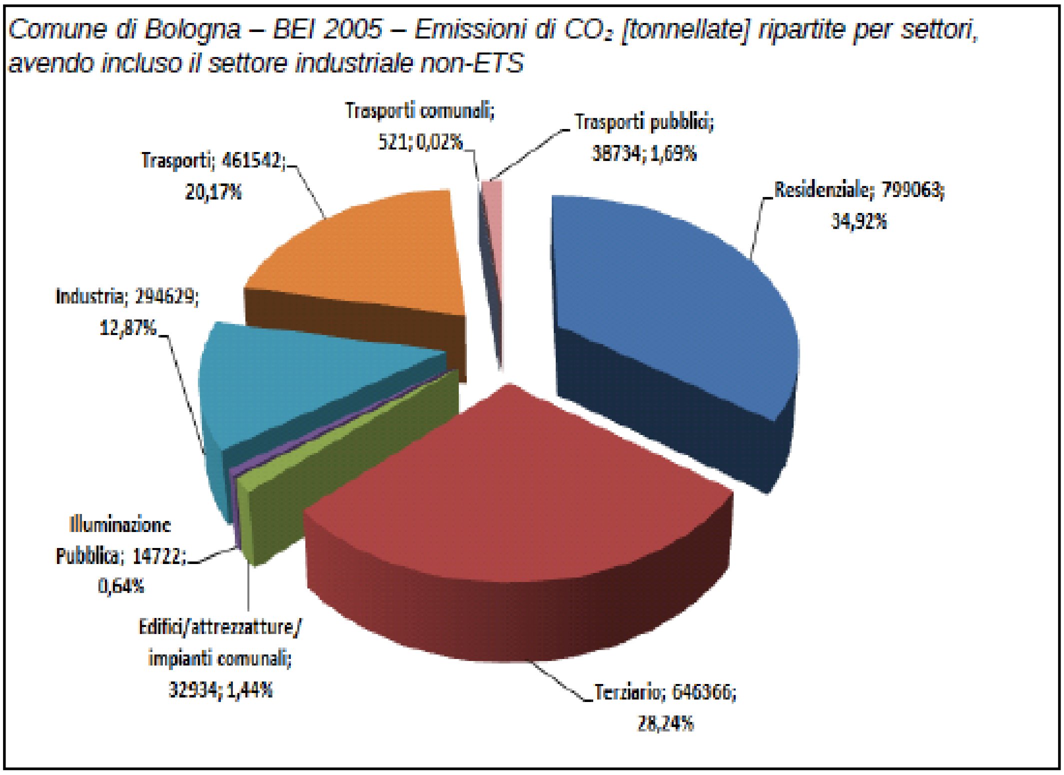


Figure 54: Baseline Emission Inventory

Within the typology of implementation, case studies to understand the current level of change inside the Covenant of Mayors include three principal sectors in regard to the level of emission: services, building, equipment/facilities and industries, transport. In the following, we identify some representative case studies which have been discussed during interviews with local policy actors active shaping both the political and technical process of the SEAP. Key documents supporting the analysis have been the Implementation Reports (Report of Interventions – MEI, Monitoring Emission Inventory).

Bologna's SEAP process contains phases which can be assimilated to transition process. The SEAP process is a kind of 'direct translation' from the long-term vision to a more detailed short and interim-term set of goals. This translation is made gradually with a direct control and support from the local authorities. There is also a indirect influence of a plurality of actors (e.g. the day of sustainability). A lot of discourses rely in arguments as: subsidy, interim objective, optimization and innovation system improvement, local and regional government central rule, and tax policy in support of sustainability. The SEAP and the initiatives within, work through diverse local authorities which have a diverse task within the process. There is the Municipal Council (Consiglio Comunale e Consigli di Quartiere) which work through a steering committee (Comitato Guida) liked to the urban planning and environment council. This represents the steering and controlling committee. There is then a central core competence which entails then the participation of the 'urban renewal' department (Dipartimento di Riqualificazione Urbana) and the 'center for energy' (Centro per l' Energia) which both interact with several other sectors, organizations and consultants. They engage with coordination practices through a partnership for the operation of the SEAP (partnership per l'operazionalizzazione del PAES) which manage specific and diverse agreements for the execution of diverse projects (Figure 55).

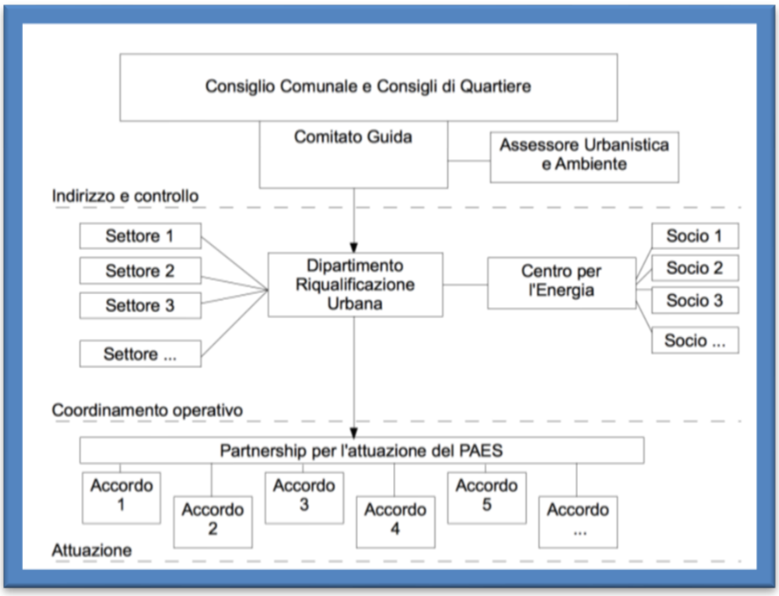


Figure 55: The SEAP process in Bologna

For the followers of the 'Multi-Level Perspective' in transition studies these diverse 'levels' say something in term of a possible parallelism. Three levels form indeed a structure of the SEAP governance with specific roles which are: strategic, tactical and operational. The Municipality of Bologna acts on the strategic level, as it takes the most important long-term decisions (e.g. "The Covenant of Mayors" signature). The *Department of Urban Requalification* together with the *Energy Center Office* manages the tactical decisions. The operative coordination is done within a *partnership dedicated to the 'niche'-implementation*. Agreements among public authorities, private companies and financial banks are related to specific 'niche' implementation and also to a specific technological sector (tertiary, building, transport, etc). Therefore, the SEAP for Bologna seems to have an interesting parallelism with transition studies, as the multi-level structure in relation to the decision-making process which is here combined with a transition management idea. The analysis of the SEAP, in relation to past changes can be seen as the multi-level perspective and structure of processes of transition. The performance of long-term objectives and the structure of authority is related to the capacity of agency. The diverse levels of structure here consist in the direct translation from the strategic to the tactical and operative decisions. The process includes all relevant projects – competed, in progress and planned. In this respect, transition management perspectives can be critically useful in the case of Bologna. We have seen that through the visions of future and increased participating actors following 'steps' have been defined in terms of: 1) the set of interim objectives which are going to be evaluated; 2) an evaluation which concerns the transition process itself and 3) the amount of learning or "enrichment" that has been taken place in the previous period. However, the analysis of Covenant of Mayors needs future orientations to look at the urban planning dimension. Due to each implementation process, the process started with the Covenant of Mayors in Bologna has an unique character, each single project can be considered a niche-innovation. According to Rootman et al. (2001), it is possible to analyze the niches in different types and to create a guide profile for the change. The support to the administration, not the imposition of the rules, is the basis to steer the achievement of the objectives. An interesting idea developed by Geels (2002), lays in the reconfiguration path. In the building field as well as in other areas, the implementation of a single niche leads to the change of technologies related to it. There are examples in the replacements of the type of technologies (fuel, biogas or electric engine) into the residential structures. However, examples carried on elsewhere in other urban contexts, as for Gothenburg and Stockholm can be useful experiences on what to learn on how to proceed. But even with several similar characteristics in regard to the areas discussed in Bologna, each city has a different public vision about sustainability and diverse governance structures for local authority. Looking at diverse European contexts as Gothenburg and Stockholm, an useful lesson to learn is about the involvement of several actors and citizens. The Municipality of Bologna is developing many initiatives in this respect as the so called "T-day" with the goal to reduce emissions inside the historical parts of the city by closing it completely for cars and busses; "the bicycle day" which has been pursued to increase public awareness of the importance of non-motorised means of transportation in relation to the quality of urban life are some examples. However, such initiatives remain still too isolated in relation to a continuous public involvement in need for a radical change. The involvement of citizens, as well as means for public involvement included the dialogue with local authorities. In relation to urban planning, a critical point is the valuation/monitoring in need that does not just take into account the results of single projects, but is located on the urban scale. This critical point is not easy to achieve and through interviews one of the gaps that the authors have perceived is at the level of a culture of the Italian Public Administration. The respect for deadlines, which seem so obvious to overcome, creates serious problems when connected projects are in place and should work simultaneously to pursue a change. To deal with this situation, the monitoring of suburban areas can be an useful option. In addition, this monitoring should include reflections and actions over the learning that has taken placed in previous experiences or period to carry on future urban projects. A close collaboration between the actors in each project and an extensive public information distribution will then also improve the efficiency of the public initiatives. The change of the public opinion is essential in order to achieve a long-term persistent change. The objective of a 20% CO_2 reduction by 2020 implies an overview over projects which shape transitions towards sustainable transitions in urban areas. A focus on transition theories invites to consider the challenge of sustainability in accordance with a socio-technical systemic approach. SEAP should include technological projects and innovative experiments at the micro-scale but at the same time, urban socio-political practice have to be developed. If SEAP wants to become an urban planning tool, more creative and participatory processes should be pursued further promoting the "community" experiences so essential to re-gain the integral urban project over systemic partial views. The successful implementation of sustainability practices relies in the performance of the public authority in planning transitions ahead, to deal with uncertainty means to work on an effective communication with stakeholders and individual citizens not just over results, but on the transition ahead in practice.

6.6.2 Grassroot initiatives of Transition Towns in Bologna area

As shown in Figure 51 , more than 1000 Transition Town initiatives in more than 38 countries, and several others are in the process of formation in many cities, towns and regions across the world. In the area of Bologna, there is one of the highest concentration of Transition Town initiatives.

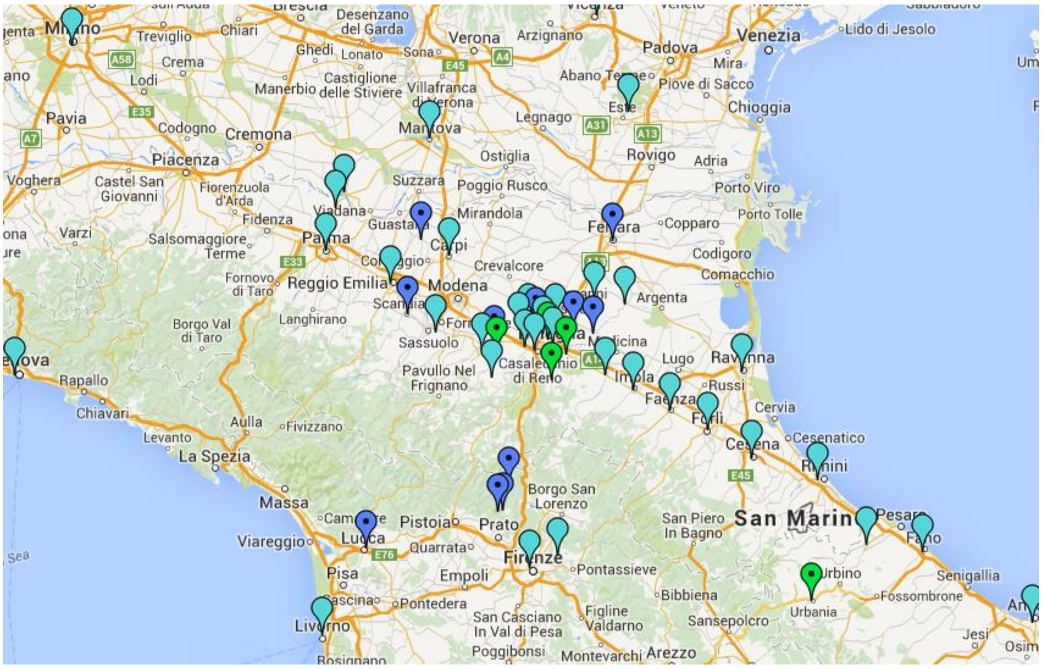


Figure 56: Map of Bologna Transition Towns Initiatives (Transition Italia, 2015)

In the map (Figure 56), the towns officially recognized by the Transition Network are indicated in green. Towns which have activated a Transition Initiative but are still not officially recognized are in blue. Finally, where there is only a small starting groups or undecided initiatives (*muller*), there are in light blue.

The first Italian Transition Town has been Monteveglio, but other Transition Towns have been realized and now engaged in a number of local initiatives. For example, San Lazzaro in Transizione (SLIT) proposes several initiatives such as places to share and exchange things (bartering market), a community garden, education program for primary and secondary school and a community energy (Figure 57).

Figure 57: Examples of Transition Initiatives organized by SLIT

Community Energy is a registered charity that provides practical help for communities in developing renewable energy projects. In San Lazzaro di Savena, a solar photovoltaics scheme is realized on the roof of a local school through a financing provided by the local community. The community energy financing gets yearly back by the local administration – owner of the local school- and by the fiscal measures introduced by the Italian Government in order to support citizens who invest in renewable energy.

Another example of collaboration with local administration has been achieved in the small town of Monteveglio. In 2009, the efforts of the local Transition group led to the local authority adopting an Energy Decent Plan, aimed at transforming Monteveglio into a "post carbon" town. The local authority developed a strategic partnership with the Association Monteveglio Città di Transizione (Transition Town Monteveglio), with both organisations having a common assessment on the depletion of fossil energy resources and the need to limit economic development, on the need to make the local community more resilient and better prepared for a low energy future, on the importance of a bottom-up, participatory process, and on the need to maintain an optimistic outlook (important challenges lie ahead, but this will also bring great opportunities to improve quality of life). On foot of this, the local authority committed itself to promoting Monteveglio as a Transition Town, with the direct participation of the whole community. Concrete actions proposed include: defining CO_2 emission measurement tools and containment policies; the designation of an Energy Manager to promote renewable energy development projects and energy efficiency; and promoting sustainable lifestyles and reforestation actions. As a result, a very successful collaboration with the local administration and a ground-breaking resolution, committing the council to deep sustainability and resilience-building is achieved.

6.7 Remarks about case studies

The transition analysis conducted in the two case studies has revealed important insights on which mechanism can characterize effective transition practices. The first case of Bologna SEAP has concerned a top-down mechanism driven by a volunteer European initiative: the Covenant of Mayors. Covenant of Mayors endorses local authorities to answer social demand for better health, softer modes of transport, more natural areas in the cities, shorter circuits for food supply, shorter distances between working, living and leisure areas, reduced vulnerability to global economic shocks, especially for the poorest populations, and the creation of local and 'sustainable' jobs. In other words, the endorsement of local authorities is crucial to improve the quality of life of their citizens and to face the challenge of sustainability. On the other hand, the case of SEAP of Bologna has demonstrated that initiatives driven solely from the top may be seen as an imposition and difficult to implement successfully. According to Pereira, Carlos, Maravall, and Przeworski (1993), if reforms are perceived to be imposed ‘from above’, it can be difficult for lower levels to accept them. In actual fact, in spite of Bologna is developing many initiatives, more creative and participatory processes still lack. Promoting the community experiences is therefore essential to re-gain the integral urban project over systemic partial views. Besides, a bottom-up mechanism (grassroot driven) allows for more experimentation and a better feeling for what is needed at the bottom. Accordingly to SNM approach, bottom-up perspective is typical of niche level and emerging trajectories have been carried by local projects (Geels and Raven 2006). Correspondingly, grassroots initiatives have delivered sustainability benefits where top–down measures struggle. This is because community action utilises contextualized knowledge and implies a better ‘fit’ of solution (Burgess et al., 2003). In this context, the case of Transition Towns in Bologna confirms that grassroot initiatives are triggering of several transition practices involving citizens through participatory processes. According to Seyfang, G. and Smith, A. (2007), in spite of grassroots innovations appear good at creating alternatives for sustainable development, they do not influence the mainstream socio-technical regimes. Therefore, the bottom-up approach alone is unlikely to achieve the cultural shift which is a precondition for institutional sustainability transformation. Effective examples as San Lazzaro di Savena and Monteveglio have demonstrated that a strong collaboration among public administration and citizens movement can allow to achieve a real sustainable actions with the direct participation of the whole community. In conclusion, the best mechanisms for transition practice is the combination both of top-down and bottom-up approaches. Indeed, approaches by themselves are actually insufficient to achieve a real and effective change.

6.8 The “living-lab” model

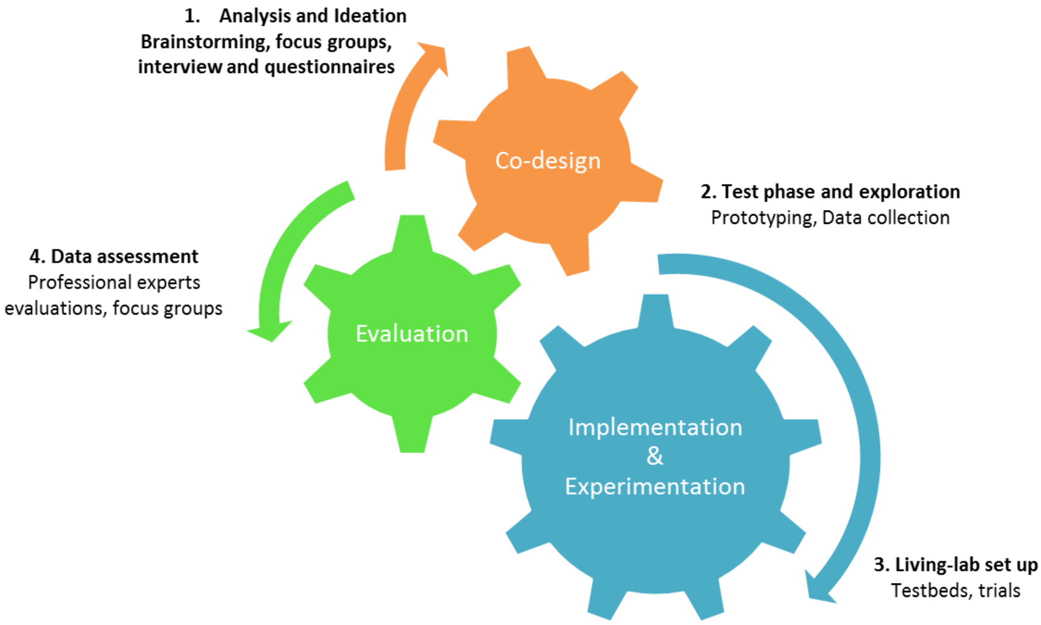
From the previous experiences, the focus on communities embedded within “real life” situations and environments is essential. Therefore, the participation of the user to the creative phases of socio-technical innovation in order to deploy services can contribute tangibly to promote healthier and more eco-sustainable individual and collective lifestyles. This process is called *co-creation*. According to Fuad-Luke (2009), co-creation offers a multiple stakeholders -including users-process to collectively solve problems. The fundamental concept is to gain direct and unfiltered access to users' ideas, experiences, and knowledge, based on their daily needs and desire so as to design solutions, environments, interactions and services that truly respond to their aspirations and requirements. The result is the creation of *living laboratory* or *living-lab*. According to the European Network of Living Labs (ENoLL, 2015), a living-lab is an environment where innovation technologies and services are conceived, designed, developed and evaluated with users' active participation. This collaborative approach to technology and service innovation goes hand in hand with what is called user-driven Open Innovation, or the process of innovation that is channeled directly from the user experience and that is open to the exchange of interdisciplinary knowledge between scientific communities, SMEs, large companies and institutions. A definition of Living Lab is provided by Bergvall-Kåreborn et a. (2009) as "a user-centric innovation milieu built on every-day practice and research, with an approach that facilitates user influence in open and distributed innovation processes engaging all relevant partners in real-life contexts, aiming to create sustainable values". Furthermore, Living Lab can be viewed as "an arena for innovation. It is a structure and a long-term societal resource rather than related to a certain project. Within this structural framework, experiences, routines and conditions are built to develop ideas into innovations" (Vezzoli et al., 2014). European Network of Living Labs (ENoLL, 2015) splits the co-creation process into 4 phases:

1. **Co-design**: A process where the end user is involved throughout the ideation and first development of a concept. Users have a proactive role and are invited to participate to a great number of different activities with the aim of generating ideas regarding products, interfaces or services.

2. **Implementation**: The phase where user and system requirements are defined and prototypes are developed. This is when the ideas from the co-design phase are refined and analyzed from a technological, ergonomic, mechanic and structural perspective.

3. **Experimentation**: The moment in which the prototypes developed during the implementation phase are delivered to the end user to experiment with. The research team observes users, collects data and measures the way in which they interact with the product, interface or service in question (via ICT as well as ethnographic studies) in real-life settings. The implementation phase and experimentation phase are part of an iterative process where the information collected from the latter are fed back into the former, in a cyclical concept refinement process.

4. **Evaluation**: This phase regards the validation of the product/interface/service in question. The insights and data gathered and derived from the experimentation phase are used to assess the concept from a cognitive, emotional, functional, mechanical, material, usable and engineering point of view.



5.

Figure 58: Living-lab phases (Adapted by ENoLL, 2015)

As shown in Figure 58, the Living-lab phases put high attention on experimentation. In addition, it can be observed that several methods and strategies of co-creation process can be assimilated to transition practice methods described in the first paragraph of this chapter. Therefore transition experiments can successfully contribute in the realization of a living-lab of sustainability. In such a fertile setting, research is brought out of traditional laboratory contexts and populates an ecosystem that grows and evolves day after day, offering future-looking experiences. In order to create services that can truly help promote healthier and more eco-sustainable life-styles (both individual and collective), it is absolutely necessary that any innovation process be open and that its creative phases are guided directly by the user.

6.9 Transdisciplinary role for the research

All this considered, a new role for the research has resulted from the emerging responses to the sustainability challenge. The integration of experiential knowledge and values about real-world problems provided by practitioners and stakeholders with scientific knowledge about systems provided by researchers is recognized as transdisciplinary, participatory, and collaborative research approaches. According to Lang et al. (2012), "transdisciplinarity is a reflexive, integrative, method driven scientific principle aiming at the solution or transition of societal problems and concurrently of related scientific problems by differentiating and integrating knowledge from various scientific and societal bodies of knowledge". Definitely, transdisciplinarity means switching from science for society to science with society and is regarded as the methodology of sustainable transition (Lang et al. 2012). The key of transdisciplinarity is a close collaboration between practitioners and scientists, keeping distinct societal roles. The point is that sustainable solutions require more than mere technological solutions. In this framework, the Living-lab represents the empirical model of transdisciplinarity. This definition highlights that transdisciplinary research needs to comply with the following requirements: (a) focusing on societally relevant problems; (b) enabling mutual learning processes among researchers from different disciplines (from within academia and from other research institutions), as well as actors from outside academia; and (c) aiming at creating knowledge that is solution-oriented, socially robust (see, e.g., Gibbons 1999), and transferable to both the scientific and societal practice (see Figure 59).

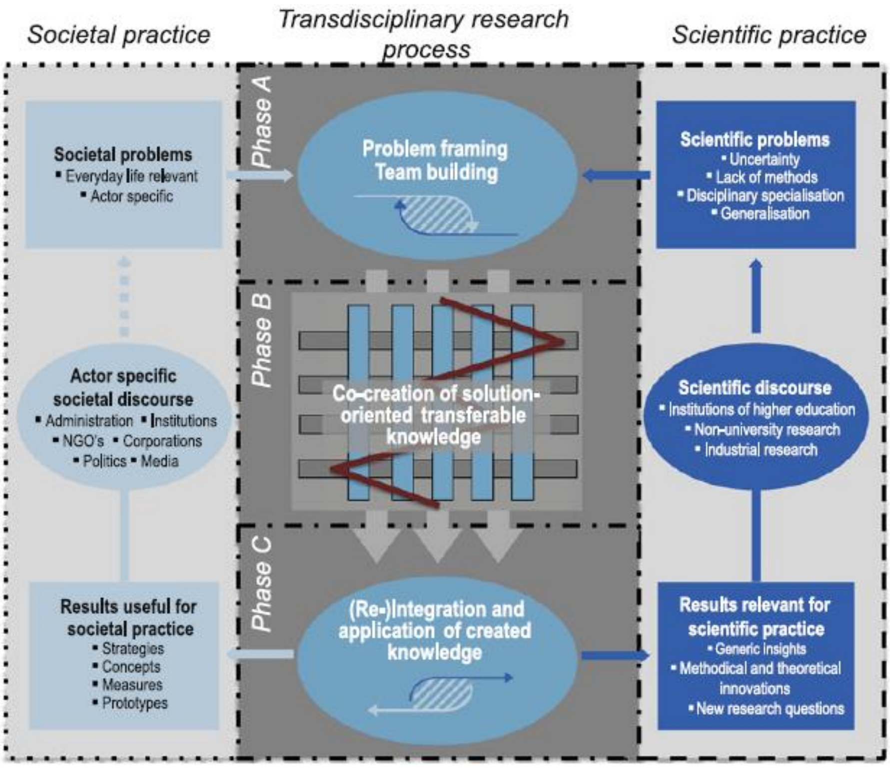


Figure 59: Conceptual model of an ideal–typical transdisciplinary research process (Lang et al., 2012)

According to Lang et al. (2012), design principles for transdisciplinary research in sustainability science can be distinguished as in Table 21.

General Design Principles
Facilitate continuous formative evaluation
Mitigate conflict constellations
Enhance capabilities for and interest in participation
Design principles for collaborative problem framing and building a collaborative research team
Build a collaborative research team
Create joint understanding and definition of the sustainability problem to be addressed
Collaboratively define the boundary/research object, research objectives as well as specific research questions and success criteria
Design a methodological framework for collaborative knowledge production and integration framework
Design principles for co-creation of solution-oriented and transferable knowledge through collaborative research
Assign and support appropriate roles for practitioners and researchers
Apply and adjust integrative research methods and transdisciplinary settings for knowledge generation and integration

Design principles for (re-)integrating and applying the created knowledge
Realize two-dimensional integration (i.e. from both the societal and the scientific perspectives)
Generate targeted products for both parties
Evaluate scientific and societal impact

Table 21: Design principles for transdisciplinary research in sustainability science (Lang et al., 2012)

Transdisciplinarity is also characterized by a joint process initiated by non-academia, including government, industry, public, and NGOs, or scientists on an ‘‘ill-defined’’ societal relevant, real-world problem that includes challenging scientific questions; joint leadership on equal footing for the process and project; joint problem definition including system boundaries; joint responsibility but taking different and complementary roles; a method-based collaborative research methodology, including deliberation and negotiation processes with stakeholders; and the construction of robust orientations and/or solutions to the problem.

6.10 Conclusion

This chapter has aimed at demonstrating the crucial role of transition practices. A central instrument of transition practices are the transition experiments, especially niche experiments, which provide an alternative approach to classical innovation projects that are focused in obtaining short-term solutions. In the framework of Transition Management, transitions are put into practice at different level: strategic, tactical, operational and reflexive. In this chapter, methods, skills and examples underpinning transition practices are investigated within different levels. Several transition practices are spreading from the research to policy domain till community-based initiatives. Especially, transitions experiences have been put into practice at urban level. Consequently, two cases of urban transition have been investigated under the lens of transition: the top-down initiative of SEAP of city of Bologna and the bottom-up initiatives of Transition Towns. Both examples have helped to identify interesting insights on what type of joint initiatives and networking contributes to accelerating transition processes towards sustainability. Especially, there are examined what mechanisms and stakeholder relations have been put in place to drive existing examples, what factors contribute to or obstruct a successful implementation, and finally, what kind of models are required to promote further this type of multi-stakeholder driven collaborations for sustainability. Definitely, it has emerged the importance of combining top-down and bottom-up approach. As final conclusion, the living-lab model as a real opportunity to implement effective transition practices has been recognized. At the same time, transition practice has been revealed as a catalyst of living-lab of sustainability in a mutual learning processes involving several actors. As a consequence, it is emerged a new role for the research embracing transdisciplinarity. The final purpose is to combine theory and practice of sustainability in a co-creation process with the society.

7 Transition Engineering: a transdisciplinarity research field for the engineering discipline

When the winds of change blow, some people build walls, others build windmills.
Ancient Chinese proverb

New challenge is arising for our society in relation to climate change and natural resources depletion issues. In this context, new challenges for the engineering discipline have increasingly emerged over the world to provide solutions and to solve problems related to the changes taking place. But sustainability involves multiple integrated elements as cultural, political, social, economic, ecological, technological components that interact each other. The basic idea is rooted in sustainability nature where resource problems and environmental issues are not only ecological and environmental issues but involve a variety of disciplines. The definition, representation, and transformation of these problems ask for theory–practice interaction and mutual learning. Really, sustainability problems are complex, thus it is crucial to integrate knowledge and information from various academic disciplines, including natural sciences, engineering, social sciences, and humanities. In this context, an holistic and transdisciplinary approach involving economic, environmental and social issues is required. According to Yarime (2012), “transdisciplinarity can be considered the engineering task of the twenty-first century”. As mentioned in Chapter 6, a definition provided by Lang et al. (2012) states that “transdisciplinarity is aiming at the solution or transition of societal problems and concurrently of related scientific problems by differentiating and integrating knowledge from various scientific and societal bodies of knowledge”. Therefore, understanding the nature and dynamics of transformative processes towards sustainability requires interdisciplinary and transdisciplinary knowledge. As described in Chapter 5, Sustainability transitions theories (ST) provide a research framework on the continuous processes of fundamental change in culture, structures, and practices of complex societal systems towards sustainability (Frantzeskaki and de Haan 2009). ST adopts a broader perspective than other approaches to sustainable development, which can encompass and complement by shifting the focus to interactions between approaches in wide-scale system transformation. The point is that sustainable solutions require more than mere technological solutions and a ST key concept is the socio-technical system. According to STRN, future research proposals in the field of ST should aspire to create new connections within the ST research community and to facilitate engagements with disciplines that have not had a strong link to transitions research. Spangenberg (2011) also suggests to switch from a “monodisciplinary” science for sustainability into “inter- and transdisciplinary” science of sustainability. With this intention, this thesis introduces the concept of Transition Engineering (TE) that was stated by Krumdieck and Dantas, (2008) raised from different sources both from technical and non-technical fields. Transition Engineering adopts a transdisciplinary approach to engineering to face the sustainability challenge and address the risks of un-sustainability. Therefore Transition Engineering comprises the adoption of steps and processes that make possible the change and contribute to sustainability. According to Krumdieck (2013), TE is an emerging discipline to deal with the future risks of both industrial and consumer activity. In effect, sustainable solutions consist not only of technical solutions, but also of strategies influencing the direction and pace of societal change dynamics. The starting point for transition engineering is to accept the social responsibility of all engineering professionals to provide safety, security, and sustainability through research, testing, and expert consensus to develop standards. The next step is to understand the facts and the nature of the risks of unsustainable growth in the consumption of energy and other resources. Engineering as a profession has always had a social responsibility to apply physical sciences, using accepted mathematical models of system behavior, to design and deliver systems that work. Transition engineering will make use of all of the successful engineering methodologies that have been previously developed. No-renewable resources consumption, fossil fuels extraction for energy, uncontrolled and incorrect water utilization are affecting the development of present and future generations. With the aim of providing people with sustainable options, engineers are “ethically required to hold paramount the safety, health and welfare of the public and answer society's need for sustainable development" (NPSE, 2014). Similarly a safety engineers manage unsafety risk, transition engineers has to cope with the risks of unsustainability.

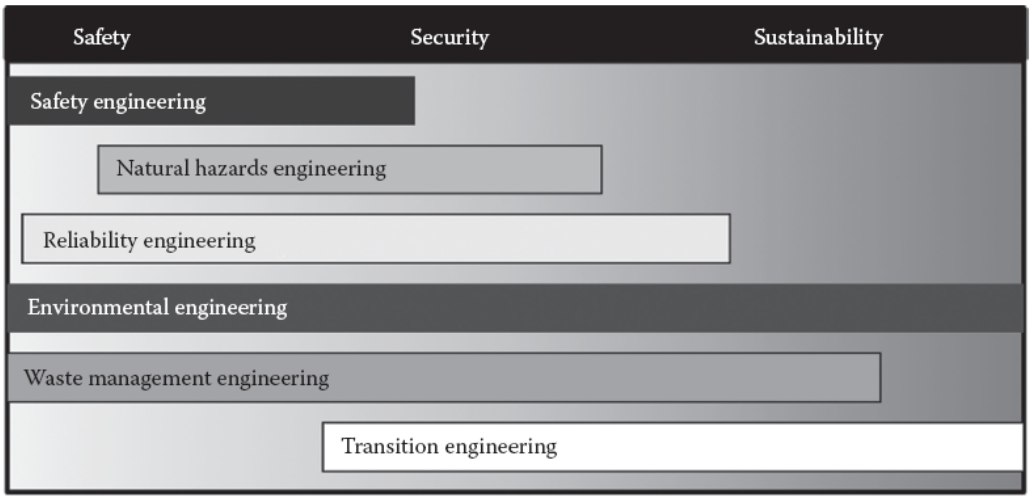


Figure 60: Engineering disciplines in the context of the safety–security–sustainability continuum (Krumdieck, 2013)

As shown in Figure 60, Transition engineers will be able to work in all fields, in much the same way safety engineers currently do. Most importantly, perhaps, transition engineering will use reliable science-based information about human needs, resource availability, and environmental impacts, and deliver adaptation of current systems for long-term global sustainability and prosperity, even if it is at the expense of short-term convenience or economic gain of some people. In this way, TE plays a crucial role that vision of a sustainability future can be identified and delivered (TRN, 2014). TE process employs existing proven techniques of engineering and management strategies so that decisions and changes can be planned and implemented based on real objectives rather than ideology, greenwash, short term marketing gain or other less than ideal foundations. Finally, we need to learn methods for complex problems that involve adaptation of established systems and entrenched ideas over a long-term planning horizon.

7.1 Transition Engineering Strategies

Another definition of Transition Engineering (Krumdieck, 2011) states that TE is focused on identifying unsustainable aspects of current systems, assessing the risks posed by those aspects, and researching and developing ways to mitigate and prevent systemic failures through adaptations.

In Chapter 2, it has been shown the urgency of actions required to mitigate the pace of global problems as climate change and to adapt to the impacts already felt today. In this circumstances, Transition Engineering provides technics, practices and models in order to face the challenge of sustainability. The main strategies of TE are identified in Figure 61.

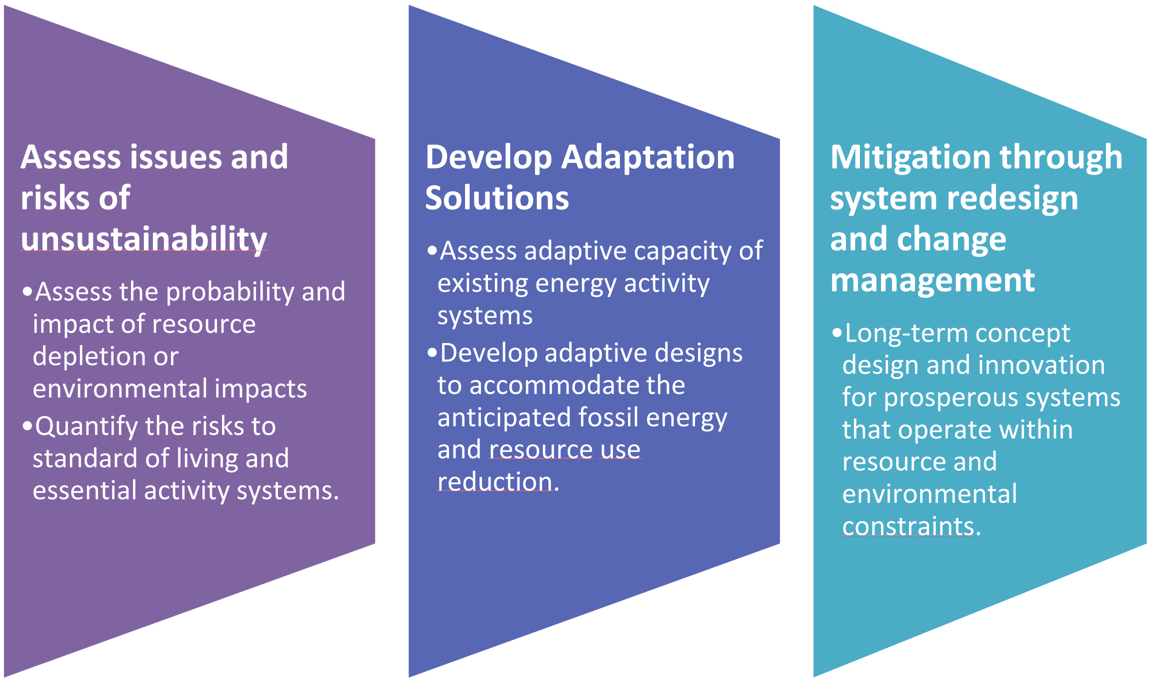


Figure 61: Transition Engineering strategies

In the following an overview of TE methods related to the abovementioned strategies is outlined.

7.1.1 Sustainability assessment

Increasing interest in assessment methods to better understand and address the impacts of products, technologies and systems along their life cycle can be seen as one of the biggest innovation in recent years. This has been stimulated by a growing of global awareness of the importance of protecting the environment, an acknowledgement of the risks of trade-offs between possible impacts associated to products and the necessity of taking account of climate change and biodiversity issues in a holistic perspective. Transition engineering can provide support in the development of these methods and procedures in order to have a better understanding of sustainability performances. Several methods are recognized to assess and benchmark different aspects of sustainability performance. The result is a multitude of sustainability indicator sets. A remarkable attempt to classify sustainability indicators into different heuristic categories was made by OECD (2009) and is presented in Table 22.

Category	**Description**	**Examples**
Individual indicators	Measure single aspects individually	Core set of indicators Minimum set of indicators
Key performance indicators (KPIs)	A limited number of indicators for measuring key aspects that are defined according to organizational goals	-
Composite indices	Synthesis of groups of individual indicators which is expressed by only a few indices	-
Material flow analysis (MFA)	A quantitative measure of the flows of materials and energy through a production process	Material balance Input-output analysis Material flow accounting Ecological footprint Exergy; MIPS; Ecological rucksack
Environmental accounting	Calculation of environment-related costs and benefits similar to financial accounting system	Environmental management accounting Total cost assessment Cost-benefit analysis Material flow cost accounting
Eco-efficiency indicators	Ratio of environmental impacts to economic value created	Factor
Life cycle assessment (LCA)	Measure environmental impacts from all stages of production and consumption of a product/service	Carbon footprint Water footprint
Sustainability reporting indicators	A range of indicators for corporate non-financial performance to stakeholders performance to stakeholders	GRI Guidelines Carbon Disclosure Project
Socially responsible investment (SRI) indices	Indices set and used by the financial community to benchmark corporate sustainability performance	Dow Jones Sustainability Indexes FTSE4Good

Table 22: Measurement of impact (OECD, 2009)

According to OECD (2009), no single set of indicators in the nine categories covers every aspect needed to address a sustainability improvement. Better, a combination of indicator sets can help to obtain a most comprehensive and appropriate picture of the economic and environmental impacts. A remarkable initiative which offers a combination of indicators to report the economic, environmental, and social performance and impacts of organizations, is the Global Reporting Initiative (GRI) (see Box 6.1).

Box 6.1: GRI - Global Reporting Initiative

The world's most widely recognized sustainability reporting framework to accomplish both thorough and transparent reporting is the Global Reporting Initiative (GRI). GRI is a non-profit, multi-stakeholder organization that strives to provide organizations with a systematic basis for disclosure regarding sustainability performance. The aim is to provide a framework that facilitates comparison and understanding of the economic, environmental, and social performance and impacts of organizations. GRI has produced a comprehensive Sustainability Reporting Framework that sets out Principles and Standard Disclosures in order to report the economic, environmental, and social performance and impacts of organizations. The reporting is developed through a global multi-stakeholder process involving representatives from business, labor, civil society, and financial markets, as well as auditors and experts in various fields; and in close dialogue with regulators and governmental agencies in several countries. The main purposes of GRI report consist in:

• Benchmarking and assessing sustainability performance with respect to laws, norms, codes, performance standards, and voluntary initiatives;

• Demonstrating how the organization influences and is influenced by expectations about sustainable development; and

• Comparing performance within an organization and between different organizations over time.

Principles of balance, comparability, accuracy, timeliness, reliability, and clarity, along with tests that can be used to help achieve the appropriate quality of the reported information. Sustainability reports based on the GRI Reporting Framework are able to disclose outcomes and results that occurred within the reporting period in the context of the organization's commitments, strategy, and management approach. The GRI framework sustainability reporting is marked to be trusted and credible so it can be used by organizations of any size, sector or location. Currently, over 5000 organizations worldwide in various industries have already created their sustainability reports according to GRI guidelines. (https://www.globalreporting.org/)

7.1.2 Risk assessment

Risk assessment adds an important contribution to advancing sustainability. In a risk assessment, risk is understood to be the possibility of adverse consequences from an event or activity. A risk assessment, therefore, is a process for evaluating the likelihood and/or magnitude of such consequences. Risk assessment should be viewed as a tool for evaluating the relative merits of various options for managing risk. This includes carefully posing the risk management questions and evaluating the options available to manage the environmental problems at hand. There are a number of context-specific types of risk assessment that can be useful in understanding aspects of sustainability in complex, real-world situations (Table 23).

Human health risk assessment (HHRA)	Human Health Risk Assessment is the process used to estimate the nature and probability of adverse health effects for humans who may be exposed to environmental stressors (chemical, non-chemical, or both), now or in the future. HHRA can help inform solutions to a broad range of problems related to human health risk
Cumulative Risk assessment	Cumulative Risk assessment combines risks from aggregate exposures to multiple agents or stressors, where agents or stressors may be chemical, biological, social, or physical (e.g. noise, nutritional status).
Ecological Risk Assessment	An ecological risk assessment is the process for evaluating how likely it is that the environment may be impacted as a result of exposure to one or more environmental stressors such as chemicals, land change, disease, invasive species and climate change. Ecological risk assessments can be used to predict the likelihood of future effects (prospective) or evaluate the likelihood that effects are caused by past exposure to stressors (retrospective).

Table 23: Types of risk assessment

Risk assessment has moved beyond the chemical-by-chemical approach and made significant strides in addressing the combined effects of multiple exposures through cumulative risk assessment. In addition, cumulative risk assessment techniques are being developed to incorporate other non-chemical stressors (e.g., health conditions and psychosocial stress) into the overall assessment of risks for populations. However, there is still great uncertainty in the approaches and the data for understanding exposures and health outcomes for cumulative risks. A wide range of information is needed to conduct risk assessments, including data on the nature and extent of contamination, fate and transport processes, the magnitude and frequency of human and ecological exposure, and the inherent toxicity of chemicals. Transition Engineering can provide a support for risk assessments evaluation through robust calculation of the uncertainties and deeply characterization of how reliable (or how unreliable) the resulting risk estimates are.

7.1.3 Assessment of adaptive capacity

Adaptive capacity is defined as energy and resource demand reduction without affecting the essential activities, goods, or services. As supplies decline, systems will necessarily change in response to pressures like price or shortages. The objective of transition engineering is to achieve the demand reduction while realizing multiple benefits. Adaptation will have impacts that depend on how important the activity, services, or goods are to wellbeing. We need to recognize that not all consumption is equal. If we do not have the capacity to adapt, then some functions of the system will fail due to unsustainable processes. Loss of essential activities or goods is considered to have a high impact, while loss of an optional or discretionary activity or products would represent a low impact. Loss of an essential good would negatively impact standard of living. Loss of a necessary good would negatively impact quality of life. Loss of an optional good would alter lifestyle without causing any reduction in health or welfare. Essentiality can be measured for any type of end use and incorporated into the risk assessment analysis and adaptive design. Adaptation responses and decisions can be categorized as measures and strategies that contribute either to:

- Building adaptive capacity – creating the information (research, data collecting and monitoring, awareness raising), supportive social structures (organizational development, working in partnership, institutions), and supportive governance (regulations, legislations, and guidance) that are needed as a foundation for delivering adaptation actions; or

- Delivering adaptation actions – actions that help to reduce vulnerability to climate risks, or to exploit opportunities.

The latter is strictly connected to adaptive design and it is described below.

7.1.4 Adaptive design

Engineers must be engaged in the design of both mitigation and resilience-building systems in order to manage the un-sustainable activities and behaviors wide-spreading. Building adaptable and resilient systems has become a strict and increasing necessity in our days. There is the growing need to act now and to enhance our resilience. As stated in Chapter 2, resilience means the ability of a social or ecological system to absorb disturbances while still retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change. Resilience theory suggests that complex systems have alternate stable states that differ in structure, function, and ability to provide services that people need or value. Therefore, adaptability of a system is the capacity to avoid changing to an undesirable state or to engineer a way out of one. Examples of adaptive design options are listed in the following (source UKCIP, 2015):

- Accepting the impacts and bearing the losses that result from those risks. In this case, no specific action is required to deal with the identified level of risk as existing systems and procedures are sufficient. (e.g. managed retreat from sea level rise)
- Off-setting losses by sharing or spreading the risks or losses (e.g. through insurance)
- Avoiding or reducing your exposure to climate risks. Options can be changing activity/location or building resilience (e.g. build new flood defenses)
- Exploiting new opportunities, as introducing new activities, behaviors, practices or species to take advantage of reduced risks. Alternatively, moving activities to a new location to take advantage of changed conditions.

7.1.5 Mitigation through system redesign and change management

Long-term concept design and innovation for prosperous systems that operate within resource and environmental constraints. Generally, the following three operational rules define the condition of ecological (thermodynamic) sustainability (Georgescu-Roegen, 1986):

1. Renewable resources such as water, soil, and groundwater must be used no faster than the rate at which they regenerate.
2. Nonrenewable resources such as minerals and fossil fuels must be used no faster than renewable substitutes for them can be put into place.
3. Pollution and wastes must be emitted no faster than natural systems can absorb them, recycle them, or render them harmless.

Designers have strengths in creativity , but these skills have not often been significantly applied to the development of new innovative sustainable technologies, products and services. Sustainability-aware 'design entrepreneurs' may start to see opportunities to create new sustainable products or product-service combinations if they can identify markets, find interested customers, have an appropriate business model and are prepared to take risks. For the most part, product designers are still at an early stage of their understanding of environmental and broader sustainability issues due to a lack of awareness and education in the issues, and more importantly because of little present internal and external (customer) pressure. Product designers use different mental models and generally do not fully consider the life cycle impacts of their decisions. Nevertheless, product design really affects environment and economics over life-cycle.

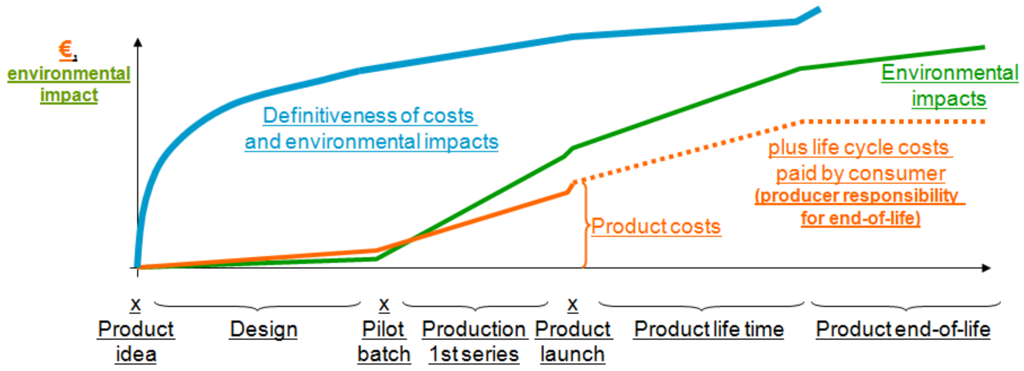


Figure 62: Product design effects on environment and economics over life-cycle

As shown in Figure 62, manufacturing, distribution, use and end of life management of energy-using products cause impacts on the environment, but approximately the 80% of all product-related environmental impacts are determined during the product design phase. Ecodesign is the incorporation of environmental considerations into the design and development of products or services. Ecodesign considers environmental aspects at all stages of the product development process. Therefore, the objective is to minimize as much as possible environmental impacts throughout the product life cycle. Successful strategies supporting the process of ecodesign are based on the 6 "RE" rule and are described in the following:

- **Re-think** the product on the basis of its functions.
- **Re-duce** energy and material consumption throughout the life cycle.
- **Re-place** harmful substances with more environmentally friendly alternatives.
- **Re-pair**. Make the product easy to repair so that the product does not yet need to be replaced.
- **Re-use** and recover. Design the product so that its parts can be reused.
- **Re-cycle** and select materials that can be recycled. Design the product such that it is disassembled easier for recycling.

In conclusion, an emerging need of more awareness and education of designers over the attributes and benefits of sustainability is arisen. Furthermore, designers need inspiring examples of sustainable solutions to switch them onto the issue.

Otherwise, they tend to consider sustainability to be a threat-based agenda, constraining their creativity. Designers also need to recognize the opportunities for innovation. In this context, Transition Engineering can play a crucial role and the development of sustainable technologies and solutions can be considered a valid support for the transition towards sustainability.

7.2 Transition Engineering process

As said above, TE research and activities are oriented to build a sustainable world taking into account environmental, social and economic aspects. At the same time, many other disciplines are committed to working in this direction. To this purpose, Transition Engineering would not have concerned the development of new concepts, but rather the embrace of all the research and application fields aimed at supporting transformation of system toward sustainability. A successful TE project lies in the engineering disciplines, but major challenges are placed in the stakeholders engagement and delivering behavioral changes. On one hand, important attributes for TE practices are based on sustainable design principles, life cycle approach, green technologies for saving and valorizing natural resources, such as raw materials, water and energy. On the other hand, other important attributes are the capability to develop stakeholder capacity, to engage participation and to generate beneficial synergies across scale. Krumdieck and Dantas have proposed a Transition Engineering process distinguished in different steps. In Figure 63, an overview of the steps and parts of TE process is provided. TE steps involve different kind of processes (Krumdieck and Dantas 2008) . The first steps are an analysis process, consisting of understanding past and current situation, problem investigation. Then a strategic process is proposed, consisting of scenario structuring and resulting in the generation of path-break system concepts. The next step concerns a tactical process, where a backcasting process is required in order to identify the essential phases and to achieve the final vision.

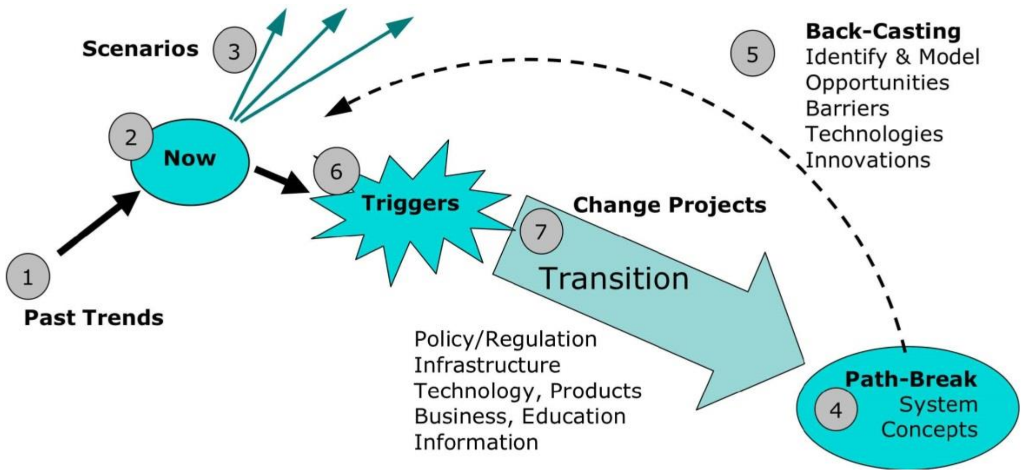


Figure 63: Steps and parts of Transition Engineering process.(Krumdieck and Dantas 2008)

As seen in Chapter 6, backcasting consists of building the steps required from the transition process to achieve a transformative change. That means identifying technologies, actors, barriers and opportunities. The final part is the trigger process in which experimenting and activating actors are realized. Experiments are the trigger that starts transition process. The results is the implementation of new regime by the means of technologies, training, equipment and infrastructures such as policy and regulation. Finally a reconsideration of achieved scenarios is encouraging for starting with another TE process.

7.3 Framing correspondences between Transition Engineering and Transition Management

On the basis of the previous consideration, it can be observed that in the transition theories several frameworks endorse transdisciplinarity. Especially, the Arena of Development proposes an inclusive and fluid transformation processes where researcher's position is included as another actor. The challenge to the researcher is searching for boundaries and stabilizing configurations. Also Transition Management suggests a researchers' role in dialogue with the other stakeholders involved in the transition process.

According to Loorbach and Rotmans, (2010) Transition Management consists of a cyclic process where "problem structuring and envisioning in multi-stakeholder arenas, developing new coalitions, implementing agendas in experiments, and evaluating and monitoring the process".

In Table 24, an attempt to identify synergies between Transition Management phases (Loorbach, 2007) and TE process are provided. As can be seen, TE process has several correspondences to the cyclic process of Transition management. Therefore Transition Engineering can be matched with TM process. The table shows that both TE and TM processes deal with managing societal change toward sustainability and achieving a strict connection between technical solutions and successful practices.

Level	**TE Process step**	**TM Phase**
Reflexive	1. Past Trends 2. Now	Evaluating Monitoring and learning
Strategic	3. Scenarios 4. Path-break	Problem structuring Establishment of the transition arena Envisioning
Tactical	5. Backcasting	Developing coalitions Building transition agendas
Operational	6. Triggers 7. Transition Change Project	Mobilizing actors Executing projects

Table 24: Comparison of Transition Management (TM) and Transition Engineering (TE)

Another common aspect is the cyclic approach that is a guiding model for transition processes. Consequently, it can be said that similarly to Transition Management, also Transition Engineering can provide a common framework for managing complex systems. One of the basic steps for transition process deeply investigated in Chapter 5 was the creation of space for successful experiments (Rotmans and Loorbach, 2009). This space where experiments are implemented is recognized as niche or transition experiment. According with Rotmans and Loorbach (2009), transition aspires "to create a portfolio of transition experiments that reinforce each other and contribute to the sustainability objectives in significant and measurable ways". Then, TE can offer a valid portfolio of tools, involving technologies, methods, practices and models for developing a socio-technical innovation. Correspondingly to the methods investigated in Chapter 6, an overview of TE technologies, tools and methods can be applied in the implementation of sustainability transition process.

As outlined in Table 25, examples of methods supporting the strategic phase are ecodesign or life cycle design. Planning tools, as sustainability report, are also powerful methods to endorse the agenda building process and to reconnect short-term actions to long-term objectives.

Transition process phase	**TE methods**
Strategic phase	Design methods (Co-design, Ecodesign, Design for sustainability,…)
Tactical phase	Planning Tools (Sustainability Report, EMAS, ISO 14001,…)
Operational phase	Technologies (Appropriate, Smart, Net-zero technologies,…)
Reflexive phase	Sustainability Assessment (Sustainability indicators, LCA,…)

Table 25: TE tools and methods contributing to transition process

Furthermore, sustainability assessment methods, such as LCA or LCSA, offer a robust framework in order to evaluate the sustainability pace of the process. Finally, technologies can be developed according to the TE principles contributing to run successful transition experiments in the operational phase. The specific features and advantages of different kind of technologies are described in next paragraphs.

7.4 Understanding new role for technologies in the transition engineering framework

This paragraph pays a particular attention on technology , especially investigating its role in order to combine the promotion of sustainability and the enhancement of resilience. Due the urgency of climate change, there is the certain need to expand the capacity to influence resilience system. At the same time, there is the need to transform engineering practices into responsible actions for improving the sustainability of the whole society. A growing number of technologies are developed and represent models of how the engineering can develop and invent solutions for shifting toward sustainability and enhancing resilience. Some examples are listed below:

- green technologies and "site specific" design in rural and urban areas in order to reduce climate-change emissions and to save water, energy, soil and natural resources;
- treatment valorization and recycling of raw materials and solid waste;
- water supply, water and groundwater saving, wastewater recovery and recycling in relation with urban, industrial and agricultural uses;
- energy recovery from solid waste and study of environmental impacts and waste production in relation with renewable energy sources;
- unconventional or recycled materials for building and construction: recycled aggregates from demolition, utilization of straw, hemp, raw land, etc. for energy savings and to reduce climate-change emissions, for zero impact buildings, and in relation to greater simplicity in the process of rebuilding in areas affected by seismic events.

In this framework, several cutting-edge technologies are matching the transition approach such as appropriate technologies, smart technologies and net-zero technologies. In the following, an overview of all sorts of benefits achieved by their employment is described in details.

7.4.1 Appropriate Technologies

Appropriate technology (AT) is a technology, a process or an idea designed to increase the development through the satisfaction of human needs. A technology is said "appropriate" when compatible with the needs of their human nature, the cultural, social, environmental and economic premises and uses human resources, materials and energy that are available on site, with tools and processes that are controlled and managed by the community it is intended for. AT proponents claim their methods require fewer resources, are easier to maintain, and have less impact on the environment compared to techniques from mainstream technology, which its contend is normally, wasteful and environmentally polluting. Appropriate technologies in terms of social, human, political, economic, environmental are those which:

- In sustainable way require fewer natural resources, using them wisely and producing less pollution;
- Socially improve living conditions and enhance cultural traditions, usages, customs and technologies of the native people without being invasive.
- Ecologically respect the balance and the laws of nature and provide the best environmental management in developing countries.
- Are appropriate to the context the environmental, ethical, cultural, social, political, and economical context.
- Do not impose cultures, ideologies or technologies that are not suited for the scenario of the specific environmental and social action.
- Are energy efficient and independent
- Require easy maintenance
- Affordable

It is also possible to distinguish between hard and soft appropriate technologies:

- Hard appropriate technology is more related to engineering techniques, physical structures, and machinery that meet a need defined by a community and utilize the material at hand or readily available. It can be built, operated and maintained by the local people with very limited technical, material or financial assistance.
- Soft appropriate technology is more dealing with social structures, human interactive processes and motivation techniques. It is the structure and process for social participation and action by individuals and groups in analyzing situations and making choices.

The employ of appropriate technologies are widely used in developing countries. One of the reasons why developing countries require AT is their particular socio-economic development. Developing countries are, in fact, characterized by a mostly rural population, poor infrastructure, inadequate and insufficient health facilities and also with shortage of economic resources. The areas covered by the appropriate technologies are mainly those concerning services to the community: health, water, education and infrastructure. AT tries to stimulate a local market and replaces imported goods with local products as competitive in terms of quality and cost trying to achieve a balanced development in poor countries. They must also be compatible with desires, culture, tradition of a particular community and should not be social destructive. In most cases, the industrialized countries develop adequate technologies that satisfy the market needs but having consideration the raw material, power, laws and economy of the destiny of the appropriate technology. This "transfer" of technologies to developing countries must take into account the prevalence of a dual economy (urban and rural) with different lifestyles and often in conflict, the high rate of population growth, the importance of the technology, the awareness of iniquity (social and economic injustice) and the fact that communities can change. On the other hand, appropriate technology can also be applied in developed nations in order to describe the use of technology and engineering that are environmentally sustainable and socially appropriate. As Schumacher (1993) stated "not only in developing countries but also highly industrialized ones must begin to think in terms of technologies more in harmony with one another and with the environment and less related to non-renewable resources." And he also asserts that such technology, as described in the book “Small is Beautiful” (Schumacher, 1993), tends to promote values such as health, beauty and permanence. Often the type of appropriate technology that is used in developed countries is "appropriate and sustainable technology" that besides being functional and relatively cheaper is intended to be very durable.

7.4.2 SMART Technologies

Making the world smarter by adding computing, sensing, and networking capacity to objects and infrastructures is a vision that emerged more than a decade ago from the field of ubiquitous computing. The concept of "smart" is a current response to the challenge to meet objectives regarding socio-economic development and quality of life. In this context, the "Smart City" concept is emerged inside an holistic vision in which every part of city's structure has to be involved: citizens, business, transport, energy, water, communications, city services. According with the survey conducted by Abdulrahman from University of Malaysia (2012) it would be interesting categorize Smart Cities into many smart system connected respectively to cities' critical activities and services. As a consequence, Giffinger (2007) has defined six core areas of Smart Cities as critical dimensions: Smart Economy, Smart Environment (with a sustainable management of the resources), Smart Governance, Smart People, Smart Mobility, Smart Living and Quality of Life. For each of them it will be defined the targets, the critical success factors and the contribution for their development. Accordingly smart technologies provide diverse and promising opportunities for reducing energy demand and greenhouse gas emissions; they are increasingly expected to shift modern societies' patterns of production and consumption towards sustainability.

Box 6.2: Smart Water Technologies

In relation with integrated solutions for drinking water usage, for groundwater management, increasing water supply and correct wastewater management, the importance of a Smart Water Management is recognized. Crucial reasons are:

- 60% of all water is allocated to domestic human use
- by 2025 the water demand in municipal areas will increase by almost 80 billion cubic metres
- worldwide, 44% of people are living in water stressed areas, and it is expected to grow dramatically in the next future
- freshwater consumption is expected to rise 25% by 2030due largely to the increase in urban population
- through the usage of ICTs, water savings in cities could reach 50%.

An example of smart water technology is provided by water and flood sensors. Thanks to tele-detection by satellite in combination with semantic web sensors, leaks and breakdowns and chemical alteration of water are detected in real-time. Communication Networks integrated to Information Treatment Systems enable water management in real-time. In that way, critical success factors can be related also with an increase awareness among users, locate distribution, optimize usage of municipal drinking water.

7.4.3 Net Zero Technologies

The concept of *Net Zero* means consuming only as much energy as produced, achieving a sustainable balance between water availability and demand, and eliminating solid waste sent to landfills. Conserving water, reducing energy use and eliminating solid waste can improve the environment, save money, and help communities become more sustainable and resilient. Net zero technologies employ cutting-edge science to achieve net zero waste, water and energy. Examples of net-zero-water technologies are water and groundwater saving, wastewater recovery and recycling in relation with urban, industrial and agricultural uses. An example of multiple water use are industrial ecosystems in which a symbiotic relationship is created between several activities. Several industrial areas can reproduce an ecosystem and represent the top level of industrial sustainable development. Cooperation generates better results and provides opportunities for companies to increase production without consuming more energy, water and raw materials. The idea behind the industrial symbiosis is for companies to utilize each other's residual- and byproducts on a commercial agreement. One company's byproduct is an important resource for other companies in the symbiosis association. The result is more resource saving processes with a positive environmental impact. A remarkable example is relates to the enterprises of the Industrial Symbiosis in Kalundborg (Denmark, see Box 6.3).

Box 6.3: Industrial Symbiosis in Kalundborg (Denmark).

For more than three decades the symbiosis concept has been a natural part of the management principles and the results are better economic and environmental performance. The enterprises of the Industrial Symbiosis are setting the scene for good environmental practice in Denmark and internationally.

For what concern **net-zero-waste technologies**, the *urban mining* concept can be considered a significant field of application. Urban mining actions and technologies recover resources from residues produced by the urban catabolism (municipal, industrial and agricultural waste, both from new production and old deposits) in terms of secondary raw materials and energy. Therefore it implicates progression beyond separate collection and the current logic of consumers responsibility, resulting in an increased recovery of resources, better quality of the same, improved environmental protection, involvement of producer responsibility and lower costs for society. With no demagogy or ideological escapes from the fundamental role of treatment and final disposal techniques in closure of the material cycle. As a result, the urban space should be conceived as the physical, or virtual, environment intended for collective use where rights and duties of citizenship, social information and education, political action, productive and economic activities are carried out.

Finally, **net-zero-energy technologies** have growing applications. One of the most prominent are zero-energy building, also known as a zero-net-energy building. These buildings have a net-zero energy consumption and net-zero carbon emissions annually. Buildings that produce a surplus of energy over the year may be called "energy-plus buildings" and buildings that consume slightly more energy than they produce are called "near-zero energy buildings" or "ultra-low energy buildings." Most zero-energy buildings are connected to the electrical grid but some are independent of grid. Energy is usually harvested on-site through a combination of energy-producing technologies such as solar and wind, while reducing the overall use of energy with highly efficient Heating, Ventilating and Air Conditioning (HVAC) and advanced lighting technologies. The zero-energy concept allows for a wide range of approaches - there are numerous options for producing and conserving energy and many ways of measuring energy (relating to cost, energy, or carbon emissions). The first goal in creating a net-zero-energy building is to minimize the actual systems involved in the building's energy consumption so that the amount of energy which must be produced on-site to offset the building use is minimized. Once this is done and defined, the quantity and capacity of the site-generated energy can be defined. Proper metering of the systems and loads in the building must be designed. In addition, metering of the site-generated power is a must and of course the utility will require some type of net meter to document the overall energy surplus or debit. One must understand that a net-zero-energy building does not need to be net zero all the time. The term net zero is used to note, over a certain amount of time, the building's energy use offset by its energy production. A good example of this is a building which has a photovoltaic (PV) solar panel array. During a day with a clear sky, the PV system will be generating power, and hopefully will fully offset the energy use of the building. In some cases, this PV power will be greater than the building's energy use and the meter will actually spin backwards. The site will be feeding power into the grid. In another example, a generator could run at night when it is less disruptive or perhaps more efficient because of weather conditions. The building could dump power into the grid, offsetting the power used during the day. This energy data is usually calculated every month and summed annually to determine if a building is truly overall net zero, although it is not net zero every minute of every day. To track this energy data well (and not wait until the end of the month or year), a utility dashboard or advanced metering system should be provided.

7.5 Introducing the concept of Transition Technology

From the previous examples, it is emerging a new role of technology role. Starting from the definition of technology as the application of scientific knowledge for practical purposes, the notion of Transition Technology (TT) can be introduced. Transition Technology can be defined as the technical instruments of the transition process which embracing a transdisciplinary approach and concurring to achieve the transition towards sustainability. In particular, the TT purpose is to combine the promotion of sustainability and the enhancement of resilience. Nevertheless, the TT purpose concerns not only the specific technical aspects of technology, rather the role that technology plays in conjunction with other instruments in all the phases of transition process: strategic, tactical, operational and reflexive. At strategic level, a shift from mere problem identification and solutions, towards technologies working toward common vision is needed (van der Leeuw et al. 2012). TT are part of vision building process and they offer practical solutions which call for the involvement of actors in order to promote a behavioral change. In effect, technologies as recycling waste, saving raw materials and minimizing environmental impacts are ineffective without an active engagement of all the users. Furthermore, the tactical role of technologies is to explore new and alternative ideas for a co-production of capability for both the long-term visions and short-term solutions. At operational level TT can definitely act similarly to the living-lab concept. Technology needs to sustain a consequent participative process which enables users to make direct experience of sustainability and resilience benefits. This co-creative process aims to engage participation and enhance collaboration between practitioners, scientists and stakeholders. Actually, there are different kind of actors such as small companies, citizens and local communities that not regularly take part to the process about sustainability. Thanks to experiential process, they can be involved in the transition pathways. The final role is that TT may contribute also to the reflexive phase. In spite of reflexivity seems no practical process, the role of technologies can inspire reflection. Indeed, making a direct experience of sustainability can generate a raising awareness process and a reinforcement of the actors engagement toward sustainability. In these contexts, experimenting TT is a real way to improve the sustainability and to create knowledge about the interactions between humans and natural systems. Change can happen through the creation of more resilient systems as well. In the following, a remarkable example of Transition Technology concerning the employment of green infrastructures as instruments of transition process is provided.

7.5.1 Green infrastructures as prototype of Transition Technology

Green Infrastructures are technologies and practices that reproduce natural processes by the use of natural or engineered systems. The effect is to improve the whole environmental quality and simultaneously to offer utility services. Principally, a green infrastructure is composed by soils and vegetation and the main effects are connected to the infiltration, evapotranspiration and/or recycling of storm water runoff. Nowadays green roofs, green streets, porous pavements, rain gardens, infiltration systems are part of the GI network. Originally the GI techniques were considered mostly for recreate the natural water cycle in cities, where most of the surface are built and impervious and the water cycle is altered by a considerable volume of superficial runoff. The GI use soils and vegetation to infiltrate and evapotranspirate storm water runoff. Nowadays the GI are increasingly addressed and studied as elements that help cities in, of course, storm water managements but also in energy saving, mitigation of Urban Heath Island Effect UHIE, achieve environmental benefits, enrich architecture, life quality and in the complex target of adapt and mitigate the overall effects of climate change. Although many urban GI require availability of land space which is usually unavailable in densely urbanized area (Berndtsson, 2010; Gambi et al., 2011), in every city there are few areas that can be transformed into green spaces but there are an abundance of roof surface that can be transformed with the green roofing technologies. Green roofs contribute to achieving numerous benefits and improving quality of live and social and community behaviors. As summarized in Table 26, scientific studies proved that the green roofs give benefits that can be theoretically split in benefits for the private and for the public sector on a building scale and on a city scale.

Public and community benefits	**Private benefits**
• Mitigate Urban heat island effect • Attenuate the storm water runoff • Water quality improvement • Remove air pollutants • Improve the water quality • Remove air pollutants • Promote urban biodiversity • Aesthetic Improvement • Improved Health and Well-Being • New Amenity Spaces • Urban Agriculture • Educational Opportunities	• Reducing noise levels • Reducing energy consumption and providing a better indoor comfort for their inhabitants. • Reduction of Electromagnetic Radiation • Increased Roofing Membrane Durability • Fire Retardation

Table 26: Green roofs benefits for the private as for the public sector on a building scale and on a city scale

One of the primary benefits of green roofs is the Urban heat island effect (UHIE) mitigation. As shown in Chapter 2, UHEI represents the temperature difference between rural and urban areas, where the second one have generally a higher average temperature than the surrounding. The employment of green infrastructures, as green roof, creates a cooler surface and consequently decreases the air temperature and also the UHIE. Essentially, the green roof surface reflects better the solar radiation and adsorb less heat than a black roof providing a cooler surface. The evapotranspiration and evaporation effects of the green roof contribute in the external air cooling. As a consequence, the need for air conditioning during the summer period is also reduced. Therefore, reducing the UHIE means also having an indirect energy savings from reduced energy needs for cooling. An example was experimented in the city of Toronto where it has been evaluated the effect of introducing green roofs in terms of 50% of the green flat rooftop. The results were a decrease to a 0.5 – 2°C in average temperatures. Considering this temperature reduction, the city of Toronto has estimated an indirect energy saving of 12 Million dollars, equivalent to 2.37kWh/m^2 per year. (Toronto, 2013).

Another important effect of green roof is a decrease of the large percentage of impervious surfaces causing high volume of superficial run off and problems for the storm water managements. In case of high precipitation events the drainage systems cannot support the run off volume. It has been proven that green roofs drastically mitigate the storm water runoff, in terms of peak attenuation and increase of concentration time and runoff volume reduction. Although during low temperature and high precipitation periods, decreased performance has been detected (Culligan 2011; Fioretti).

Concerning the water quality improvement by green roofs, studies have proven an advance (Berndtsson), but it is important not using chemicals fertilizer for the vegetation that could be solved in the water and funded in the green roof storm water runoff. (Gregoire, 2011) Other benefits are related to the promotion of urban biodiversity (TCRA, 2006) and the removing of air pollutants (Yang, 2008) and dust. This benefit combines with the increased water quality can decrease demands for health care. Moreover the decrease of health care can be considered as green roofs indirect benefit.

Green roofs have also an aesthetic value, urban greening is boosted as a simple and effective strategy for regenerate degraded urban areas, enriching the built area and becoming marketing opportunity. Additionally green roofs can supply a large quantity of functions and uses, including community gardens, recreational space, meeting points, educational facilities and children’s playgrounds. On one hand, an organized green space can be a source for community empowerment, increasing social cohesion. On the other hand, the combination of green roof with urban agriculture promote the creation of a local food system, improving the community’s level of nutrition and reducing the urban footprint. A green roof can be also a place for educational projects that aim at increasing the awareness of sustainability.

There are other green roofs benefits that have a special significance for the private owner of the single building. Green roofs and vegetated walls are beneficial too. The biggest private economic advantage is related to the reduction of the energy consumption, reducing the energy required to mitigate the indoor temperature and providing an indoor comfort. The amount of reduction depends from climate and locations, but is mostly related to the energy saving in the summer period and in a small part for the insulation in the winter. Other direct private benefits are: reducing noise levels (Renterghem, 2010), reduction of Electromagnetic Radiation due to wireless devices and mobile phone communication. According to Herman (2003), green roofs are capable of reducing electromagnetic radiation penetration by 99.4%. Another direct green roof benefit is the increased roofing membrane durability. Due the lower exposure to temperature oscillations and ultraviolet radiation, waterproofing membranes have less micro-tearings. Finally, thanks to a much lower burning heat load than do conventional roofs, green roofs improve the fire safety property of the buildings. (Köehler 2004). In conclusions, thanks to the several benefits described above, green roofs can be considered a distinctive example of Transition Technology. The vision offered by the green roofs is not only improved sustainability and resilience performances but also the creation of a place for experimenting behavioral change towards sustainability.

7.6 Conclusion

In this chapter, the basic requirements for engineering discipline aimed at making sustainability happen were explored. Following these intentions, Transition Engineering (TE) is an emerging field committed to drive engineers going beyond sciences and reorganizing processes for the reunion of the science with the society. The development of research in the field of sustainability transitions is a continuous, evolutionary process. Especially, the importance of adopting a transdisciplinary approach and synergies among Transition Engineering in the Transition Management have been outlined. With the aim of translating sustainability into concrete actions, TE can provide a portfolio of tools and methods that allow to put into practice successful transition experiences. Therefore, Transition Engineering can certainly play an important role in the transition process especially regarding the role of technologies. As a result, the notion of Transition Technology has been introduced and defined. Consequently, the focus has been not only on the specific aspects of technology, rather on the role that technology plays in conjunction with other instruments of the transition process. The final vision is that TT combine to bring about the co-creation of living-labs of sustainability. According to Sustainability Transitions Research Network (STRN, 2010), ST emerging future lines need to focus on deepening the empirical basis for Sustainability Transitions research and also expanding the application domains of transitions into new problems. And in the last years, different lines of research has broaden the field of ST studies. Nevertheless, the core research strands is mainly belonged to social-science (Markard et al. 2012). Whereas, as emphasized by the transdisciplinarity approach, sustainability requires an integrated approach of knowledge and information that overcomes the general trend to deal with sustainability science by rather separate clusters of individual disciplines (Kajikawa et al. 2007). Hence, the emerging research discipline of Transition Engineering presented in this chapter can therefore become part of the Sustainability Transitions research fields. This is in line with the European Sustainable Development Network (ESDN, 2010) indications for the sustainability research. ESDN encourages a transfer of scientific approaches and greater collaborations. Definitely, new ways to experiment sustainability transitions research fields beyond the boundaries of traditional disciplines are needed.

8 University in Transition: the road for systemic transformation towards sustainability

Education is the most powerful weapon which you can use to change the world.
Nelson Mandela

In the previous chapters, it has been deeply demonstrated that a large number of actors and interests are involved in Sustainability Transitions transformation processes. In order to empower the promising framework of Sustainability Transitions, an important issue for the ST research agenda is building bridges and improving conceptually by making connections between different disciplines. With this purpose, this thesis has introduced the discipline of Transition Engineering (TE) and the correlated aspects and applications. As a consequence, TE could provide practical applications that can be decisive for the establishment of socio-technical systems toward sustainability. In addition, the Sustainability Transitions Research Network (STRN, 2010), has identified that emerging future lines of ST need to focus on expanding the application domains of transitions into new problems such as education, health care, welfare state, etc. This chapter investigates education as promising domain for ST research. Education is an important driver in order to achieve sustainable production and consumption patterns. The universities are a model for a formal and organised education. For this reason universities can define and also become models of sustainable practices. According to Lozano et al. (2013), Sharp (2002) and Senge (1999), Higher Education Institutions (HEI) can be considered as multi-structured, complex systems. Similarly to city, university is characterized by interlinked and interdependent elements and many universities are engaged in extensive growth. Therefore, university play a significant role in forging the path to a sustainable future (Orr, 2002) especially because they are tasked with training the world’s future leaders. Definitely, university can play a critical role in the transition towards sustainability. This chapter is aimed at describing the nature, risks and challenges associated to the university commitment to sustainability. With this purpose, barriers and exemplary initiatives which can affect the transition towards sustainability are identified. The final aim is to understand how to strengthen a real transformation of university system towards sustainability.

8.1 The role of university in the sustainability challenge

Education is humanity's best hope, according to UNESCO (2007), education serves society in a variety of ways:

"*The goal of education is to make people wiser, more knowledgeable, better informed, ethical, responsible, critical and capable of continuing to learn. Were all people to possess such abilities and qualities, the world's problems would not be automatically solved, but the means and the will to address them would be at hand. Education also serves society by providing a critical reflection on the world, especially its failings and injustices, and by promoting greater consciousness and awareness, exploring new visions and concepts, and inventing new techniques and tools. Education is also the means for disseminating knowledge and developing skills, for bringing about desired changes in behaviours, values and lifestyles, and for promoting public support for the continuing and fundamental changes that will be required if humanity is to alter its course, leaving the familiar path that is leading towards growing difficulties and possible catastrophe, and starting the uphill climb towards sustainability. Education, in short, is humanity's best hope and most effective means in the quest to achieve sustainable development*".[4]

In 2014, the United Nations Decade of Education for Sustainable Development, DESD (UNESCO, 2014) was concluded. One of the main principle which has been promoted, affirms: "Education for Sustainable Development (SD) means including key sustainable development issues into teaching and learning. It also requires participatory teaching and learning methods that motivate and empower learners to change their behavior and take action for sustainable development". In actual fact, since 1990, the Taillors Declaration (1990) has stated that "universities educate most of the people who develop and manage society's

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[4] UNESCO, United Nations Educational Scientific and Cultural Organization, Educating for a sustainable future, "A transdisciplinary vision for concerted action, 2007.

institutions. For this reason, universities bear profound responsibilities to increase the awareness, knowledge, technologies, and tools to create an environmentally sustainable future". According to Steed (2014), as universities' mission and activities are not directly tied to financial or political gain, they have the capacity to test system and technologies, and to advance innovative solutions to global challenges in ways that companies and municipalities cannot. Furthermore, universities are considered as centres of the most advanced knowledge. Through their teaching and their institutional practice, they should therefore embody role models of excellence and microcosms of best practices for the future (Cortese, 1999). Corcoran, Calder, and Clugston (2002, 99) expressively state: "*college and university are vested by society with the task of discerning truth, imparting values, and socializing students to contribute to social progress and the advancement of knowledge. They have a profound responsibility to impart the moral vision and technical knowledge needed to ensure a high quality of life for future generations. Sustainable development is the current context in which higher education must focus its mission*". Consequently, university can contribute as much as possible to the solution of societal problems and sustainability challenges (Jucker, 2003). This clearly implies that graduates of every discipline will need a sound working knowledge of sustainability and environmental challenge. This includes the development of an understanding of sustainability issues through policymaking, capacity-building, technology transfer, science and research. In the end, universities as educational institutions have the special responsibility to provide leadership on education for sustainable development

8.2 Sustainability dimensions of universities

By their nature, universities are focused on research, teaching and service and, as an institution, they are tasked with training the world's future leaders. Effectively, there are many ways in which universities can be involved in SD, e.g. management, planning, development, education, research, operations, community service, purchasing, transportation, design, new construction, renovation and retrofit. In engaging with the issue, a university may have a particular focus, a programme or even a holistic mission. Basically, a university is an organization with a purpose that it fulfils by implementing programmes within the context of the operation of faculties, possibly located on a campus. In discussing the issues, risks and challenges of university sustainability it is helpful to separately review the “triple bottom line” dimensions of environment, economy and society / culture, recognising both their inter-relationships, and the crucial role of the fourth “bottom line” – governance– across these three dimensions.

8.2.1 Environmental

Universities embody the environmental issues, risks and challenges of the wider communities in which they are situated, but also express their own unique characteristics. On one level, a university may be likened to a small town, with all the associated issues of spatial planning, management of physical growth and development, maintenance of buildings and open spaces, supply of electricity, water and other utilities, and often provision of residential accommodation and ancillary services. In addition, there are the typically corporate functions of finance, procurement, human resources, etc. However, the distinguishing feature of a university is its core purpose of teaching, research and community outreach. This generates a plethora of distinctive environmental issues on top of those typical of the small town or the corporate office, which often include significant (indeed semi-industrial) levels of resource consumption, carbon emissions, waste and pollution. Risks here include the reputational and financial aspects – linked to legal compliance – which on their own are enough to motivate some institutions towards sustainable development. The broader challenge is to minimise the legally compliant but environmentally unsustainable impacts of the university’s activities while maintaining and extending its teaching / research / outreach core.

8.2.2 Economic

Universities are major employers, major investors and major purchasers of goods and services. There are opportunities across all these areas for intervention, in terms of direct and indirect support for local jobs, ethical/ sustainable investment and “green” procurement strategies which can help integrate sustainability along the supply chain (for example by specifying standards of environmental performance in tender documentation). One challenge common across many nations is a declining level of public funding. Cost is a significant factor in most sustainability investment, and in some cases may appear insurmountable. However, even in situations where natural disaster or difficult economic conditions limit university budgets to the minimum necessary to keep their doors open, options to address sustainability imperatives are available. Typically these will involve the capture of savings around management of the key flows (inputs and outputs) of energy, water and materials, which can provide a buffer for future capital and operational investment in sustainability initiatives. The risk is that senior management may welcome the savings, but be reluctant to channel any (let alone all) into new greening endeavours, thereby relinquishing the opportunity for continual improvement. The key here is management buy-in – which means a shift from a "command and control" mentality to a shared vision.

8.2.3 Socio-cultural

The socio-cultural dimension of sustainability needs to be considered at two levels: internally with respect to the university's own formal and informal organisational structures; and externally with respect to the university's relationships with a wider community. Regarding the former, the key issue is gaining support and commitment from students, academic staff, operational staff and senior management, groups whose motivations, priorities and ways of thinking and doing may be on some issues not just unaligned, but diametrically opposed.[5]

In conclusion, universities have the possibility to teach, operate and contribute to the global knowledge of sustainability (Rotmans, 2012). Therefore universities can develop a virtuous circuit of "learning-by-doing" and demonstrate how to answer the multiple challenges of sustainability.

8.3 Sustainable Campus Initiatives

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[5] UNEP, Greening Universities Toolkit: Transforming universities into green and sustainable campuses, 2013.

In this context, a large number of universities has begun pathways to integrate sustainability into their university policy, organization and activities. Since 1972, at the Stockholm Conference (UNEP, 1972) education has been formally recognised to play an important role in fostering environmental protection and conservation. Ever since, many academic declarations, charters and partnerships were developed and designed to foster environmental education, sustainable development and education for sustainable development (Table 27). Regional and international conferences, higher education associations and intergovernmental organizations such as UN and UNESCO have developed a variety of agreements, declarations and charters on university sustainability with the aim to help, coordinate and strengthen campus efforts. There are different networks that support major institutions, universities and corporate campuses that allow the exchange of information, ideas and best practices to achieve concretely the development of sustainable campus. In 2011 there were more than 30 such international agreements, signed by more than 1400 universities globally (UNEP, 2013). For example, in Europe, the COPERNICUS Alliance is the European Network on Higher Education for Sustainable Development (www2.leuphana.de/Copernicus). In the UK, the Environmental Association for Universities and Colleges (EAUC, www.eauc.org.uk) strives to lead the way in bringing sustainability to the business management and curriculum of institutions across the UK and further afield. In addition, the International Alliance of Research Universities (IARU, http://www.iaruni.org), established in 2006, is a collaboration between a number of the world's leading research-intensive universities which share similar values, a global vision and a commitment to educating future world leaders. Central to these values is the importance of academic diversity and international collaboration. In the US, the Association for the Advancement of Sustainability in Higher Education (AASHE, www.aashe.org) has recently launched the Campus Sustainability Data Collector in collaboration with the Sierra Magazine, The Princeton Review and the Sustainable Endowments Institute (in the past creator of the College Sustainability Report Card).

Year	Event/declaration	Level or focus
1972	Stockholm Declaration on the Human Environment, United Nations Conference on the Human Environment, Sweden	Society
1975	The Belgrade Charter, Belgrade Conference on Environmental Education, Yugoslavia	Education
1977	Tbilisi Declaration, Intergovernmental Conference on Environmental Education, Georgia	Education
1987	"Our Common Future", The Brundtland Report	Society
1990	Talloires Declaration, Presidents Conference, France	Higher education
1991	Halifax Declaration, Conference on University Action for Sustainable Development, Canada	Higher education
1992	Report of the United Nations Conference on Environment and Development (Rio Conference); Agenda 21, Chapter 36: Promoting Education, Public Awareness and Training and Chapter 35: Science for Sustainable Development	Society
1992	Association of University Leaders for a Sustainable Future founded, USA	Higher education
1993	Kyoto Declaration, International Association of Universities Ninth Round Table, Japan	Higher education
1993	Swansea Declaration, Association of Commonwealth Universities' Fifteenth Quinquennial Conference, Wales	Higher education
1993	COPERNICUS University Charter, Conference of European Rectors (CRE)	Higher education
1996	Ball State University Greening of the Campus conferences were in 1997, 1999, 2001, 2003, 2005, 2007, and 2009	Higher education
1997	Thessaloniki Declaration, International Conference on Environment and Society: Education and Public Awareness for Sustainability, Greece	Education
1999	Environmental Management for Sustainable Universities (EMSU) conference first held in Sweden. Following conferences in 2002 (South Africa), 2004 (Mexico), 2006 (U.S.A.), 2008 (Spain), and in 2010 in The Netherlands.	Higher education
2000	Millennium Development Goals	Society
2000	The Earth Charter	Society
2000	Global Higher Education for Sustainability Partnership (GHESP)	Higher education
2001	Luneburg Declaration on Higher Education for Sustainable Development, Germany	Higher education
2002	World Summit on Sustainable Development in Johannesburg, South Africa (Type 1 outcome: Decade of Education for Sustainable Development; Civil Society outcome: the Ubuntu Declaration)	Society
2004	Declaration of Barcelona	Higher education
2005	Start of the UN Decade of Education for Sustainable Development (DESD)	Education
2005	Graz Declaration on Committing Universities to Sustainable Development, Austria	Higher Education
2009	Abuja Declaration on Sustainable Development in Africa: The role of higher education in SD, Nigeria	Higher Education
2009	Torino (Turin) Declaration on Education and Research for Sustainable and Responsible Development, Italy	Higher Education

Table 27: History of the initiatives taken in society, education, and higher education to foster sustainable development. (Lozano et al., 2013)

A remarkable initiative is the Greening University Initiative promoted by UNEP under the umbrella of the Global Universities Partnership for Environment and Sustainability (GUPES). UNEP has developed a toolkit (2013) aimed at inspiring, encouraging and supporting the implementation of transformative strategies for establishing sustainable campuses. GUPES is an intergovernmental platform launched by UNEP in 2010 that engages universities globally in responding to the challenges of sustainable development, by supporting innovative and relevant approaches to education. The main objectives are the implementation of UNEP's cross-cutting thematic priorities by sharing UNEP's knowledge base with academic community, harnessing the potential of universities as vehicles of change and transformation within communities, and by promoting south-south collaboration amongst institutions of higher learning through mainstreaming of environment and sustainability issues. All these programs and initiatives aspire to help universities to commit themselves to principles of sustainability and give the impulse to start with implementing sustainability into every day processes. Another initiative in which campuses from around the world have the opportunity to report on and take action for sustainability is the International Sustainable Campus Network (ISCN). ISCN has reached 58 members spanning 23 countries from Australia and Singapore to India, Italy, Sweden, South Africa, Canada, and Ecuador. Finally, the GreenMetric Ranking of World Universities is an initiative promoted by the Universitas Indonesia (UI) intended as an entry-level means of assessment for higher education institutions (HEIs) around the globe. GreenMetric is an attempt to compare the universities efforts towards campus sustainability. In Figure 64, the GreenMetric ranking investigates the university under six main categories: Green Statistics, Energy and Climate Change, Waste management, Water usage, Transportation and Education. Each category has assigned a weight in order to compare the different elements which characterize the university efforts. Universities which participate in GreenMetric by submitting their data to be included in the ranking can expect to enjoy a number of benefits, which include internationalization and recognition, awareness raising of sustainability issues, encouraging social change and actions.

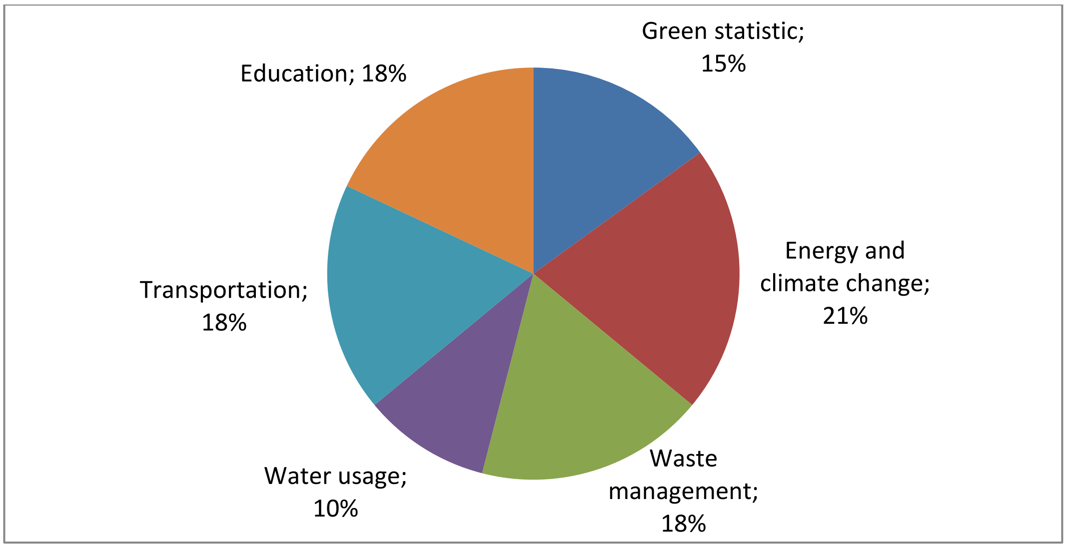


Figure 64: GreenMetric Ranking categories (UI, 2014)

Nevertheless, the ambition of creating a world university sustainability ranking is a complex issue and needs to consider the diversity of types of universities, their missions and their contexts. This could pose problems for the methodology. GreenMetric has not been based on a specific existing ranking system, but it was developed taking a number of existing sustainability assessment systems and academic university rankings into account. In particular, universities differ with regard to levels of awareness and commitment to sustainability, to their budgets, the amount of green cover on their campuses and many other dimensions. In any way, GreenMetric is committed to continually improving the ranking so that it will be both useful and fair to all.

8.4 Occurring barriers

Despite a high number of sustainable campuses and universities are committed to improve sustainability, in general several barriers affect them. Firstly, universities are complex, multi-faceted entities with diverse organisational subcultures, traditions and concerns (Sharp, 2002), and the transitory nature of university life for the bulk of the campus community may mean the real impacts of the institution remain unacknowledged (Flint, 2001). There may be individual high quality initiatives aimed at addressing these impacts, but where these are restricted to one or a handful of organisational units they inevitably are ad hoc and uncoordinated. In addition, limited funding and multiple calls on capital budgets favour short-term fixes over green investments with long-term paybacks. Staff and students have heavy workloads; limited time and multiple expectations as to how that time is used can make it problematic to initiate, maintain, complete and evaluate projects, and compound natural resistance to change. Moreover, universities generally lack the incentive structures necessary to promote changes at the individual level (Ferrer-Balas, 2008). Therefore, several institutions have shown a hardly application of the ground-breaking innovative technologies developed by the university itself (Lozano, 2006, Elton, 2003). According to Lozano et al. (2013), some of the reasons that may explain the resistance of universities to engage with SD include: lack of SD awareness (Davis et al., 2003; Lozano, 2006); insecurity and threat to academic credibility from teachers (Peet et al., 2004); over-crowded curricula (Abdul-Wahab et al., 2003; Chau, 2007); lack of support (Velazquez et al., 2005); SD considered to have little or no relevance to the course or discipline; uncertainty of the efforts required to engage with and incorporate SD (Lozano, 2010) and discipline restricted organisational structures (Lambrechts et al., 2009; Velazquez et al., 2005). Or perhaps, it is just academic conservationism/ traditions that tie universities to old mechanistic mental models.

8.5 Elements for driving university towards sustainability

Some actions that have been proposed to overcome universities' resistance to engage with SD include: implementing SD through campus experiences, by incorporating SD into the day-to-day activities in the university experiences (Lourdel et al., 2005); 'Educating-the-Educators' on the concepts, values, tools and procedures of SD, by replicating and multiplying the applications of the new SD approaches throughout all curricula (Huisingh and Mebratu, 2000). Such actions can help to reduce the time taken for the integration of SD into the entire university institutional framework, especially when SD becomes the 'Golden Thread" that permeates throughout the university system (Lozano Garcia et al., 2006). Integration can also be facilitated by working to ensure the engagement of the institutional leaders in promoting SD (Ferrer et al., 2010) and by empowering and rewarding SD faculty champions to catalyse the SD multiplier effects throughout the faculty, students, staff and the broader society (Elton, 2003; Lozano, 2006; Rogers, 1995). According to Lozano (2006) and Cortese (2003), there are inter-linked elements representative of the scale of SD implementation in HEIs .

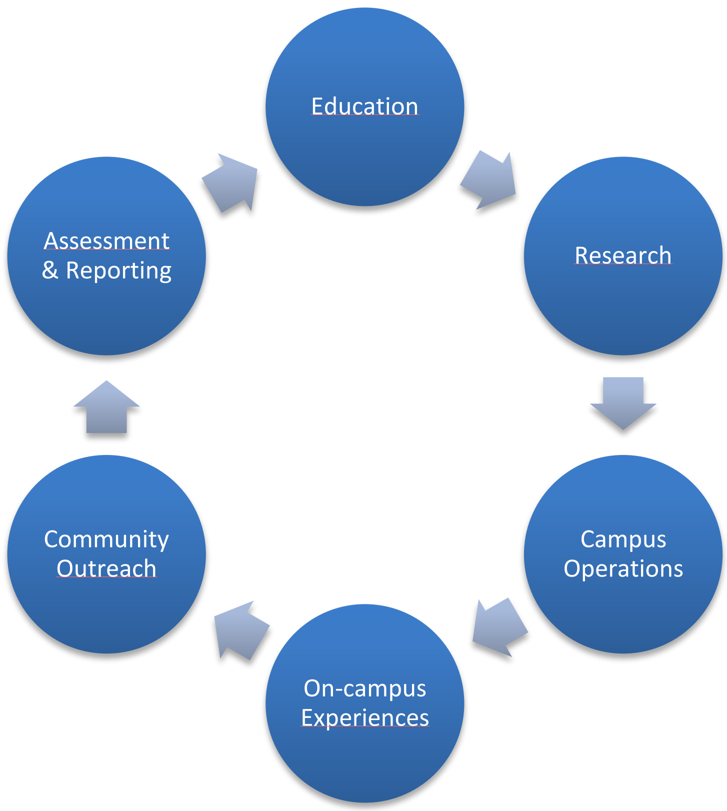


Figure 65: SD HEIs Interlinked-elements (Lozano et al., 2013)

As Figure 65 illustrates, the principal inter-linked elements are listed below:

- **Education**: integration of social, economic and environmental sustainability across the curriculum, commitment to critical system thinking and interdisciplinary, sustainability literacy expressed as a universal graduate attribute;
- **Research**: dedicated research on sustainability topic
- Campus **operations**: physical operations and maintenance focused on supporting and enabling "beyond zero" environmental goals, including effective monitoring, reporting and continual improvement;

- **SD through on-campus experiences**: the campus as a "living laboratory" where students are involved in environmental learning to transform the learning environment.
- **Community outreach**: outreach and service to the wider community, including partnership with school, government, non-governmental organizations and industry;
- **Assessment and reporting**: campus planning, design and development structured and managed to achieve and surpass zero net carbon/water/waste, to become a regenerative organization within the context of the local bioregion.

Besides, other elements can play a significant role (Lozano et al., 2013), such as a clear articulation and integration of social, ethical and environmental responsibility in the institution's vision, mission and governance which means making SD an integral part of the institutional framework; moreover, policies and practices which foster equity, diversity and quality of life for student, staff, and the broader community within which the university is based; finally, celebration of cultural diversity and application of cultural inclusivity and framework to support cooperation among universities both nationally and globally.

A recent survey (Lozano et al., 2014) conducted with 84 respondents from 70 HEIs, analyses the implementation of Sustainable Development in Higher Education based on the HEI system proposed by Lozano et al. (2013).

	Campus Operations	Education	Research	Outreach and collaboration	On-campus experiences	Assessment and Reporting
Operations	83	6	2	9	17	17
Education	6	45	18	16	5	9
Research	2	18	38	13	3	8
Outreach and collaboration	9	16	13	19	8	1
Campus experiences	17	5	3	8	29	6
Assessment and Reporting	17	9	8	1	6	34

Table 28: Interlinking the implementation of sustainable development within the different elements of the higher education system (Lozano et al., 2014)

In Table 28, the results of the survey based on the six sections focusing on the SD implementation are outlined. The results of the survey show the presence of inter-linkages between education and research, education and outreach, campus operations and on-campus experiences, campus operations and assessment and reporting, and research and outreach. Furthermore, there is a strong relation between SD commitment, implementation, and declaration and charter signing. On the other hand, a very low number of links were found between the dimensions of operations and research, education and on-campus experiences, research and on-campus experiences, and assessment and reporting and outreach and collaboration. In general, the relatively low frequencies for all the different combinations of the dimensions indicate that compartmentalisation still seems a critical key within SD integration in HEIs.

To sum up, universities are really generating a great deal of sustainability relevant research, but much of it never makes it any further than campus archives. As a result, campus operation still remains very conventional and innovations are derived from the market. Sustainability is usually affected by a structural separation of academic staff and the campus day-to-day practices. On one hand, focusing on campus structural issues is often viewed as a distraction from the core mission of the university. On the other hand, most of high quality sustainability initiatives are uncoordinated and limited to few organizational units. As a consequence, lack of whole engagement of the university community and of a real commitment toward sustainability can be observed. As a result, sustainability risks to be a marginal part of the university life. Now therefore, there is the growing need to change current practice on campus and turn universities into key players in the transition towards a resilient and sustainable society. Definitely, university can be a role model for society and education must play a central role in making the transition to sustainability. The challenge that still remains for HEI leaders and staff is to address SD holistically by committing to it, signing a declaration or charter, and implementing it into their system.

8.6 ISCN: exemplary initiative embracing holistic approach

One of the major worldwide network of universities is the International Sustainable Campus Network ISCN. The general mission of the International Sustainable Campus Network (ISCN) is to provide a global forum to support leading colleges, universities, and corporate campuses in the exchange of information, ideas, and best practices for achieving sustainable campus operations and integrating sustainability in research and teaching. In particular, ISCN has created a nested hierarchy of principles as key focal points of international exchange. Within its principle, ISCN integrally adopts the holistic system thinking. In particular holistic is intended as approach which cuts across traditional disciplines providing critical educational opportunities, in addition to innovative, applicable solutions. In order to address sustainability holistically, ISCN in conjunction with GULF (Global University Leader Forum GULF convened by the World Economic Forum) identify the Sustainable Campus Charter which structures campus commitments about sustainability into a nested hierarchy encompassing individual buildings, campus-wide planning and target setting, and integration of research, teaching, outreach and facilities for sustainability (see Figure 66).

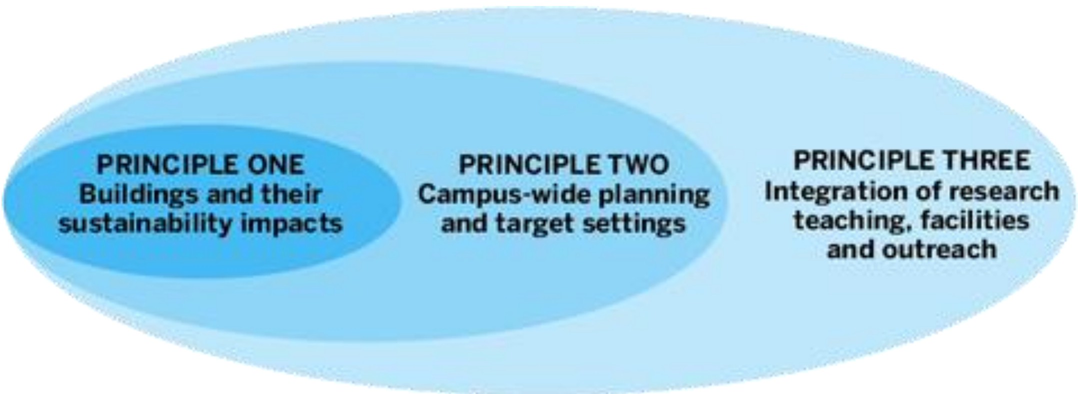


Figure 66: International Sustainable Campus Network Principles.

In the **principle one**, sustainable campus infrastructure is governed by respect for natural resources and social responsibility, and embraces the principle of a low carbon economy. Concrete goals embodied in individual buildings can include:

- minimizing environmental impacts (such as energy and water consumption or waste),
- furthering equal access (such as non-discrimination of the disabled),
- optimizing the integration of the built and natural environments.

To ensure “building on campus” principle can meet these goals in the long term, and in a flexible manner, useful processes include participatory planning (integrating end-users such as faculty, staff, and students) and life-cycle costing (taking into account future cost-savings from sustainable construction). In Table 29, goals and indicators of principle one are described.

According to the **principle two**, the sustainable campus development needs to rely on forward-looking planning processes that consider the campus as a whole, and not just individual buildings. These processes can include:

- comprehensive master planning with goals for impact management (for example, limiting use of land and other natural resources and protecting ecosystem),
- responsible operations (for example encouraging environmentally compatible transport modes and efficiently managing urban flows),
- social integration (ensuring user diversity, creating indoor and outdoor spaces for social exchange and shared learning, and supporting ease of access to commerce and services).

Such integrated planning can profit from including users and neighbours and can be strengthened by organization-wide target setting (for example greenhouse gas emission goals). Existing low carbon lifestyle and practices within individual campuses that foster sustainability, such as easy access for pedestrian, grey water recycling and low levels of resource use and waste generation, need to be identified, expanded and disseminated widely. Table 39 presents goals and indicators of principle two.

Finally, in the **principle three**, a sustainable campus, the built environment, operational system, research, scholarship, and education are linked as a “living laboratory” for sustainability. Users (such as students, faculty and staff) have access to research, teaching, and learning opportunities. Campus sustainability programs have concrete goals and can bring together campus resident with external partners, such as industry, government, or organized civil society. Beyond exporting a sustainable future in general, such programs can address issues pertinent to research and higher education (such environmental impacts of research facilities, participatory teaching, or research that transcends disciplines). Institutional commitments (such as a sustainable policy) and dedicated resources (such as a person or team in the administration focused on this task) contribute to success. Table 31 lists goals and indicators of principle three.

In Tables 29, 30 and 31, the ISCN Charter Report proposes a set of indicators with the aim to measure the performances in compliance with the previous principles. The indicators are referred either to the Global Reporting Initiatives (GRI) indicators or to Sustainability Tracking, Assessment & Rating System (STARS).

Principle	Goal	Indicators
Principle one Sustainability performance of building on campus	To demonstrate respect for nature and society, sustainability considerations should be an integral part of planning, construction, renovation, and operation of building on campus.	Resource use, e.g. o Direct (fuels) and indirect (electricity/steam etc.) energy use o Water use o Energy and water costs, and savings achieved o Overall purchased products/materials (e.g. paper) o Other … • Waste, recycling, local emissions, and non-compliance, e.g. o Solid waste and recycling o Waste costs, and savings achieved o Emissions contributing to local air pollution o Incidents of non-compliance with environmental regulations o Other … Research/IT facilities and sustainability, e.g. o Energy use in laboratory/IT facilities o Chemicals consumed o Hazardous waste from laboratory/IT facilities • Users, e.g. o Handicap Access o Indoor air quality o Stakeholder participation in planning (integrated design) • Building design aspects, e.g. o Building standards applied and explored o Long-term planning/life-cycle costing o Landscape integration of building design

Table 29: ISCN Principle one goal and sustainability indicators

Principle	Goal	Indicators
Principle two Campus-wide master planning and target setting	To ensure long-term sustainable campus development, campus-wide master planning and target-setting should include environmental and social goals.	Institution-wide carbon target(s) and related achievements, e.g. o Direct emissions (Scope 1) o Indirect emissions (Scopes 2) o Other emissions (Scope 3; e.g. using examples like flight emissions) • Master planning, e.g. o Extent of master planning coverage of campus area o Other … Transportation, e.g. o Transport on campus, and student/staff commuting o Urban mobility integration • Food, e.g. o Food supply chain and environmental impact (e.g. local, low carbon footprint) o Fair trade food sourcing • Social inclusion and protection, e.g. o Diversity in faculty, staff, and students o Incidents of discrimination o Access to education, interaction spaces, and services o Participative campus planning with users and neighbors o Respect for minimum wage regulations and collective bargaining rights o Workplace health and safety o Programs for health and wellbeing, including work-life balance • Land-use and biodiversity, e.g. o Land and building reuse o Landscaping impacts and biodiversity

Table 30: ISCN Principle two goal and sustainability indicators

Principle	Goal	Indicators
Principle three Integration of facilities, research, education, and outreach as a "living laboratory" for sustainability	To align the organization's core mission with sustainable development, facilities, research, and education should be linked to create a "living laboratory" for sustainability.	Topical integration, e.g. o Programs connecting facilities, research, and education o Labeling of courses that integrate sustainability o Courses and/or research that transcends disciplines o Other … • Social integration, e.g. o Connecting campus users with industry, government and civil society o Student interaction and social cohesion on campus o Courses using participatory and project based training o Behavioral programs aiming at more sustainable actions by students, staff, or external community members o Other … • Research and education projects on laboratory/IT facilities and sustainability, e.g. o Research and education on mitigating laboratory/IT energy use o Research and education on decreasing hazardous waste from laboratories o Other … • Commitments and resources for campus sustainability, e.g. o Existence of a sustainability policy that integrates academic with operational issues o Commitment to external sustainability principles or initiatives o Dedicated resources (processes, human and fiscal resources) for campus sustainability o Other …

Table 31: ISCN Principle three goal and sustainability indicators

GRI was already described in chapter 7, as one of notable multi-stakeholder organization that strives to provide companies and other organizations with a systematic basis for disclosure regarding sustainability performance. GRI provides stakeholders with a framework that facilitates comparison and understanding of disclosed information. The latter, STARS, has been developed by the Association for the Advancement of Sustainability in Higher Education (AASHE) as a transparent self-reporting framework for North-American colleges and universities to gauge relative progress toward sustainability. It is intended to cover the full spectrum from community colleges to research universities, and from institutions just starting their sustainability programs to long-time campus sustainability leaders. Basically, the ISCN initiative aims to improve the campus profile on energy, water, and environment related issues. An example of the "average ISCN member campus" performance has been calculated for the sample of members and reported in Box 7.1.

Box 7.1 ISCN "average campus" sustainability performances (2013)

According to an annual calculation for a sample of reporting ISCN members, the "average" campus presents the following performances:

- about 9 MWh of energy consumption per student per year, which includes the energy spending of energy intense research laboratories,
- about 28 m^3 of water consumption per student,
- about 0.04 tonnes of waste recycled per student
- about 0.05 tonnes of waste sent to the landfill.
- about 1.2 tonnes of direct (scope 1) and indirect (scope 2) CO_2 emissions while commuting to and from the university (scope 3) adds another 0.5 tonnes per student, annually.
- about 1.9 tonnes of total CO_2 emissions per student per year.

ISCN
International Sustainable Campus Network

www.international-sustainable-campus-network.org/

Therefore, the Sustainable Campus Charter commits the signatories to set concrete and measurable goals for each of the three principles, to strive to achieve them and also to report regularly and publicly on their organizations' performance in this regard. The Signature of the charter represents an organization's public commitment to aligning its operations, research, and teaching with the goal of sustainability. Finally, ISCN acknowledges that organizations of research and higher education have a unique role to play in developing the technologies, strategies, citizens, and leaders required for a more sustainable future.

8.7 Conclusion

Sustainable development is one of the biggest challenges of the twenty-first century. In this context, university can play a significant role in forging the path to a sustainable future. Actually, university can teach and demonstrate the theory and practice of sustainability and as the training area for future leaders has therefore a specific responsibility to move society towards a sustainable future. Several universities have begun the commitment to sustainability and initiatives aimed to integrate it into their university policy, organization and activities. In spite of the large number of outstanding higher education initiatives, several barriers still affect the truly holistic adoption of sustainability. Certainly, universities are complex, multi-faceted entities with diverse organizational subcultures, traditions and concerns. For this reason, sustainability requires a new paradigm for the complex systems of universities. In this chapter, we have seen that as centers of educational and research excellence, campuses are in a unique position to offer a large variety of elements representative of SD implementation in HEIs. Exemplary initiatives as ISCN network encourage the role of sustainable campuses in spearheading the drive towards future production and consumption systems. Nevertheless, the link between sustainability commitment and implementation still requires a strengthening of the holistic system thinking. Therefore, the greatest HEIs challenge is to deeply inter-connect into university system all the different HEIs elements, as education, research, campus operations, community outreach, assessment and reporting. And moreover collaboration with other universities, commitment to make sustainable development an integral part of the institutional framework and on-campus life-experiences. The promising approach of transition broadly described in this thesis as a powerful way to stimulate sustainability transitions on the scale of regions, cities and neighborhoods, can be considered crucial in setting up the framework for steering sustainability of the university system. Furthermore, similarly to other complex systems as cities are, university can become a polycentric model in which multiple and interconnected stakeholders are involved in governing sustainability issues.

9 Experimenting Sustainability Transition process within the School of Engineering and Architecture in Terracini Campus

There is a difference between knowing the path and walking the path.
The Matrix

In order to demonstrate the potential of the Sustainability Transitions (ST) approach, this chapter describes the adoption of the Transition Management process within the entire system of university (Cappellaro and Bonoli, 2014a). One of the main challenges is the systemic integration of several key elements characterizing Higher Education Institutions, HEIs, such as curricula, education, research, operations, community outreach, on-campus experiences, assessment and reporting. To achieve that, one year of experimentation of Transition Management process has been conducted within the University of Bologna. As previously seen, Transition Management provides a valid opportunity both for successful initiation and long-term maintenance of the transition process. Therefore, TM application can enhance university sustainability commitment and programs. Accordingly, this chapter presents the Transition process implemented at the School of Engineering and Architecture in Bologna located in Terracini Campus. Terracini Campus has provided a place where to implement Transition experiments and to apply Transition Engineering practices. Transition Terracini case is aimed at demonstrating not only sustainability best practices within the campus, but also the importance of the engagement of staff and students in the creation of the sustainability process. With this purpose, Transition Terracini acts as a niche in order to understand and to steer a socio-technical system transformation of the whole university. The final vision is to realize a living-lab of sustainability where to experiment the theory and the practice of sustainability.

9.1 University of Bologna

The University of Bologna also known as UNIBO was established in 1088. As of 2013 the University's crest carries the motto *Alma mater studiorum* and the date A.D. 1088. With more than nine centuries of history, the University of Bologna has been geographically expanded through the city acquiring more and more separate buildings instead of being concentrated in few campus. Furthermore, in the last 20-25 years the Romagna campus (Rimini, Cesena, Ravenna and Forlì) has been also added to University of Bologna (see Figure 67).

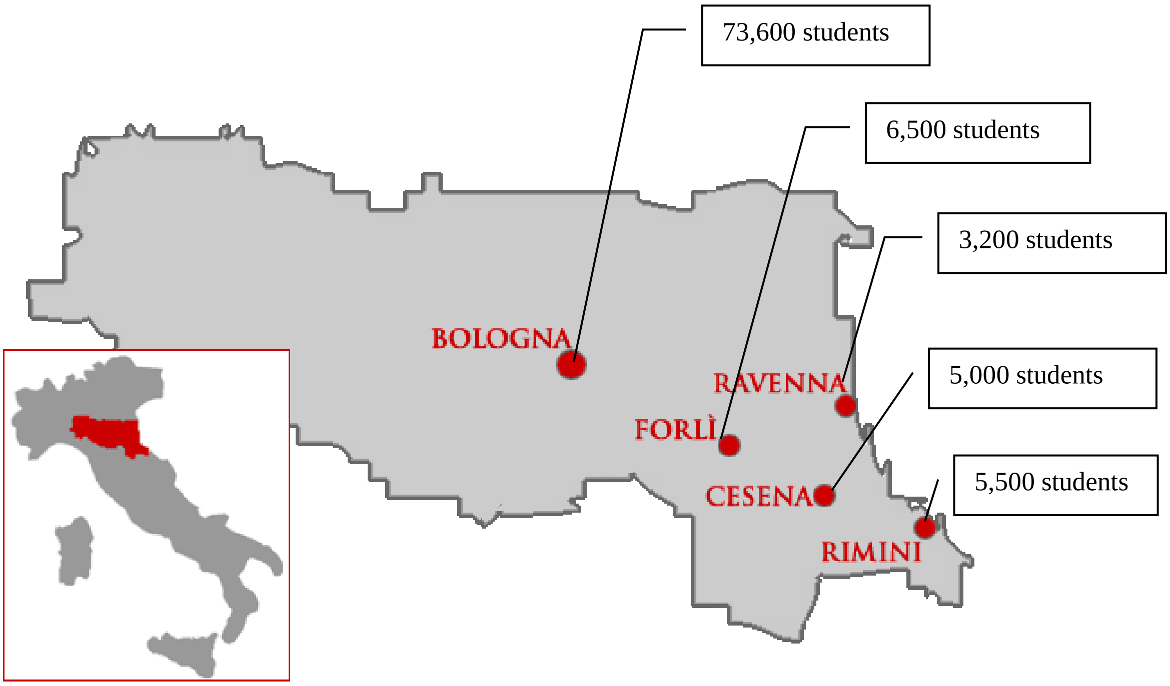


Figure 67: University of Bologna Campus Area.

Currently, there are 23 Faculties, 68 Departments, over 200 degree programmes and 92,000 students (including around 5,000 international students). Around 80% of the University's students are enrolled in Bologna.

University of Bologna (5 Campus) – 2013	
Student population	92.000
Academic staff	5.942
Finance (M€)	631.5 (equity capital)
Area (5 Campus)	934.000 m^2

Table 32: University of Bologna in figures

Unibo is recognised as the oldest university in continuous operation, considering that it was the first to use the term *universitas* for the corporations of students and masters which came to define the institution. The University of Bologna has among its natural purposes the transfer and valorisation of knowledge, and serves as a promoter of innovation, it is aware of the proper role within the dynamics of local, city and regional.

9.2 Mapping the state of sustainability within University of Bologna

9.2.1 Energy and Environmental Sustainability Action Plan

Since 2009, University of Bologna has engaged in the implementation of a sustainability process, developing initiatives and measures included in the Energy and Environmental Sustainability Action Plan. When this research project began, in 2012, Unibo had therefore implemented the Energy and Environmental Sustainability Action Plan, named MOSES, MObility Sustainability Energy Solutions, (Battistini and Bernardi, 2009). This three-year plan included measures and interventions mainly devoted to the comprehensive strategic planning energy management. Effectively, both European and Italian regulatory framework requires public organisations with 1.000+ TEP energy consumptions to have an energy management plan . A similar obligation is also required for mobility management aspects. Therefore, the Unibo plan was principally related to energy aspects and the Energy and Mobility Sectors, part of the Administrative and Technical Division AUTC-Facility Management, was responsible of it. In particular, MOSES objectives concerned the following aspects:

- Promotion of energy savings
- Use of renewable energy sources
- Improvement of energy efficiency of existing buildings
- Adoption of sustainable energy efficiency measures for new buildings
- Reduction of air pollution
- Promotion of sustainability awareness

As it can be observed, the objectives were principally devoted to aspects of energy both type and consumption. Only a few measures concerned comprehensive sustainability issues, such as the promotion of a sustainable mobility and travel plan, the introduction of separate collection system for urban waste of Unibo (paper, glass and plastics). Furthermore, the plan set targets for energy use, energy efficiency and waste. No targets are set yet for the other sustainability topics such as CO2 emissions and water.

9.2.2 Waste management

In addition to the MOSES measures, the University of Bologna presented other initiatives which can be connected with sustainability issues. One of them is related to waste management. Since 1998, University of Bologna has started to approach the problem of hazardous waste management in a centralized way both from organizational and economical points of view. In this framework NuTeR (Nucleo Tecnico Rifiuti, i.e. the waste technical unit) was established. NuTeR is a group composed by technicians who deal with hazardous waste in every single university centre with research laboratories under the responsibility of one coordinator (Bonoli, Ferroni and Prandstraller, 2013). In 2012, NuTeR was composed by 37 Local Unit (Schools, Faculties, Departments or aggregation of them sharing the same building/area) and about 80 members. Being the unauthorized transportation of waste on public street prohibited by law, these numbers are mainly due to the geographical delocalization of the University of Bologna principally expanded through the city and allocated in separate buildings. In almost 15 years, NuTeR members have grown together through experience and competence broadening its field of interest to other typologies of waste. NuTeR was principally committed to the management of infective, chemical or radioactive wastes. In the last years, also electrical and electronic equipments waste (WEEE) has grown attention, especially for what concerns IT/Computer WEEE (IWEEE) stored inside the university. Actually, university Offices and Departments produce yearly a very big quantity of IT waste in relation with the growth and upgrade in IT and the necessity to exchange old equipment with the most up to date. In this framework, a centralized management complying with an approach of economics and environmental sustainability has been realized with the aim at minimizing waste production. This approach has seen the design of a centre for the recovery and preparation for re-use as service for the University of

Bologna. In addition, in 2010, a student association has already developed an interesting *'trashware'* experience at the Cesena campus,. Trashware is computer equipment that is assembled from old hardware, using cleaned and checked parts from different computers, installed with free software, usually for use by disadvantaged people to bridge the digital divide. The students association called S.P.R.I.Te. (Studenti Polo Romagnolo in Informatica e Tecnologie) was established with the purpose of recovering this kind of waste and re-generating a new EEE, especially personal computer (see Figure 68).

Figure 68: Trashware activity of S.P.R.I.Te. students association.

The *know-how* has been developed within the course of "Operative Systems" of "Information Technology and Science Degree". The project has been co-funded by the municipality of Cesena, by the Cesena Campus of the University, and by the municipal utility for solid waste disposal. The disused IT equipment is collected from the municipal offices, companies, banks, and the refurbished equipments are donated to no profit associations or even to citizens who apply for it in the relevant municipality office. In the period between April 2013 and January 2015, the number of reconditioning computer was 332. The Cesena experience is very interesting because represents a model that can be followed, with the appropriate modification for the scaling up.

Another remarkable initiative related to waste reduction is the realization of a compost plant at the University Botanic Garden in Bologna. The application of home composting in the Botanical Garden could be a good answer both for the management of residual green waste deriving from cuttings and prunings of all gardens present inside the University and also to generate a fertilizer supply. From the economic point of view, by internal green waste composting, it is possible to obtain soil fertilizers without additional costs, and reducing costs for waste disposal. The Botanical Garden could easily use the amount of compost produced for the fertilization of soils and plants as a service for all structures of the University of Bologna (see Figure 69).

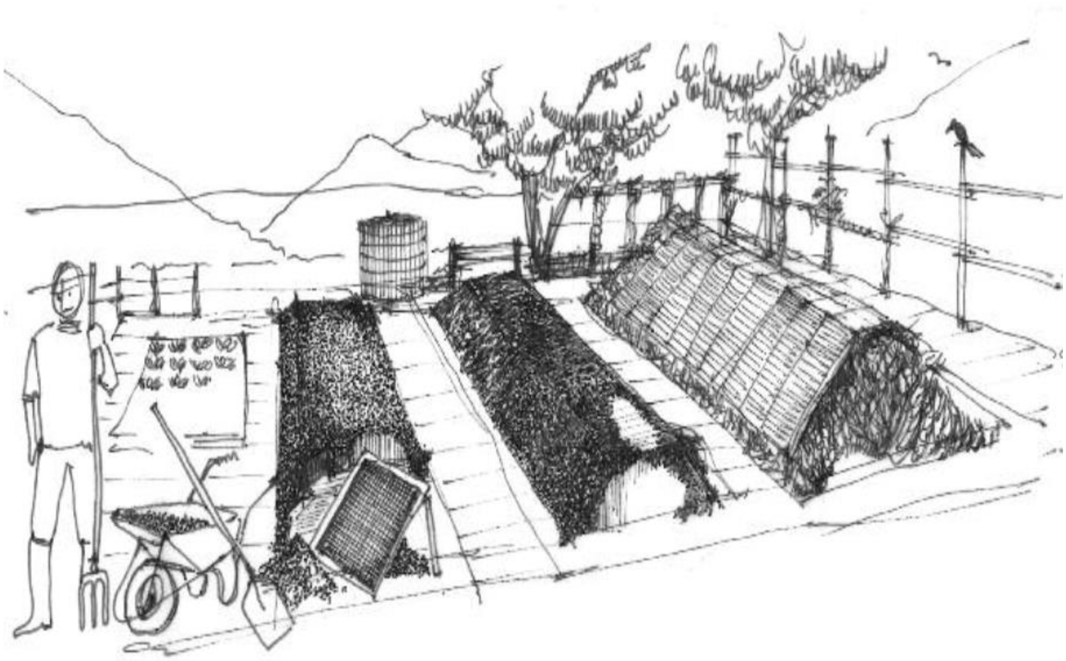


Figure 69: Design of compost plant for the Botanical Garden of Unibo

9.2.3 Educational Programs

Concerning educational programs, University of Bologna offers several courses and curricula related to sustainability. Especially, in the field of Engineering discipline, there is an international Master's Degree Program in Environmental Engineering - Earth Resources Engineering (ERE). The program is open to students of any nationality. The venue of the program is the School of Engineering and Architecture of the University of Bologna. The central theme of ERE is the conscientious stewardship of our finite natural resources, namely minerals, fuels, energy, water, and land. Students taking ERE Programme will attain a broad background in environmental engineering and earth resources covering water resources, pollution prevention, energy, resource economics, recycling, waste and biowaste valorization, alternative and renewable raw materials, reclamation, and health. The main goal of the Master's degree is to educate professionals with the necessary in-depth scientific and technical knowledge to be successful in the field of environmental engineering and in a multi-cultural educational environment. The program is intended to prepare students with firm technical bases while nurturing decision-making and leadership potential. It prepares graduates to practice their profession at an advanced level and with a unique exposure to an international environment to better understand the global issues of environmental engineering. The basic issues proposed by ERE are related to:

- **Water resources**: providing both a capacity for understanding the variability in the context of decisions for water resources and related sectors of impact; and skills for integrated risk assessment and management for operations and design, as well as for regional policy analysis and management.
- **Energy and materials**: availability of natural resources, their geographic distribution, the economic and environmental cost of resource extraction, and avenues for increasing energy utilization efficiency, technologies for efficiency improvement in the generation of energy from fossil fuels, and technologies for addressing the environmental concerns over the use of fossil fuels, air quality and health impacts focus on the consequences of energy use.

- **Sustainable waste management and recycling**: the next best thing to do after waste reduction. Composting: both aerobic and anaerobic, is the next step in the hierarchy of waste management. Waste-to-energy: processing wastes to produce energy. Landfilling: constructing sanitary landfills that prevent liquid effluents from contaminating ground and surface.

Main Content	Topics
Principles of sustainable development and sustainable use of resources	Natural and recycled resources. Renewable and non-renewable resources.
The water resource.	The water cycle. Uses and technologies to increase the water resource. The treatment and recycling of waste water.
The solid natural materials: classification of raw materials and regulatory aspects.	Representation of a set of solid particles, analysis and grading curve. Characterization and quality of natural materials. Machines and plants for the reduction and size classification.
Techniques of separation.	Gravimetric and magnetic separation.
Definition and recovery of recycled materials.	Recovery of metals. From water and soil as well as by specific types of solid waste.
Integrated management of municipal waste collection and treatment.	The pre-treatment plants and selection, mechanical biological treatment, the energy recovery, the disposal in landfills.
Treatment of organic fraction and the process of composting.	The use of biomass.
Recovery and recycling of inert stone materials from construction and demolition (CDW).	Characterization of inert waste and the types of recycling facilities and the different stages of treatment. Uses of recycled aggregates.
The recycling of post consumer plastic and aluminum.	Examples for recycling from municipal and special waste: glass, paper, steel, vehicles and tires end-of-life, electrical electronic equipment waste. Main physico-mechanical properties and fields of use of raw materials second.
Life cycle assessment (LCA)	Life cycle approach for materials recycling and waste management.
Appropriate Technologies	Definitions, examples of application to the developing countries with particular attention to the management and recycling of waste water for potable use, management and recovery of waste.

Table 33: Contents of Engineering Master Course of Resources and Recycling at University of Bologna

As example of education pathway of waste responsibility, the main contents of the Master Degree Course in Resources and Recycling are presented in Table 33.

9.2.4 Research projects and initiatives

A large number of projects and initiatives involving the University of Bologna in the research field. UniBo has been awarded the use of the logo "Human Resources, HR Excellence in Research", identifying UniBo as provider and supporter of a stimulating and favorable working environment In 2005 UNIBO signed the Charter & Code (C&C) Declaration of commitment thus undertaking to implement the C&C principles and promoting them. Since January 2012, UniBo carried out an internal analysis resulting in the drafting of the Strategy and Action Plan approved by the European Commission. In October 2013, the European Commission DG Research & Innovation approved the Strategy and Action Plan and assigned the logo "HR Excellence in Research". The logo "HR Excellence in Research" remarked the quality of Unibo strategy for researchers. Principally, Unibo has been involved in projects funded by European, National or Regional programmes. Furthermore, Unibo is member of MED EU (Matching Excellence Directly for EU), a strategic platform supported by the Emilia-Romagna Region aiming to raise EU funds for scientific research and innovation. An interesting research framework promoted by Unibo are the Integrated Research Teams (IRTs). IRTs are critical masses of teachers and researchers from various Departments of the University, who share research interests in a transversal thematic sector or specific geographical area. They are innovative models of organization and coordination of the many scientific expertise at the University of Bologna, introducing a concrete integration of multidisciplinary competences in the related thematic area, an interdisciplinary approach and strategic vision promoting scientific excellence. Moreover, IRTs offers a single, facilitated access to a multitude of competences for the sector stakeholders. The Integrated Research Teams of the University of Bologna work in research in a range of sectors: agri-food, social economy, civil society, sciences and technologies for the cultural heritage. Besides, the IRT Brasil provides university's scientific competences for the geographical area of Brazil and Brazilian relations with Italy, Europe and Latin America.

According to the consideration of Chapter 8, the implementation of sustainability process within university system is a big challenge. Based on the mapping of Unibo, sustainability actions and initiatives are characterized by a structural separation of academic staff and campus management. Additionally, there are high quality initiatives (such as research projects and programmes), but they are fragmented and uncoordinated. As result, a lack of engagement of the whole university community, a lack of communication and real commitment including a lack of funding are emerging. All things considered, sustainability tends to remain a marginal part of university life.

9.3 SWOT analysis of Unibo sustainability elements

From the previous paragraphs, it emerges that University of Bologna is a complex organization with a variety of projects, programs and initiatives related to sustainability. In order to identify future perspectives for the sustainability process within university system, a SWOT-analysis has been conducted. As described in chapter 6, the SWOT analysis provides a support for prioritizing actions and to identify which problems can be addressed. In the figure below, Unibo sustainability actions and initiatives running during 2012 have been evaluated by means of SWOT analysis. In order to analyze the effectiveness of sustainability process, there are considered the interlinked HEIs elements described in chapter 8 and based on Lozano et al. (2013).

Strength	Weaknesses
• Energy and environmental sustainability plan (MOSES) • Educational programs • Research Projects and Initiatives • Centralized Waste Management • Students Initiatives	• Separation of operations, research and educational initiatives • Lack of whole sustainability indicators reporting and monitoring •Insufficient Commitment: global Vision and Strategy and no dedicated Staff
Opportunities	**Threats**
• Sustainability as Competitive Factor • Sustainability as integral part of the institutional framework •University of Bologna as model of “living-lab of sustainability”	•Multi-campus: High complexity structure and management •Lack of financial incentives from the National Government

Figure 70: SWOT analysis of Unibo sustainability elements

On the basis of the previous mapping (Figure 70), strengths and weaknesses can be described following the inter-linked elements.

- **Assessment and reporting**: Although since 2009 there is an Energy and Environmental Sustainability Action Plan (MOSES), it was principally devoted to energy aspects. Only few initiatives are related to comprehensive sustainability issues. Generally, no measures had incorporated sustainability with a holistic approach. A lack of sustainability reporting method (connected to international standards) has appeared.
- **Campus operations**: The 2012 situation reveals remarkable initiatives connected with waste management which has a centralized management and monitoring. In addition, due to the MOSES plan, energy-related aspects are continuously monitoring and reporting. Nevertheless, a lack of monitoring system for the whole sustainability performances and an integrated management of all sustainability-related elements is emerging.

- **Education**: In spite of a large offer of courses and educational programs, a lack of integration of social, economic and environmental sustainability across the curriculum is revealed. In addition a lack of interdisciplinarity and sustainability literacy as a universal graduate attribute is also emerging.
- **Research**: Unibo presents an excellent and favourable research environment. On the other hand, a lack of a full embedding of sustainability themes affects this research framework.
- **SD through on-campus experiences**: Owing to the geographical delocalization of the University of Bologna principally expanded through the city and allocated in separate buildings, a general lack of on-campus experiences is present. Especially, there is a little evidence of a "living laboratory" set of experiment in which students are involved in sustainability experiential learning (i.e. S.P.R.I.T.e).
- **Community outreach**: in 2012 there are not specific partnership with school, government, non-governmental organizations and industry in the field of sustainability.

Furthermore, SWOT puts in evidence the subsequent threats and opportunities.

9.3.1 Threats

Multi-campus: high complexity of structure and management: managing a multi campus is difficult because the different faculties and facilities are located in different cities and what may work for one establishment sometimes does not work for others. In addition, most of the faculties of the University of Bologna are located in the historic centre of the city, where many historic buildings are public property in which there is the crucial issue of energy efficiency and use of renewable sources. The fuels used for heating these buildings are expensive, in addition, there are specific standards to be met to achieve redevelopment consequently the results so far are insufficient.

Lack of financial incentives. Due to the current financial situation in Italy, in particular because of the crisis, University of Bologna cannot predict how many incentives from government will be issued to become more sustainable.

9.3.2 Opportunites

Sustainability as Competitive Factor Sustainability needs to become a marketing strategy in order to compete with other Universities. Sustainability monitoring and reporting could help to demonstrate the economical advantages of sustainability initiatives. Fixing a recognizable set of sustainability indicators could quantify the advantages to undertake sustainability actions. Not only economic advantages, but also non-monetary returns, such as a more healthy campus, improvement in social issues, etc.

Sustainability as integral part of the institutional framework: the establishment of a formal Sustainability Structure which involves not only technical and administrative divisions but also faculties, departments and the whole university is an important action which will consent the integration of sustainability principles into the existing organizational units. Moreover, the establishment of such organizational structure would support the main strategic mission comprised in the Sustainability Plan and can be a support for the management of the complexity due to the Multi-campus structure.

University of Bologna as living-lab of sustainability Considering the integration of the university within the city of Bologna, Unibo could become a role model of sustainability for the entire city. What is being implemented within the university can simply be replicated for the city to create not only a more sustainable university but a sustainable city.

In the end, the SWOT analysis has shown that a number of remarkable initiatives on sustainability are present at University of Bologna. Nonetheless, several weaknesses still inhibit a real transformation of university in place of sustainability. There is the necessity of re-orienting the university trajectories for a long term perspective on sustainability.

9.4 Setting a transition process for University of Bologna

According to Sharp (2002), a crucial challenge for university system can be to "achieve mission alignment between teaching, research and campus operations, harnessing the vast collective learning process that is currently underway within its walls, to benefit its own systems". Consequently, the final vision is the transformation of the whole university system into living laboratory of sustainability. As stated in the preceding chapters, a living-lab aims to implement participatory processes in order to engage staff, students and the university stakeholders with the establishment and the co-creation of sustainability initiatives. According to UNEP (2013), several examples of living-lab initiatives can be implemented in a HEI.

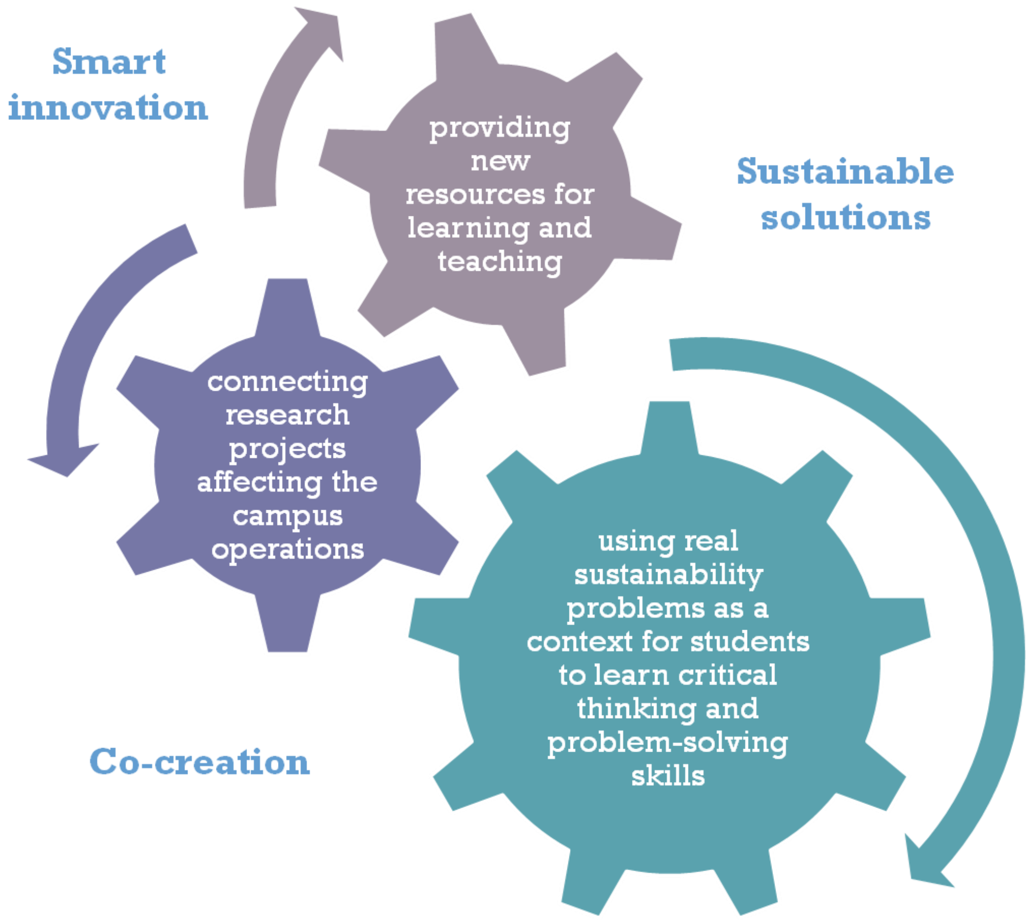


Figure 71: Living-lab of sustainability applied in the university (Cappellaro and Bonoli, 2014b)

As Figure 71 illustrates, university living-lab can be characterized by the following scopes: connecting research projects to the campus operations, providing new resources for learning and teaching and using real sustainability problems as a context for students to learn critical thinking and problem-solving skills. These scopes are interconnected each other and the campus can function as a living laboratory for staff, student and research. The advantage is that the outcomes are likely to be more long-lasting. Involving potentially major innovations affecting the campus fabric and operations, and also providing new resources for learning and teaching into the future.

As deeply emphasized in Chapter 6, transition practices have been revealed as a catalyst of living-lab of sustainability in a mutual learning processes. Due to the systemic approach, transition experiments can stimulate the implementation of living-labs of sustainability in an integrated way. In the university domain, the creation of living-labs allows for a participatory process to be finalized at involving a university wide-community in making practical applications of the theory. In this context, Transition Engineering and especially the introduction of Transition Technology may provide a valid support. Furthermore, in order to build coalitions, transition experiments can activate participative processes among different actors that recognize the benefit of joining forces in performing innovative experiments. With the purpose to provide an evidence of the potential of transition approach, the experimentation of a transition process has been executed as empirical part of this research project. The main aim is to overcome weaknesses and lacks that still inhibit a real transformation of university system toward sustainability. The experiment investigates the steps to define a transition pathway in the university domain through a transition initiative implemented within the School of Engineering and Architecture of University of Bologna (Cappellaro and Bonoli, 2014a, 2014b).

9.5 Experimenting Transition within Terracini Campus

Since 2007, Terracini is one of the campus of the Engineering and Architecture School of University of Bologna. This recent campus includes classrooms, offices and research laboratories. Common areas and spaces for students are also present, such as reading classrooms, library, cafeteria. With regard to the implementation of sustainability measures, since 2009, most of MOSES plan initiatives are devoted to Terracini Campus. Examples are a monitoring system of energy consumption and environmental comfort, the installation of photovoltaic plant and since 2011 a waste separate collection system. In addition, a NuTeR Local Unit is located in Terracini.

Category	***Action***	***Location***
Energy	Monitoring system of energy consumption	Bologna, Terracini Campus
Energy	Photovoltaic plant	Bologna, Terracini Campus
Comfort	Monitoring system of environmental comfort	Bologna, Terracini Campus
Waste Management	Separate waste collection system	Bologna, Terracini Campus and Risorgimento Campus
Waste Management	NuTeR Local Unit IWEEE management and recovery	All campuses of Bologna, Forlì, Cesena, Rimini
Buildings	Green roof	Bologna, Terracini Campus

Table 34: Sustainable initiatives at Terracini Campus, Bologna in 2012.

In Table 34, it could be noticed that a sustainable initiative concerns an experimental research project related to green roofs. Particularly, two pilot green roofs were built on the engineering laboratories of University of Bologna, Italy. This project was the first measured green roof in the city of Bologna where no green roofs have been monitored for annual storm water retention in this area (Bonoli and Conte, 2013). The monitoring is based on measuring several parameters and testing their components, principally aimed at providing more evidence on green roof storm water performance (see Figure 72).

Figure 72: Installation of Green Roofs - University of Bologna Via Umberto Terracini 28 (Maglionico et al., 2014).

The current monitoring research on the green roof prototypes are about the investigation of several performance factors such as rainwater runoff reduction, the potential of green roofs in the storm water management, the adaptation of native plants on the roof comparing with the sedum ones, the implementation in the green roof design with recycled materials for a lighter and sustainable substrate, a LCA study and a Cost-Benefit study on the green roof technology. The next research is about energy saving, the Heat Island Effect mitigation and the removal of air pollutants (Maglionico et al., 2014).

The green roofs project is revealed significant not only because is a pioneer application of Transition Technologies described in Chapter 7, but also for the transdisciplinary nature of the project. Indeed, the experimentation was mainly promoted by a research group of professors, researcher and students from the Department of Civil, Chemical Environmental and Materials Engineering (DICAM). Even though, other researchers were directly involved in the project design such as the Interdepartmental Center for Research and Innovation (CIRI), the Agriculture Department (DIPSA) and the administrative and technical division

(AUTC) of the University of Bologna. Furthermore, the monitoring and simulation phase has been carried out by University of Bologna in collaboration with the Columbia University of New York. In particular, both roof sections (green and black see Figure 73) were instrumented to monitor runoff profiles within the roofing systems using two types of custom designed devices: a surface hydraulic device made in the DICAM-CIRI, UNIBO laboratory and an in-pipe runoff weir sensor made in the Columbia University laboratory.

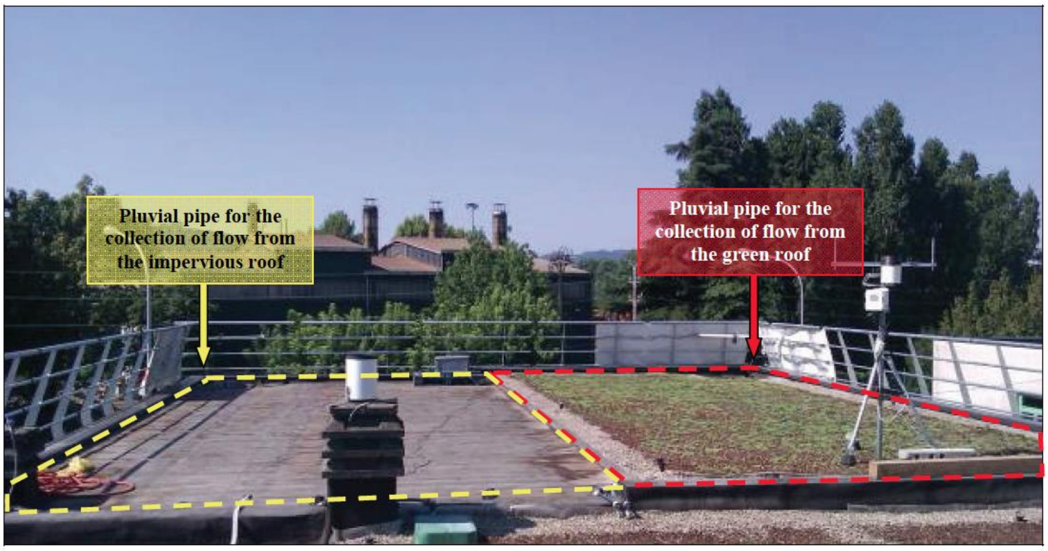


Figure 73: Representation of the green roof and the impervious roof with the bituminous membrane (Maglionico et al., 2014)

Thanks to these significant initiatives, the Engineering and Architecture School located in Terracini has been chosen as the place for experimenting a transition process at university domain. Of course other remarkable sustainable initiatives already existing within University of Bologna, but in this thesis I refer to my own experience implemented in Terracini campus. The challenge is that the campus could considered as *transition niche* in which to apply strategies and actions driven by an holistic and transition approach.

9.6 Application of Transition Management

Several interesting transition frameworks can be considered in setting up a framework for sustainability transition in university system. As university is a complex system (Sharp, 2002), it can be examined with a multilevel perspective (Rip and Kemp, 1998, Geels, 2002, Schot and Geels, 2008). But in case of nascent initiatives, a most promising transition approach broadly applied for managing complex societal systems is Transition Management (TM) (Rotmans and Loorbach, 2009). As shown in chapter 5, TM has been developed basing on practical and theoretical understanding of sustainability transition studies and aims at influencing the direction and pace of societal change dynamics in the context of contributing to sustainability. The process of Transition Management has been described in chapter 5 and consisting of 4 cyclic steps acting at different level: strategic, tactical, operational and reflexive .

Level	Key activities	Key Output
Strategic	- Process design - Reframing challenge - Actor identification - System analysis	Transition team (TT)
Tactical	- Transition Arena formation - Participatory context assessment - Participatory vision process - Selection of key priorities	Transition Lab for Students with the involvement of TT members.
Operational	- Translating the perspective into specific actions - Agenda formulation - Broadening the network - Influencing regular policy - Coalition forming - Implement pilots	Environmental Sustainability Plan Measures as Transition experiments Transition Network
Reflexive	- Learning - Evaluation - Reflection on vision and strategy - Adaptation of strategy	Evaluation of key initiatives and sustainability indicators. New issues and proposal for the Sustainability Plan.

Table 35: TM Process design for Terracini Campus

Table 35 shows the first activity of TM consisting in the process design. The aim is to identify the focus (topic and objectives) of the process, and subsequently the expected intensity of the phases. As detailed above, the focus is to implement a transition process in the university domain for the purpose to obtain a systemic transformation towards sustainability. In the following paragraphs, the phases of TM process for Terracini Campus are described.

9.6.1 Creation of a Transition Team

As largely illustrated, the creation of a Transition Team is crucial for the implementation of a transition process. As the transition team is a multifunctional and transdisciplinary team therefore this phase has seen the engagement of different members of the university community: faculty, staff, administrators, students and transition management experts. Most of involved members has been part of DICAM and in particular of the research group coordinated by Prof. Alessandra Bonoli. On the other hand, personnel involved in sustainability issues were also invited to participate, such as AUTC staff and NuTeR coordinator. According to other transition practices and especially the Transition Towns Movements, Transition Training initiatives were organized with the purpose of supporting the creation of Transition Team. The training has consisted of several modules conducted with the guide of 1 or 2 transition-expert facilitators. In particular, the first module was mostly devoted to sustainability awareness raising and to introducing Sustainability Transitions concepts. Secondly, a 3-day course was organized with the aim to set up, run and grow the Terracini Transition initiative. During the training (see Figure 73), participants were involved in problem identification and in the sharing of ideas with the aim to identify a common vision. Emerged by the training, a first common vision was “to transform Terracini Campus into a living-lab of sustainability”.

Figure 74: Examples of sharing ideas methods realized during the Transition training course.

At the end of the training path, Terracini Team was established and regular meetings have been organized monthly. In addition a logo (see Figure 75) was created and a mailing-list and facebook page too. During the meetings, several sustainability operations-related issues affecting the Terracini Campus have been analyzed. Different working groups have been established dealing with water management, energy efficiency and saving, waste reduction and recycling, sustainability awareness and education, communication.

Figure 75: Logo of Terracini Transition Team

9.6.2 Establishing a Transition Arena

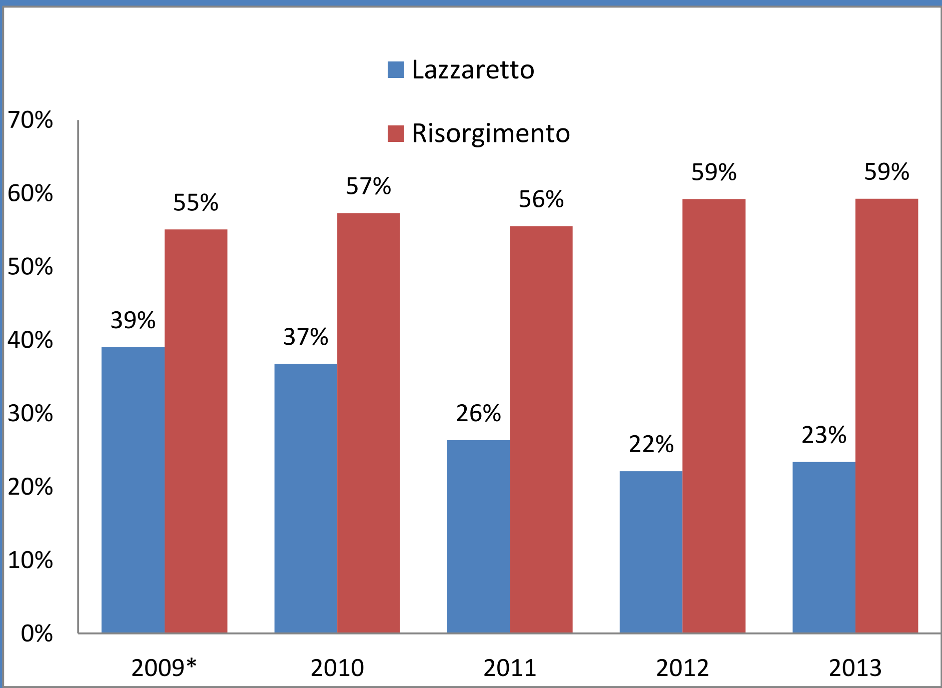
As already observed, most of Transition Team issues are part of the measures included in the Energy and Environmental Sustainability Plan (MOSES) of University of Bologna. Whereas the MOSES plan were due at the end of 2012, several members of Transition Team took part in the preparation of the current plan: the Environmental Sustainability Plan (2013-2016). Consequently, the engagement of the administrative staff together with students, researchers and academia have become crucial for a successful implementation of Sustainability Plan measures. Therefore, the process of Transition Arena formation was began. The Transition Arena objective is to enhance the involvement and the empowerment of the whole university community in the sustainability transition process. To achieve that, a decisive activity called Transition-Lab has been organized in the framework of the MS course on Resource and Recylcing. The Transition-Lab has been devoted to engineering students who have been directly engaged in the design of the Environmental Sustainability Plan measures of the Terracini Campus.

Figure 76: World Cafè session of Transition-Lab.

During the Transition-Lab an experiential learning approach was adopted through the experimentation of several Transition Practice methods such as World Cafè, visioning, etc (Figure 76). With the support of the Transition Team members as supervisors, the students have worked on "real world" problems affecting the Terracini Campus. In the following, two hot spots are described in box 8.1 and 8.2.

Box 8.1 Separate waste collection (Battistini and Bernardi, 2013)

The introduction of a separate waste collection system was firstly located only on some small campuses, such as the Engineering and Architecture School located in via Terracini, Bologna. The initiative had a positive result in the first year with an important increase in the percentage of separate waste, but in the years after, the results were not satisfying (see Figure. Terracini Campus is in blue - Lazzaretto).



Avarage percentage of separate collection (in 2013)

Emilia Romagna	50,1%
Bologna	39,9%
Italy	37,7%
Terracini	26%

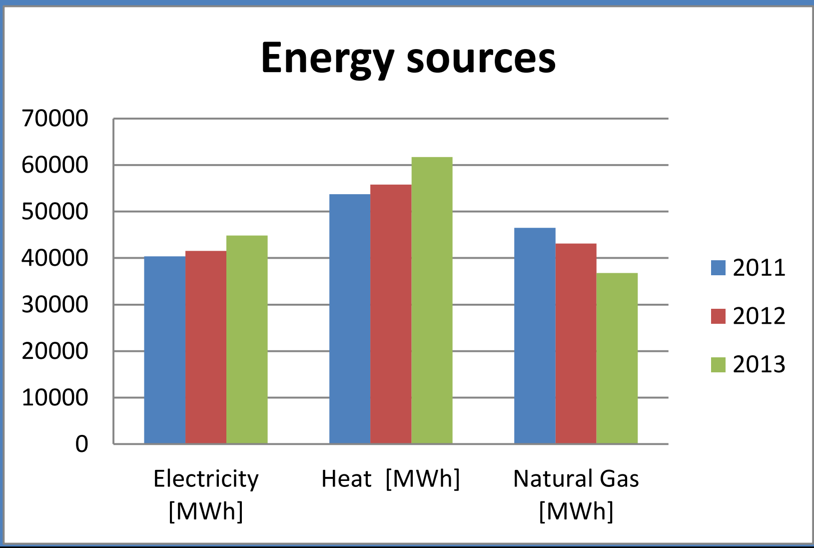
(Source: Battistini and Bernardi, 2013)

Box 8.2 Energy consumption

The table shows that in 2013 UNIBO has consumed about 106583 MWh of Primary Energy, compared to 2012 UNIBO has consumed about 8% more electricity, about 1% more heat and about 17% more natural gas.

Energy	2011	2012	2013
Electricity [MWh]	40342,72	41569,98	44877,31
Heat [MWh]	53744,32	55792,9	61705,12
Natural Gas [MWh]	46523,25	43106,13	36812,43
Tot [MWh]	**94087,05**	**97362,88**	**106582,4**

The increase in consumption is mainly due to the opening of new universities. It should be considered that the university's energy consumption varies notably in relation to seasonal cycles or weather events as well.



The previous graph shows the trend of consumption, is possible to notice that the heat consumption is much greater than the electricity consumption and natural gas consumption. This trend is also confirmed in Terracini Campus. (Source: Battistini and Bernardi, 2013)

As a result, the Transition-Lab has provided a context for students to learn critical thinking and problem-solving skills. The challenges emerged by the Transition-Lab, were strictly connected to campus operations weaknesses and in order to steer a systemic transformation of the campus towards sustainability, a series of transition experiments were proposed (Figure 77).

Figure 77: Transition-Lab experiential learning phase

9.6.3 Transition Experiments

The Transition-Lab has therefore resulted in the design of Transition experiments which consist of practical sustainability measures and actions developed for solving critical aspects of Terracini Campus.

Figure 78: Transition Experiments of Terracini Campus

As shown in Figure 78, the Transition Experiments consisted of experimental green roofs system, flow regulators and timers for water consumption reduction, the introduction of water dispensers in order to reduce plastic waste from bottled water, the creation of Informatics for the Waste of Electrical and Electronic Equipment (IWEEE) Recovery Centre and rainwater collection and reuse.

Transition experiments are outlined in Table 36. As illustrated, the Transition experiment measures were designed by the employment of different Transition Technologies which were also the subjects of the engineering course attended by the students. Some examples of the employed Transition Technologies are: green infrastructures technologies, innovative techniques for water supply, water and groundwater saving, wastewater recovery, raw materials recovery, solid waste treatment, valorization and recycling. More detailed on Transition Experiments are outlined in the Annex II.

Sustainability Issue	Critical aspect	Transition Experiment
Waste	IWEEE management	IWEEE Recovery Centre
Waste	Waste production	Separate Waste collection system
Waste& Water	Plastic waste from bottled-water	Water dispenser "Casa dell'acqua"
Waste	Organic waste management	Compost plant
Water	Water consumption	Water flow regulators Bathroom tap (sensor or pedal) Packaging toilet, Rainwater collection
Land use	Impermeable concrete areas	Green areas
Energy	Energy efficiency of buildings	Green roofs

Table 36: Transition experiments

The results of Transition Experiments are two-fold. Firstly, these experiments have contributed to enrich the measures of Environmental Sustainability Plan. Secondly, Transition Experiments have enhanced the awareness and the engagement of the university community in the sustainability process. A general overview of the results can be seen in Annex III.

9.6.4 Transition Network

Finally, the implementation of transition process has definitely promoted the development of participatory approach not only within the campus of Terracini, but also outside the campus and the whole of the University of Bologna (Figure 79).

Figure 79: Actors of Transition network from Terracini campus to the entire University of Bologna and outside.

In fact, the campus has been transforming into a living-lab, a platform for sustainability experimentation through collaboration and networking among the university stakeholders including external suppliers of goods and services, the local community, public and private sector funding bodies, students' families, etc. Other favorable initiatives that have contributed to the network creation have been collaborations with other universities. Recently, a first exchange of transition experiences has been realized in the context of the European Programme Climate-KIC, Pioneers into Practice Programme (Cappellaro and Bonoli, 2014c). In addition, Unibo has also began the process of taking part in the International Sustainable Campus Network (ISCN). Similarly in Italy, Unibo has promoted the creation of a National Network of Sustainable Universities. More details on the results and consequent recommendations are examined in the following chapter.

10 Discussion and Results

Vision without action is just a dream. Action without vision just passes the time.
Vision with action can change the world.
Joel A. Barker

Recognizing the urgency to adopt a systemic approach for achieving sustainability in a wider sense, this thesis has presented the effectiveness of the Sustainability Transitions (ST) approach. In this framework, the Transition Management (TM) instrument has been investigated and then applied at the university domain. The adoption of TM has contributed to identify a holistic approach for the transformation of the entire university system. In the framework of ST, Transition Engineering provides a valid support, especially regarding the employment of Transition Technologies in the implementation of Transition practices. The empirical part of this research project has consisted in the case of the Terracini Campus, University of Bologna. As shown in chapter 9, the experimentation has comprised the establishment of the Transition Team and the creation of a Transition Arena which have been helpful to re-connect staff, student and faculties. Furthermore, by means of Transition Technologies several Transition Experiments have been launched. Consequently, learning and research outcomes have directly affected the campus operations and simultaneously the transition experiments have provided new resources for learning and teaching into the future. As a result, transition experiments have facilitated the combination of individual building measures and campus-wide planning. Therefore, the living-lab concept has been introduced as an integral part of university sustainability plan. Finally, the transition process has resulted in the creation of a Transition Network, a platform on which to exchange experiences and to influence each other. The Transition process initiated within Terracini Campus can be then considered as a transition niche. Accordingly to Strategic Niche Management (SNM), described in the chapters 5 and 6, the case of Terracini Campus has demonstrated that Transition Experiments contribute to steer the transitions process. Principally, the case has confirmed the duality between experiments and niches. As indicated by Raven et al. (2010), experiments create and reinforce niches and simultaneously niches make transition experiments possible. In the following, it is described how the niche of Terracini Campus has contributed the take-off of the sustainability transitions of University of Bologna. The main consequence is the deepening, broadening and scaling up of transition experiments through the interactive connection with other contexts. Based on SNM (Van den Bosch and Rotmans, 2008), the mechanism of deepening is related to the direct context of the transition experiment (in this case the Terracini niche). Through the deepening, the Unibo actors have learned about new practices, culture and structures that deviate from the existing regime. Within Terracini Campus, many improvements are achieved such as the amplification of the sustainability implementation of University of Bologna. Correspondingly, Terracini transition process has started to contaminate other contexts and the niche experiments are broaden. Finally favorable conditions for scaling up are generated. In the following, several transition processes which are stimulated by the Terracini Transition initiative are illustrated

10.1 Transition to the integration of sustainability at institutional level

The Terracini Transition process has firstly allowed to develop a systemic integration of the HEIs elements such as campus operations, education, research, community outreach, on-campus experiences, assessment and reporting. Definitely, the transition initiative has intensified and deepened the implementation of sustainability process within the University of Bologna. In particular, Terracini Transition has mainly shaped the Energy and Environmental Sustainability plan which has been transformed from an energy-related plan (2009-2012) into whole-sustainability plan. Accordingly, the title of the plan has indeed changed from “MOSES-Mobility Sustainability Energy Solutions” into “Environmental Sustainability plan” (see Figure 80) .

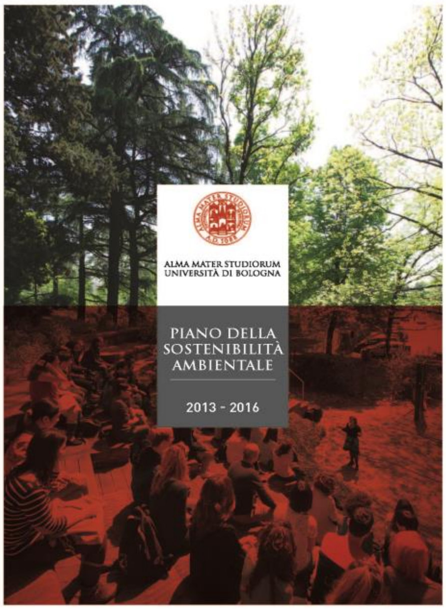


Figure 80: Environmental Sustainability Plan (2013-2016) (Battistini and Bernardi, 2013)

With reference to the Environmental Sustainability Plan, the measures devoted to environmental issues of sustainability have increased from 2 measures in the 2009 (related to waste and sustainability awareness) to 11 measures in the 2013.

Goal	Measure
Reducing natural resources consumptions and conservation	AMB 1. 1 Extension of separate waste collection to all Unibo Bologna campuses AMB 1. 2 Water drinking fountain
Expanding green spaces	AMB 2.1 Flowerbeds AMB 2. 2 Expansion of green areas AMB 2. 3 AlmaTree AMB 2. 4 Green and Flower Terraces
Improving social sustainability	AMB 3. 1 Barrier Free for the Disabled Accessibility AMB 3. 2 Sustainable Food
Increasing the sustainability awareness of university community	AMB 4. 1 Participation in the ISCN Network AMB 4. 2 Education AMB 4. 3 Sustainable Patrol

Table 37: Environmental sustainability measures of the Unibo plan (2013-2016).

Thanks to the introduction of the Terracini Transition process, the plan has considered not only separated measures but also integrated measures related to specific university campus. At first, thanks to the proposal of Transition experiments, several integrated measures for Terracini Campus are included, such as water drinking fountain, green areas, green roofs and sustainability educational programs. In addition, other measures are also devoted to other campus such as the School of Agriculture and Veterinary Medicine located in via Fanin, Bologna.

Corresponding to this transition process, also AUTC Division has structural changed. Firstly, its designation has shifted from "Energy, Mobility and Innovation Sector" to "Environmental Sustainabilty and Facilities Management Sector" and the Unibo sustainability coordinator has been established. At the present, the mission of the AUTC Sector is: "to define strategies in the context of environmental sustainability and facility management, taking care of the relationship between the building and environmental context, working in collaboration with the university departments and divisions and with the sustainability coordinator of the university. The activities are conducted primarily in measures to energy saving, promotion of sustainable mobility, realization of eco-compatible architectures, environmental conservation; real estate management, in view of the maintenance over time of the building and the continuous improvement of services and its functions".

10.2 Transition to transdisciplinary research team dedicated to sustainability

Another interesting context affected by the transition process has been the framework of the Unibo research initiatives. The transdisciplinary approach of Terracini Transition process has inspired the creation of an Integrated Research Team (IRT) especially dedicated to the fields of energy, environmental sustainability and the transition towards a "low carbon" society. As seen in the Chapter 9, heretofore any IRTs were strictly dedicated to sustainability. In 2014, a multi-disciplinary group named Alma Low Carbon was however established. Alma Low Carbon is composed over one hundred professors, researchers and research staff from over twenty university departments: a significant critical assembly, aiming to improve scientific and technological exchanges and relations with socio-economic areas to foster the development of new ideas in research and innovation. This objective is achieved by the cross-fertilisation of the different expertise working together in Alma Low Carbon, tackling challenges in the energy and environmental fields (Figure 81).

Figure 81: Alma Low Carbon logo

The Alma Low Carbon Integrated Research Team coordinates the scientific competencies of the University of Bologna in the following research area:

- Energy Efficiency
- Competitive Low Carbon Energy
- Waste: a resource to recycle, reuse and recover raw materials
- Water: boosting its value for Europe
- Sustainable supply of natural resources and raw materials
- Growing Low Carbon, resource efficient economy with sustainable supply of raw materials

- Social, environmental and Economics aspects of the energy system

Alma Low Carbon has been instituted as a qualified interlocutor and key partner for all stakeholders in the sector, for academic, industrial and strategic initiatives: a single point of access for the many energy and environmental competences of the University of Bologna.

Figure 82: AlmaLow Carbon Kick-off event

As illustrated in Figure 82, the kick-off event of Alma Low Carbon establishment was held in October 2014. This event has involved the City of Bologna Mayor, the University of Bologna Chancellor as well as the Vice Rector for Research and other University and Regional exponent. As key-speaker Rob Hopkins, Transition Towns movement co-founder, was hosted.

10.3 Transition to the participation in international network and rankings

As listed in Table 38, one of the measure concerns the participation in the International Sustainable Campus Network (ISCN), that provides a global forum to support leading colleges, universities, and corporate campuses in the exchange of information, ideas, and best practices for achieving sustainable campus operations and integrating sustainability in research and teaching.

Subsequently, the inclusion of Unibo in the UI GreenMetric ranking has been achieved. In the following the rate of Unibo performances are outlined.

	Rank	**Overall score**	**Setting and Infrastructure**	**Energy and Climate Change**	**Waste**	**Water**	**Transportation**	**Education**
Weight			*15%*	*21%*	*18%*	*10%*	*18%*	*18%*
2014	96°	6,094	557	1,460	1,650	750	1,325	351
2013	182°	4,680	654	0,960	1,425	125	1,200	325

Table 38: Unibo Performances in the GreenMetric Ranking (UI, 2014)

On January 2014, UI Greenmetric World University ranking (UI, 2014) was published. It can be observed that Unibo has scaled up the ranking and has shifted from the 182nd (of 300 university) position in 2013, to 96th (of 535) in 2014. This excellent result has been certainly achieved also thanks to the transition process which has involved AUTC and other Unibo Department in the improvement of sustainability performances. Presently, Unibo is placed first as Italian university in the ranking, followed by the University of Torino (99th),University of Bari (140th), University of Padova (142nd), Cà Foscari University of Venice (153rd), Polytechnic University of Milan (163rd).

10.4 Transition towards an Italian Sustainable Campus Network

Driven by a proposal of University of Bologna, the creation of an Italian Network has been launched (Bonoli et al., 2015). The proposal was born with the purpose of joining the different experiences of several Italian universities, since most of which are committed to sustainability and members of ISCN. Actually, the network involves more than ten of excellent Italian universities that are realizing relevant practices of sustainable campus. The involved universities are listed below:

- Bari Polytechnic
- Polytechnic University of Milan
- Polytechnic of Torino
- University of Torino
- Verona University
- University of Milano-Statale
- University of Milano-Bicocca
- Ca' Foscari University of Venice
- Venice International University
- University of Ferrara
- University of Salerno
- IED- European Institute of Design, Roma

Therefore the network is a powerful initiative to share experiences, to contaminate each other. A future objective could be the promotion of national strategies supporting sustainability campus implementation and management.

10.5 Transition to the university engagement in local agreements

The University of Bologna has recently subscribed the SEAP - Sustainable Energy Action Plan of City of Bologna (PAES, 2015). As seen in chapter 6, SEAP is a document that defines energy policies of the local authorities (in this case the City of Bologna) in order to reach the European target of reducing CO2 emissions by 20% by 2020. This goal has been pursuing by actions to reduce energy consumption of the city and increase the production of energy from renewable sources. Recently, a it was activated a process of stakeholder engagement, in order to share and to promote energy initiatives. The process has involved more than 150 organizations and launched a series of implementation projects.

10.6 Transition to transfer the university sustainable innovation to other stakeholders

Another significant initiative which has involved Unibo is the European campus network project Sustainable Campus Launching Customer (SCLC). SCLC presents the adoption of sustainable transitions approach developed by several European Campus in the framework of the European Institute of Innovation & Technology Climate-KIC Program. The pathfinder project SCLC aims to bridge the societal demand for climate innovation and the scientific knowledge supply from a network of nine European university campuses (Cappellaro et al., paper approved).

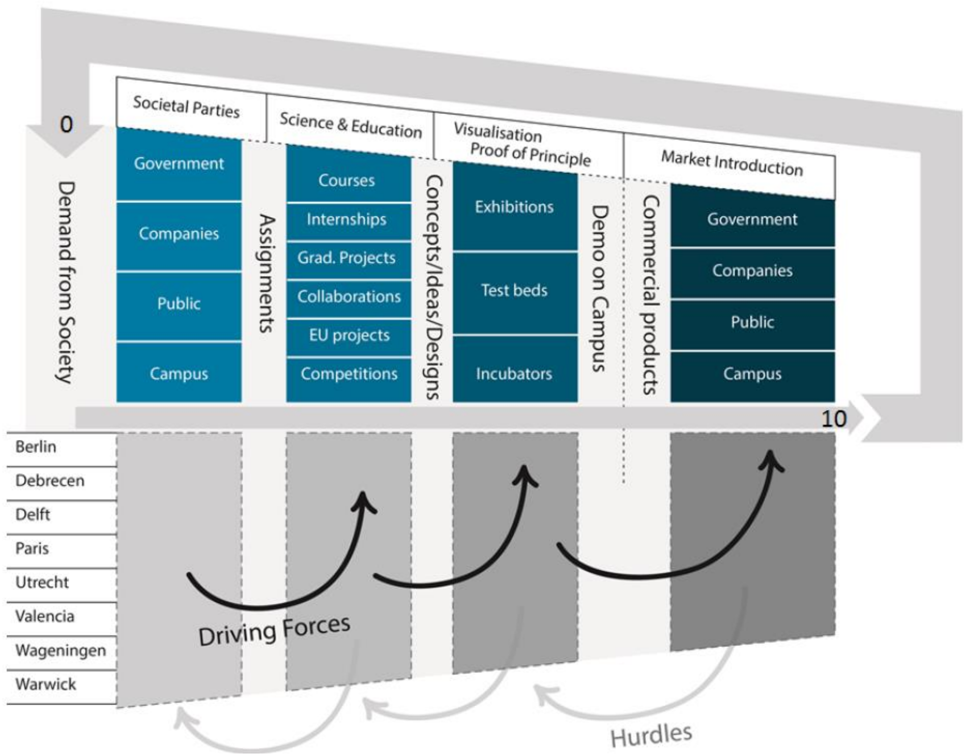


Figure 83: University's low carbon innovation approach in the context of SCLC Project (Cappellaro et al., *paper approved*).

The creation of SCLC European campus network aspires to function as climate innovation engines. As Figure 83 shows, SCLC aims at bringing climate innovation research into the market, making use of the nine European university campuses as test-beds prior to implement climate innovations into the market. With the ambition to remove the aforesaid barriers, universities engaged with the project have a shared research interest in sustainability and high motivation for their campus. They address a great variety of focus areas, ranging from local energy use to implementing low carbon transport systems. In most of the cases the campus is used as a living-lab to make testing in practice possible. In addition, it will create synergies between innovative initiatives from different thematic foci, aiming for interventions at supra building level (beyond traditional unit level) and impact on regional scale. Some of the thematic foci taken into consideration in the SCLC project are: energy, environment, assets, biodiversity and infrastructure, innovation demand and knowledge supply, living lab, entrepreneurship, best practice cases. The core of the project has consisted of sharing amongst the partners best practices of approaches and research-valorization examples. Indeed, a lot of climate innovation is already taking place on different campuses.

Alma Low-Carbon Integrated Research Team	Inter-disciplinary research group of more than 160 teachers and researchers from various department, who share research interest in sustainability and climate change issues.
Environmental Sustainability Plan (2013-2016)	Sustainability Action Plan, measures and actions, such as energy-efficiency, water and resource use, waste management and eco-building by the adoption of the appropriate technology
Green roofs	For the "green roofs" project two green roofs on a lab of the Engineering and Architecture school were realized to be studied and monitored.
Sustainability Transitions-Lab	Sustainability Transitions laboratory, specific sustainability measures have been designed with the engagement of engineering students.
Transition Team Terracini	Transition Team aims to steer the transition process in order to create a living-lab of sustainability. The team involves researchers, professors, administrative staff, technicians, PhD and Master students.

Table 39: Unibo Diamonds in the framework of SCLC Project

By sharing best practices, called diamonds, inspiring each other, defining what this project is looking for and what is worth sharing the amount of examples, processes and strategies can grow very fast. The diamonds have shown that all participating campuses have embarked on a sustainability strategy with diverging focus areas, like water, energy, resources and mobility, and with varying impact. Whereas some campuses only deal with incremental innovations like replacing light bulbs with LED-lamps, other campuses are developing visionary playgrounds to experiment with all kinds of new sustainable innovations. Unibo has presented several diamonds (see the Table 39). The full collection of diamonds is available at the link: www.sustainablecampus.eu/eplanete/diamonds/

10.7 Conclusion

The transition towards sustainability of University of Bologna has now began. However, due to the high complexity of multi campus management, further improvements are still required. An example is the implementation of a sustainability indicators monitoring system in compliance with the ISCN Guidelines. The university monitors different aspects of sustainability (i.e. Energy, Water, Waste, Mobility), but there is no system for monitoring emissions of CO2. Other future perspectives may concern the definition of strategies in order to extend the sustainability communities actively engaged in sustainability. Despite involving only single campuses, the whole university has to engage. The first conclusion emerged by the experimental case of Terracini Campus is that Sustainability Transitions has led up the initiation of a new paradigm for developing sustainability as an integral part of the university system. By pooling this knowledge of best practices, solutions and lessons learned, the transfer of experiences in a vital network becomes substantial for a successful transformation of higher education institutions into places of sustainability. Terracini Campus has been revealed as a living-lab in which Transition Engineering technologies and participatory processes can be developed involving different stakeholders from inside and outside academia. As a result, the link between university formal commitment and users engagement and behaviours have been strengthened. Furthermore, Terracini Transition process provides a learning platform through knowledge and enabling people to network and create communities of practice. Definitely, universities and their campuses can be great sources of sustainable innovation brought about by their scientists, students and entrepreneurs. Although universities have the potential to be leading change agents in both climate change mitigation and adaptation, currently they are, in many respects, coming up short. Accordingly, several hurdles concur to limit the potential of university. For instance many of the innovative ideas developed at universities are not taken any further than the research stage. Consequently, a great amount of potentially significant innovations is being ignored, while very few are actually being implemented. In this context, there is the need to bridge this systemic gap through novel approaches, both at campus level and between the different stakeholders. Correspondingly, the development of new social norms and cooperation can allow to consolidate the link among various organisations and institutions This establishes favourable conditions for scaling up the transition process. With this purpose, the Terracini Transition experiment has demonstrated that living-labs of sustainability may become a initial mechanism for experimenting a novel approach of collaboration, learning and adaptation. According to resilience thinking, these collaborative, flexible and learning-based approaches allows to build resilience system. Connectivity, as networks of people and organisations at multiple levels, consents to enhance our capacity to withstand crisis events. Absolutely, the transition to sustainability opens up new challenges, but also tremendous opportunities to overcome boundaries towards a better future.

11 Conclusions and recommendations

Emerging at the end, we will not be the same as we were; we will have become more humble, more connected to the natural world, fitter, leaner, more skilled and, ultimately, wiser.
Rob Hopkins

This thesis explored *Transition* as an emerging approach to sustainable system innovation. In our increasingly unpredictable world, there is a growing need for effective solutions to the multiple challenges facing humanity. Resource constraints, financial instability, socio-economical inequality and environmental degradation are all aspects of the global crisis affecting our times. The development of sustainable and resilience-building systems has become a strict necessity for our future. The global crisis is the greatest challenge of the 21st century. In fact, the current geological period has been labelled as ‘Anthropocene’ - the age of man. However, crisis is a tremendous opportunity to transform the ‘business-as-usual’ model into sustainable one. Currently, the global crisis and related sustainability challenges are calling for a fundamental change in culture, structures, and practices. This thesis reported an in-depth investigation and experimentation of different strategies, approaches and technologies for effective advances in making sustainability transitions happen. A special focus was devoted to evaluate the technical-technological, transdisciplinary and ethical role of Engineering in the process of transition towards sustainability. Engineering is indeed both a profession and a discipline whose aim is to apply the knowledge and results of Mathematical, Physical and Natural Sciences in order to contribute to the satisfaction of human needs. In providing people with sustainable options, engineers are ethically required to hold the safety, health and welfare of the public paramount and to satisfy society's need for sustainable development. This thesis embraced Sustainability Transitions (ST) as promising frameworks for radical system innovation towards sustainability and for the adoption of a transdisciplinary approach to Engineering. To this purpose, different but correlated objectives were finally achieved.

The **first objective** of this thesis was to characterize different approaches and initiatives to face the sustainability challenges in order to recognize all the potential of sustainable innovation (Chapter 3, 4, 5, 6). Actually, in spite of the variety of sustainable innovation approaches, “there is an untapped potential of sustainable innovation and its intensity is not-yet enough” (EIO, 2013). In order to find an effective approach, the evolution of sustainable innovation was first analyzed. As shown in Chapter 3, sustainable innovation has evolved from the pollution control and end-of-pipe approach, through preventive cleaner production and life-cycle approaches, before reaching proactive approaches such as closed-loop production and industrial ecology. Furthermore, the perspective of sustainable innovation was expanded beyond the production-side to include the consumption-side.

Secondly, the urgency of a radical systemic transformation was recognized. This means transformative change in the entire system of practices and provisions. Additionally, various aspects characterizing innovation towards sustainability were identified. One of the first aspect concerned the heart of the sustainable innovation approach which was not necessarily represented adequately by a single set of target and mechanism characteristics. Instead, sustainable innovation was found to be best examined and developed using a range of characteristics including the modifications or creation of products, processes, organizations, social aspects and institutions. Another aspect, the growing importance of actors and networks in the innovation process towards sustainability arose, became evident. Further aspects recognized that a dichotomy between technology-oriented and behaviour-oriented approaches has not been necessary. Rather, a *co-evolutionary* approach could be adopted. In fact, the purpose of co-evolutionary approach was to abandon the competition in favour of collaborative and inclusive approach.

In Chapter 4, the role of a co-evolutionary approach was investigated by two case-studies of sustainable innovation. The first case has regarded the automotive industry sector and the other has related sustainable innovation at the urban level. In particular, the introduction of a water fountain in a small town in Italy was investigated. Both cases confirmed the co-evolutionary approach and demonstrated that not only technological aspects, but a number of complementary agents have functioned as key drivers for change development.

In conclusion, I found that sustainable innovation has to occur at broad system level. In fact, several international studies have emphasized the growing urgency of radical system innovation to pursue sustainable development goals. Hence, this thesis confirmed the need for system innovation and the correlated need for a socio-technical system approach (Chapter 5).

The **second objective** of the thesis was to identify an effective approach to facilitate radical system innovation towards sustainability. In particular, the Theories of Sustainability Transitions (TST) was recognized as a valid research field and framework to move towards more sustainable systems. In effect, Sustainability Transitions (ST) are directed toward redesigning entire systems of practice and provisions. The thesis recognized that ST can go beyond incremental environmental improvements and efficiency gains. Consequently, ST allow for the adoption of a systemic approach to steer and create pervasive change in socio-technical system. In Chapter 5, different frameworks which emerge from the TST have been explored, such as Technological Innovation System (TIS), Multi-Level-Perspective (MLP) and Strategic Niche Management (SNM) and Transition Management (TM). All these theories aim at developing a co-evolutionary approaches and highlight the multi-dimensional inter-connection of actors and socio-technical regimes. The thesis has also emphasized the role of *niches* in the transition path. According to TST, niches are small-scale protective spaces where actors experiment with radical innovations which may challenge and break-through into the prevailing regime. In these protective spaces, innovation is shielded from the mainstream selection pressures and has potentially radical consequences. Basically, niches enable experimentation and learning about novel or deviant culture, practices and structures. Similarly, niches themselves are also shaped by learning experiences that become aggregated and embedded in new or deviant constellations of culture, practices and structure. Moreover, the notion that niches and experimenting are crucial for stimulating transitions was confirmed. With the aim to prove the fundamental role of experimenting, a series of inspiring Transition Practices that allowed for the identification of advances in making sustainability transitions happen, was studied. As shown in Chapter 6, several transition initiatives were implemented especially at the urban level. In particular, two cases of urban transition were analyzed under the lens of transition: the top-down initiative of Sustainable Energy Action Plan (SEAP) of the city of Bologna and the bottom-up initiatives of Transition Towns. Both cases helped to identify interesting aspects which contributed the acceleration of transition processes. Two fundamental drivers were distinguished: the importance of supporting multi-stakeholder collaborations and the combination of top-down and bottom-up approaches. Finally, the thesis endorsed the effectiveness of transition approach in combining the theory and practice of sustainability in a co-creation process with the community. From a theoretical point of view, the concept of experimenting in practice to learn about possible and desirable transition pathways was emphasized. To this purpose, the framework of Transition Management (TM) was embraced. Actually, TM is an instrument able to steer sustainability transition process effectively. Indeed, as described in Chapter 5, TM was characterized by a prescriptive cyclical process of co-evolving activities able to influence the transition towards sustainability. From an empirical point of view, a model for successful transition practices was recognized: the living laboratory (*living-lab*). As shown in Chapter 6, living-lab was revealed as a model of the co-creation of innovative technologies and services with active participation of users. Finally, transition practices in turn were also identified as catalysts for the living-lab in a mutual learning processes.

Recognizing the effectiveness of ST approach, the **third objective** of thesis was to distinguish the role of Engineering in both Sustainability Transitions Theories and Transition practices. In fact, the adoption of transition approach requires a new role for the research in the field of science of sustainability. To this purpose, sustainability research needs to be *transdisciplinary*. As described in Chapter 7, transdisciplinarity means to meet the following requirements: (a) focusing on societal relevant problems; (b) enabling mutual learning processes among researchers from different disciplines (from within academia and from other research institutions), as well as actors from outside academia; and (c) aiming at creating knowledge that is solution-oriented, socially robust and transferable to both the scientific and societal practice. In this framework, the thesis aimed to delineate a new role of Engineering embracing transdisciplinarity. According to the European Sustainable Development Network (ESDN) indications for the sustainability research, a transfer of scientific approaches beyond the boundaries of traditional disciplines has been encouraged. Accordingly, the thesis supported and strengthen the concept of *Transition Engineering* (TE). TE was firstly defined by Krumdieck and Dantas as an emerging field committed to drive engineers going beyond sciences and reorganizing processes for the reunion of the science with the society. Actually, TE has revealed a disconnection from the other TST. The thesis improved TE concept and connected it to TST. The connection has been based on the correlation between TE and TM.

Another concept connected to TE has been the introduction of the notion of Transition Technology (TT). In particular, the thesis has defined TT as technical instruments of TE allowing to combine the promotion of sustainability and the enhancement of resilience within transition process. A practical example of TT presented by the thesis has been the green roof. In fact, the green roofs offer several benefits related to the improvement of sustainability and resilience performances. Moreover, the green roofs allows the creation of places in which the comfort of sustainability can be experimented. Therefore a behavioural change has been facilitated. In general, TT could be recognized as instruments to trigger a direct experience of sustainability. Consequently, a raising awareness process and a reinforcement of actors engagement toward sustainability could be generated. As final consideration, TT combine to bring about the success of transition process and the co-creation of living-labs towards sustainability. As a result, the notion of TT introduced by the thesis allowed to deepen the empirical basis for Sustainability Transitions research. Thus, the TST application domains has been expended.

The **final objective** of the thesis concerned the practical experimentation of the theoretical frameworks presented above. The aim of the experimentation is to demonstrate the effectiveness of both ST approach and TE strategies and technologies. The experimentation has mainly consisted in facilitating a real transformation of a complex and fundamental system as university is. As described in Chapter 8, university can play a significant role in forging the path to a sustainable future. Actually, university can teach and demonstrate the theory and practice of sustainability and as the training area for future leaders has therefore a specific responsibility to move society towards a sustainable future. Nevertheless, the sustainability of university still lacks of a fully adoption through a systemic approach. For all these reasons, university has been chosen as the application domain of the transition process experimentation. In particular, the experimentation has consisted of the implementation of a systemic transformation of the School of Engineering and Architecture of University of Bologna at Terracini Campus. The challenge has been to make sustainable development an integral part of university system'. This means to connect different but interrelated HEIs elements such as education, research, campus operations, community outreach, on-campus life-experiences, assessment and reporting. As shown in Chapters 9 and 10, TM and TE were chosen as methods and instruments to guide the Terracini Transition process. At the end of this experimental project, several results were achieved. First of all, the creation of a Transition Team in Terracini Campus. In the second place, the realization of living laboratory of sustainability involving engineering students, staff and academia has realized the establishment of a Transition Arena. Both the Transition Team and Transition Arena were helpful to re-connect staff, student and faculties. Furthermore, the transition process has initiated a transformation of Terracini Campus into a living-lab of sustainability. The living-lab was based on the experimentation of TE instruments and strategies. In particular, the design of transition experiments have employed several Transition Technologies, such as green infrastructures, innovative techniques for water supply, water and groundwater saving, wastewater recovery, raw materials recovery, solid waste treatment, valorization and recycling. The final result has been the Transition Network: a platform to exchange experiences and to influence other stakeholders.

At the end of the transition experimentation, Terracini Campus could be considered as a transition niche. According to the theory of SNM, favourable conditions for broadening and scaling up the Terracini 'niche' were shaped.

Actually, Terracini in Transition has begun to broaden and to contaminate other contexts. Thus, the integration of sustainability has start to contaminate the institutional level. Some examples of the broadening process have been: the creation of a transdisciplinary research team dedicated to sustainability (Alma Low Carbon), the participation in international network (ISCN, Italian Sustainable Campus Network) and the higher classification of Unibo in the UI GreenMetric ranking. Other exemples of the scaling up process have been: the university engagement in local agreements as SEAP of Bologna and the involvement in the project Sustainable Campus Launching Customer (SCLC). All these experiences can provide the opportunity to transfer the sustainability innovation generated by the university to other stakeholders.

To conclude, the consequences of this thesis were two-fold. Firstly, the thesis promoted the initiation of a new paradigm for the Engineering discipline (**Transition Engineering, TE**). TE has been also connected to the sustainable system innovation frameworks, especially to the Theories of Sustainability Transitions (TST). Secondly, the thesis has demonstrated the effectiveness of the transition process to achieve a system innovation in a specific context: the School of Engineering and Architecture of University of Bologna (**Engineering in transition**). Future perspectives could concern both theoretical and practical aspects. A recommendation for the theoretical point of view is related TE. Further developments and implementations of TE are required, especially for what concerns Transition Technologies. Actually, there is the growing necessity to integrate mitigation and adaptation technologies. Therefore, new strategies, tools and analytical methods should be developed for the promotion of sustainability and the enhancement of resilience. In particular, the concept of resilience should require a further investigation adopting transdisciplinary and analytical approaches.

Other recommendations are related to the practical experimentation. Concerning the transition practices initiated by this research project, the success of Terracini Transition process could be extended to other campuses or areas of University of Bologna. At the same time, the Sustainability Action Plan of Unibo should be more expanded promoting a transition approach. Another recommendation concerns the adoption of analytical methods and assessment indicators. In fact, the sustainability progress should be reported by more comparable and quantitative targets such as CO2 emissions reduction or other GRI indicators. Finally, it would be interesting to prove the effectiveness of the university transition model by the transfer and the experimentation to other scales, i.e. urban scale or organizational scale.

In conclusion, this work has shown that it is possible to generate concrete strategies and approaches toward solutions that tackle the complex, dynamic factors fuelling the global crisis. Sustainability is definitely an opportunity to shape our future. It is up to us to embrace this challenge.

Glossary

Anthropocene: The Age of Man, a new name for the present geological epoch defined by our own massive impact on the planet's climate and ecosystems. Coined in 2000 by Nobel Laureate Paul Crutzen.

Competence: Competences are conceived of here as the combination of explicit and professional knowledge, 'implicit' or tacit knowledge, skills and attitude.

Culture The sum of shared images and values (paradigms) that together constitute the perspective from which actors think and act. Changes in culture comprise shifts in thinking, mental models and perceptions.

Innovation: Innovation is the creation of better or more effective products, processes, services, technologies, or ideas that are accepted by markets, governments, and society. Innovation differs from invention in that innovation refers to the use of a new idea or method, whereas invention refers more directly to the creation of the idea or method itself.

Institutions: A central concept within the social science of natural resource management whereby institutions are defined as the norms and rules governing human interactions. These can be formal, such as rules and laws, but also informal (unwritten), such as norms and conventions of society.

Landscape: Term from the Multi-Level-Perspective (MLP). Most often this is understood as the external and social context that enables and constrains the possibility for regime change; the outcome of behaviour/decisions of many people and major changes in society of natural conditions. Examples of landscape developments are: demographic developments, increasing encroachment and interference of state, onset of climate change or fluctuating oil prices. Also major crises are considered to be elements of the landscape.

Learning: An (inter) active process of obtaining and developing new knowledge, competences or norms and values. Literature on transitions to sustainability emphasizes the importance of social learning - a process in which multiple actors interact and develop different perspectives on reality. In transition processes an important aspect of social learning is second-order learning: reconsidering or changing the 'frame of reference' and perspective of actors involved. First-order learning involves learning about the problem, analysis or solution of a problem, but with preservation of the initial theoretical insights or deeper beliefs or values.

Multi-level perspective: The Multi-Level Perspective (MLP) or Multi-Level-Model is a prominent framework that has been developed to understand and analyse transitions. The MLP distinguishes between the meso-level of 'socio-technical regimes', the micro-level of 'niches' and the macro-level of 'landscape trends and developments'. Within this model, transitions are conceptualized as the result of different dynamics and interactions between these levels.

Niche: A new and relatively unstable set of rules and institutions for innovative practices. More abstractly: a 'space' or 'location' that is protected from the dominant regime and which enables actors to develop and apply an innovation without immediate or direct pressure from existing regimes.

Natural capital: An extension of the traditional economic notion of capital, coined to represent the natural assets that economists, governments and corporations tend to leave off the balance sheets. It can be divided into non-renewable resources (e.g. fossil fuels), renewable resources (e.g. fish) and services (e.g. pollination).

Persistent problems: are complex and involve uncertainties because of many causes and consequences; are embedded in the dominant regime/institutions; have the involvement of many and various actors who have to work together for a solution but most often have varied goals or agendas. Consequentely, persistent problems are difficult to solve and often recur notwithstanding various efforts to overcome them.

Regime: Coherent and dominant rules and institutions that guide actors (e.g. firms, users, policy actors, scientists) in a specific direction, by enabling and constraining their choices. A distinction can be made between:

- Regulative rules or institutions: formal rules, laws, sanctions, incentive structures, reward and cost structures, governance systems, power systems, protocols, standards, procedures;
- Normative rules or institutions: values, norms, role expectations, authority systems, duty, codes of conduct;
- Cognitive rules or institutions: priorities, problem agendas, beliefs, bodies of knowledge (paradigms), models of reality, categories, classifications, and jargon/language.

Reflexive monitoring: a participatory process of gaining insight into how a transition project or programme progresses and into its effects, in relation to, and in interaction with, the context followed by reflection on this, and on the initial starting points for the project or programme and on initial, more deep beliefs which probably are questioned and the adaptation of the project or programme on the basis of the conclusions of the collective reflection in order to sustain the ambition of system innovation.

Resilience: The capacity of a system – be it a forest, city or economy – to deal with change and continue to develop; withstanding shocks and disturbances (such as climate change or financial crises) and using such events to catalyse renewal and innovation.

Societal challenge: An issue related to a persistent societal problem, which guides the search and learning process in a transition experiment. An example of societal challenges is how to realize a sustainable, i.e. clean, reliable and affordable energy supply system. Another example is how one can deal with the ageing of the population and rising costs in health care, and still provide for good health care.

Transformation: The creation of a fundamentally new system when ecological, economic or social conditions make the continuation of the existing system untenable.

Vulnerability refers to the propensity of social and ecological system to suffer harm from exposure to external stresses and shocks. Research on vulnerability can, for example, assess how large the risk is that people and ecosystems will be affected by climate changes and how sensitive they will be to such changes. Vulnerability is often denoted the antonym of resilience.

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ANNEXES

ANNEX I – Examples of methods for Transition Practices

Method for System Analysis: Multi-Level-Perspective (MLP) Analysis

Challenge	Defining the relevant societal context of a transition practice.
Description	The multi-level model can be applied to identify the major barriers and possibilities for the context of transition practice on three levels: macro, meso and micro. • The landscape level: exogenous major social changes in the field of politics, culture and world views (such as globalization and individualization) or natural characteristics that are difficult to influence and usually change slowly. Landscape developments are the outcome of ideas and acts of a great many players, that you have to deal with. • Regime: the structural layer that constitutes the context of common practice. This entails the institutions, such as sets of legal and financial rules and procedures, the existing actor configuration (who matters; who do not), physical infrastructure and culture including certain mental models • Niches with innovative, social, economic, technological or policy practices, that deviate and are protected from the dominant structure. Niches with innovative, social, economic, technological or policy practices, that deviate and are protected from the dominant structure.
Results	Define the relevant landscape developments, regime elements and other relevant niche projects for the transition practice. Next, define the implications for vision and activities. Relevant landscape developments have to be taken into account, since they cannot be influenced. Instead, one can only adapt or reframe the project or programme to make it more evident or attractive given the developments at this level. Unfavorable regime be changed, at least in principle, or one could start with finding a niche-regime with more advantageous conditions.
Source	http://www.transitiepraktijk.nl/en

Method for System Analysis: SWOT analysis

Challenge	Prioritizing actions and experiments.
Description	SWOT Analysis is used to structure insights and to evaluate the Strengths, Weakness, Opportunities and Threats involved in a project, or any other situation requiring a decision.

	The SWOT analysis identifies: • Strengths: internal characteristics which may be deemed favourable. • Weaknesses: internal characteristics which may be deemed unfavourable • Opportunities: external characteristics which may be used to take an advantage. •Threats: external characteristics which may be potential sources of failure.
Results	The SWOT analysis can be useful to reveal which problems can be addressed and for which problems actions are required at other institutional levels. A SWOT analysis can be done for the current situation, but also for the future situation (indicating the expected strengths, weaknesses, opportunities and threats), or both.
Source	http://www.themusicproject.eu/

Methods for sharing the vision: Visioning

Challenge	Visioning is meant to open up new, guiding futures and may help to prevent locking-in into existing practices and may also have a mobilising power.
Description	A simple visioning method is described in the following: 1. Begin by choosing a function: e.g. housing, mobility, food production, water management, and in the case of a group assignment form small groups around this function. In addition, choose a physical environment, such as a region, district, or collection of buildings. Also, you could probably choose a production chain, or you can combine the different points of departure. Note that as your vision creation process proceeds, you may adapt and refine your original definition as required. 2. Start the visioning. Image that you are in the future and in a low-carbon society - say in 2050 - and that you are showing your child or grandchild what the function looks like, for example, mobility in your region or housing or a food production (chain). Make it as concrete as

	possible, for example, when and how do you, others or goods go from one place to another other (in the case of mobility)? How and where do people live, in different stages of their life? What do buildings look like, how are they grouped, where do you find them, in what environment? Think of cross-links with other functions/assets. 3. Tell each other your dream and bring ideas together in a drawing. 4. Discuss underlying problems, cross-links and criteria 5. Identify interesting experiments, which experiments or pilots could contribute to the vision.
Results	Visioning activities also help you to identify accepted truths and existing structures that make unsustainable practices persistent and that are to be addressed in order to define consistent transition agendas or pathways. Made in a participatory way, visions may reflect collective ambitions and can contribute to collective learning about what is at stake.
Source	http://www.transitiepraktijk.nl/en. See also https://www.transitionnetwork.org/ingredients/starting/visioning

Backcasting Method

Challenge	Defining a desired future and working backwards to identify the steps needed to attain it, it is easier to achieve a transition. Thinking in terms of the present you are more likely to remain caught up in familiar thought patterns.
Description	Backcasting essentially involves defining one or more future scenarios for a sustainable future and then identifying the steps needed to achieve them from the present situation. Backcasting produces a strategy for achieving a sustainable future scenario. A series of specific activities can be suggested with a relatively short time horizon for implementing that long-term strategy. These activities can be grouped in a programme.
Results	Determining activities that can be taken in the short term to realise a system innovation based on a long-term vision.
Source	http://www.transitiepraktijk.nl/en

Brainstorming method: World Café

Challenge	Awakening and engaging collective intelligence through conversations about questions that matter.
Description	World Café is a powerful brainstorming tool for exploring specific questions and issues. It is based on the idea that for many people, the place where the richest conversations take place are places where they feel relaxed. Below, a guide to World Café: 1. Plan the event well, frame the question(s) that will be explored, decide who should be there and how you will invite them, where and when it will be, and what outcomes you are hoping for from the event 2. Create a hospitable space, somewhere people will feel comfortable, with round tables set out café-style, with room at each for around 5 people, with paper tablecloths, marker pens, flowers and perhaps a candle, and provide food and drink 3. Make sure that the questions you will be exploring (either one overarching one or a number of questions that explore different aspects of an issue) are relevant to those attending, are clear, thought-provoking and invite reflection, invite the exploration of possibilities and connect those present to why they came 4. Encourage everyone to contribute by maximizing the number of interactions. Every 15 minutes, a bell is rung indicating it is time to move to another table. Over the space of a few hours, participants get to meet most, if not all, of the people in the room, and exchange ideas and thoughts with them. 5. Each time people move to another table, they bring threads of conversation they were at to a new group of people. Each table has a Host, whose responsibility it is to scribe the points raised in each conversation on the tablecloth, so as to create an accurate (and legible) record of what was discussed. Each time the groups change, the new session begins with the Host sharing what was previously discussed at that table, and the new people briefly share what happened at the tables they were on previously 6. At the end, the event is drawn together through a sharing of the collective discoveries. You might pin up all the written-on tablecloths for all to see, you could have a 'go-round' where each host summarizes the main conversation points on his or her table. This could then be followed by a more general 'go-round' to give people an opportunity to share reflections on the process, how it went for them, and what deeper questions were raised. This process can also be continued by typing up the sheets and emailing them out to everyone a few days later, as 'minutes' of the discussion.
Results	Creating a living network of collaborative dialogue around questions that matter in service of the real work.
Source	For more information see here http://www.theworldcafe.com

Method for Agenda building: Open Space Technology

Challenge	Enhancing the responsibility of realizing the vision. Create an eager commitment to continue with specific actions.
Description	Open Space Technology is a method for groups from 800 to 1,000 people who need to explore a major issue. According to its originator, Harrison Owen, it is based on 4 simple 'rules': 1. Whoever comes is the right people 2. Whatever happens is the only thing that could have happened 3. When it starts is the right time 4. When it's over, it's over A step-by-step guide to facilitating Open Space is provided in the following: • Set up a room large enough for those attending to be able to sit in a circle, and a wall you can stick things onto, and also a number of distinct places (rooms, tables, corners) where conversations can take place. • Prepare a clear question, which has been circulated in advance in publicity and invitations for the event • Sit participants in a circle. In the centre is a pile of sheets of paper and pens, and on the wall is an empty timetable, with the timings of the different sessions on one axis, and the various breakout spaces on the other. • Explain the rules of Open Space and that the only prerequisite for proposing a question is that you undertake to host that discussion and take legible notes of what is said. • Anyone with a question writes it on a sheet of paper and sticks it to the wall (you may well end up with more questions than you have slots available, in which case consolidate relevant ones together). • Once your timetable/agenda is complete, allow people a few minutes to look at it and work out what they want to go to, and then ring a bell, or something similar, to announce the convening of the first session. • In theory, the rest of the day will now organize itself! • At the end of each session, ring a bell to let people know it is finished, then go round and collect up the note-filled sheets, and put them up on the wall in the area you have pre-designated as the 'Market Place'. • Leave 30-40 minutes or so at the end for a go-round, for reflections on the event and the process itself, rather than issues raised.
Results	The overall objective of this method is to jointly formulate an agenda as a compass for future actions.

Source	For more information see http://www.openspaceworld.org/

Method for planning actions: Dragon Dreaming

Challenge	Creating successful projects. Fostering diversity, creativity and vitality.
Description	Dragon Dreaming offers simple and lively methods for visionary processes, planning, implementation and evaluation. Developed by John Croft, a specialist on community-led change processes, the approach supports community development and consist of four stages: 1. Dreaming or Visioning: the initial stage of asking "what would happen if…?", "what would this sort of project look like?", "what do you think, does this sound like a good idea?", "can you imagine our town with…?" and so on, an unfettered and bold look forward into the possibilities of the future 2. Planning: here the project leaves the world of concepts and steps into the practice. In this stage questions asked might include: "how do we make this happen?", "who's going to design it?", "how many people in the team?", "what skills are we missing, or do we have?", and "how might we finance it?" 3. Doing: by the time you reach this stage you have signed your contracts, employed your workers, and installed the phone lines. The theory is now practice, and with time and familiarity it becomes so second nature that you forget that it was only a theory not so long ago. This is the time for action. 4. Celebrating and Evaluating: at this stage the emphasis is on celebrating the success of the project and looking at the failures and difficulties before starting the cycle again, asking, among other things: "has the project reached your expectations?", "which phases of the project went well?", "which phases were difficult?" and "was the project fun to work on?"
Results	Put into practice transition projects and initiatives.
Source	For more information see http://www.dragondreaming.org/

Design Framework: Permaculture

Challenge	Identifying sustainable and resilient strategies and solutions.

Description	Permaculture was born as approach for the design, implementation and maintenance of agricultural systems modelled on natural systems. Now it has evolved and it goes beyond agriculture. Now it is perceived as a design system which draws from observations of how natural systems function and insights from systems thinking, applying them to how we design the world around us. Permaculture is a creative design process that is based on ethics and design principles. 1. Observe and Interact 2. Catch and Store Energy 3. Obtain a Yield 4. Apply Self-regulation and accept Feedback 5. Use and value Renewable Resources and Services 6. Produce no Waste 7. Design from Patterns to Details 8. Integrate rather than Segregate 9. Use Small and Slow Solutions 10. Use and Value Diversity 11. Use Edges and Value the Marginal 12. Creatively Use and Respond to Change The basic principles of permaculture provide a set of universally applicable guidelines that can be used in designing a large variety of sustainable and resilient systems.
Results	Designing sustainable systems, working with the forces of nature rather than trying to reshape them.
Source	For more information see https://www.permaculture.org.uk/

ANNEX II - Terracini Transition Experiments

Nome della tecnologia: **Sistema di raccolta e riuso dell'acqua piovana**	**CLASSIFICAZIONE**
Cosa sono: Sistema utilizzato per il recupero di acqua piovana attraverso superfici di raccolta; filtrata, trattata e raccolta in appositi serbatoi. E' a tutti gli effetti un impianto idraulico che serve a prelevare l'acqua dal serbatoio e a distribuirla agli apparecchi che la utilizzano (soprattutto sanitari).	**Tema:** **Ottimizzazione dei consumi idrici** **Tipologia:** Soluzione tecnica **Macroarea:** L'acqua come risorsa
Vantaggi e Benefici: • Consente una modesta riduzione del consumo idrico; • Vantaggi economici legati a bollette più basse per l'approvvigionamento idrico; • Non implica impatti ambientali drastici; • Rivalutazione economica dell'immobile; • Ridondanza delle fonti idriche a servizio delle strutture.	Risparmio idrico ed energetico: 1 2 3 (Basso Medio Alto)
Svantaggi e Limitazioni: • Richiede interventi manutentivi frequenti e costanti; • I serbatoi di raccolta devono essere costruiti con materiali costosi; • Richiede una rivisitazione dell'impianto idraulico;	Costo di investimento 1 2 3 (Basso Medio Alto)
Gestione e Manutenzione: • Controllare ogni 2-3 mesi la trasparenza dell'acqua; • Svuotare i serbatoi e pulirli completamente ogni 1-2 anni;	Richiesta di Manutenzione 1 2 3 (Basso Medio Alto)

• Scegliere materiali resistenti all'azione chimica e meccanica agli inquinanti atmosferici; N.B: Il grado di manutenzione e gestione varia in base all'uso che si deve fare delle acque recuperate. Nel caso si voglia utilizzare l'acqua anche per uso domestico, sono necessari ulteriori accorgimenti.	

Come funziona:

In una generica utenza, i fabbisogni idrici sono coperti con acqua potabile pubblica, che viene utilizzata indistintamente sia per scopi potabili (igiene personale e cottura dei cibi) che per scopi non potabili (cassette di risciacquo dei wc). In questo modo si ottiene un doppio spreco: si utilizza acqua di alta qualità per scopi non potabili, buttandola via subito dopo in fognatura.

Un sistema di recupero delle acque piovane permette di utilizzare, una volta filtrate e trattate, tali acque per usi definiti secondari (non potabili), permettendo un efficiente risparmio idrico. Si pone come una soluzione all'imminente crisi idrica: I sistemi per il recupero dell'acqua piovana sono relativamente poco costosi e l'intero principio può godere di un'alta efficienza, l'unico limite è imposto dalla capacità del serbatoio di stoccaggio e dalla superficie di raccolta.

Un sistema di questo tipoè solitamente composto da quattro elementi: una superficie di raccolta (nella situazione più classica si tratta di un tetto), un sistema di convoglio (generalmente costituito da una grondaia), un condotto di drenaggio che conduce l' acqua piovana recuperata in un contenitore di stoccaggio. Inoltre è necessario eseguire due importanti pratiche a valle di tale recupero: il trattamento di tali acque e la manutenzione dell'impianto.

Un'operazione di trattamento (con filtri ed eventuali trattamenti chimici) è necessaria ad eliminare qualsiasi rischio in fase di utilizzo per la salute dell'uomo. Per quanto riguarda la manutenzione, infine, tale impianto richiede piccoli accorgimenti da eseguire costantemente: i serbatoi che contengono l'acqua raccolta devono essere svuotati e ripuliti 1-2 volte all'anno, occorre pulire i filtri per evitare la proliferazione di batteri e controllare la trasparenza dell'acqua ogni 2-3 mesi. Questo perché gli impianti di raccolta dell'acqua piovana non possono e non devono essere considerati come macchine autonome e autosufficienti

Confronto costi/benefici con soluzioni convenzionali:

Costo tecnologia:

E' difficile dare un valorepreciso al costo complessivo che tale tecnologia richiede, questo perché le variabili in gioco sono molte:

- Il tipo di serbatoio, la sua posizione e la sua dimensione;
- Il tipo di filtro utilizzato nel sistema filtrante;
- La centralina per il controllo del sistema nel complesso.

Tuttavia controllando i cataloghi presenti online di aziende che si occupano dell'istallazione di tali tecnologie (come Starplast e Acquarius), appare evidente che il costo del serbatoio dipende dalla posizione in cui può essere collocato (all'interno dell'edificio, interrato oppure fuori terra), dai materiali con cui può essere costruito, dalla capacità contenitiva e edall'usochesideve fare dell'acquaraccolta (solo per l'irrigazione del giardino o per servizi come wc e lavatrici)
E' fondamentale valutare attentamente la capacità del serbatoio da utilizzare.Per il calcolo della capienza del serbatoio si tiene conto del periodo secco medio ovvero della quantità di settimane o giorni durante i quali si può verificare assenza di precipitazioni:
Considerato un periodo secco di 21 giorni – (fabbisogno annuo) x (numero giorni periodo secco) / (365 giorni)
La stima del quantitativo di acqua di serviziovafatta in funzione del numero di abitanti, del tipo di apparecchiutilizzatiovvero del tipo di irrigazioneprescelta.

(Per eventuali informazioni aggiuntive guardare l'immagine alla fine della scheda).

Per quanto riguarda il sistema di filtrazione, l'investimento fondamentale riguarda la scelta del filtro (in particolare il filtro serve ad evitare l'immissione nel serbatoio di detriti e corpi estranei raccolti dall'acqua piovana sul suo percorso. Da ubicarsi comunque a monte dell'accumulo!). Le tipologie di filtro possono essere.

- Integrato al pluviale,
- Centrifugo,
- A camere,
- Autopulente

Benefici ambientali della soluzione tecnologica:

- Non produce depositi di calcare;
- Permette di disporre di una riserva in caso di necessità;
- Aiuta la conservazione di un bene prezioso;
- Nell'ambito pubblico: in quanto la maggior parte dell'acqua potabile proviene dalle riserve sotterranee di falda che, necessitano di tempi lunghi di ricarico; quindi facilita lo smaltimento fognario e riduce la possibilità di allagamenti.

LISTINO

modello	dimensioni manufatto				pompe			€ cad.	€ cad.		€ cad.	
	vol.	LxLxh	he / hu	Ø tubi	potenza pompa		Ø tubo	BASE	IRRIGAZIONE		IDRAULICO	
	lt	cm	cm	mm	kW		"	BA 00	IR 60	IR 90	ID 60	ID 90
IAP N 2000	2000	210x125x162	139/134	125	0,60	0,90	1"1/4	1.180,00	2.410,00	2.480,00	3.670,00	3.740,00
IAP N 3000	2960	290x125x162	139/134	125	0,60	0,90	1"1/4	1.610,00	2.840,00	2.910,00	4.100,00	4.170,00
IAP N 9000	8650	285x210x264	241/236	125	0,60	0,90	1"1/4	3.410,00	4.640,00	4.710,00	5.900,00	5.970,00
IAP MP 5000	4800	451x125x162	139/134	125	0,60	0,90	1"1/4	2.230,00	3.460,00	3.530,00	4.720,00	4.790,00
IAP MP 7000	6800	632x125x162	139/134	125	0,60	0,90	1"1/4	3.290,00	4.520,00	4.590,00	5.780,00	5.850,00
IAP MP 9000	8800	813x125x162	139/134	125	0,60	0,90	1"1/4	4.210,00	5.440,00	5.510,00	6.700,00	6.770,00
IAP M 12000	12000	440x210x264	241/236	125	0,60	0,90	1"1/4	4.870,00	6.090,00	6.160,00	7.410,00	7.480,00
IAP MN 15000	15000	465x210x264	241/236	125	0,60	0,90	1"1/4	6.570,00	7.790,00	7.860,00	9.110,00	9.180,00
IAP M 18000	18000	620x210x264	241/236	125	0,60	0,90	1"1/4	8.270,00	9.490,00	9.560,00	10.810,00	10.880,00
IAP MN 21000	21.110	645x210x264	241/236	125	0,60	0,90	1"1/4	8.870,00	10.090,00	10.160,00	11.410,00	11.480,00

Listino fornito dal catalogo “Starplast”

Scheda riassuntiva del progetto "Casa d'acqua"

Nome della tecnologia: **Case d'acqua**	**CLASSIFICAZIONE**
 **Cosa sono:** Distributori d'acqua potabile (naturale e frizzante) con un sistema di trattamento e refrigerazione. Può essere installata sia all'interno che all'esterno dell'edificio universitario.	**Tema:** Distributori d'acqua potabile **Tipologia:** Tecniche **Macro-area:** Acqua, rifiuti
Vantaggi e Benefici: • Riduzione rifiuti plastici; • Flessibilità e facilità d'installazione; • Scarsa manutenzione; • Basso costo d'acquisto dell'acqua; • Minor spreco d'acqua (riduzione del consumo delle bottiglie e, di conseguenza un minor consumo di acqua necessaria alla produzione di quest'ultime); • Riduzione delle emissioni in atmosfera.	Riduzioni emissioni: 1 2 3 (Basso Medio Alto)
Svantaggi e Limitazioni: • Costi di refrigerazione e gassatura; • Costo della sorveglianza degli impianti se installata all'esterno; • Investimento a fondo perduto (solo dal punto di vista finanziario) per l'università.	Costo di investimento 1 2 3 (Basso Medio Alto)
Gestione e Manutenzione: • Controllo della qualità dell'acqua e manutenzioni programmate; • Sostituzione dei filtri periodicamente; • Gestione del fine vita degli elementi dell'impianto (bombolette di CO_2, filtri e lampade UV).	Richiesta di Manutenzione 1 2 3 (Basso Medio Alto)

Come funziona:

La casa dell'acqua è un insieme di apparecchiature atte a filtrare, refrigerare, gassare e distribuire acqua potabile trattata, per il cui funzionamento è necessario l'allacciamento alla linea elettrica e alla linea di distribuzione dell'acqua. Un ruolo fondamentale all'interno della casa dell'acqua è svolto dal sistema filtrante, che ha lo scopo di migliorare le caratteristiche organolettiche dell'acqua, riducendo l'odore e il sapore del cloro.

La gassatura avviene nel carbonatore, all'interno del quale viene miscelata l'acqua refrigerata con la CO_2. L'acqua contenuta nella vasca viene raffreddata attraverso una serpentina di rame. Sulla serpentina di rame si forma del ghiaccio che costituisce una riserva di freddo necessaria nei periodi di maggior consumo.

Sono disponibili diverse tipologie di casa d'acqua, alcune delle quali devono essere installate all'esterno degli edifici (chiosco) e altre all'interno (modello Vending). In entrambi i casi, l'acquisto dell'acqua può essere effettuato o in contanti o tramite la chiavetta ricaricabile.

Confronto costi/benefici con soluzioni convenzionali:

Costo tecnologia:
canone mensile ~ 1200 €/anno*macchina

Confronto costi rispetto a soluzioni convenzionali:
Il costo di mezzo litro di acqua risulta essere di gran lunga inferiore a quello di una bottiglietta che si può trovare all'interno dei distributori automatici, con nessuna differenza sulla qualità del prodotto offerto.
Da un punto di vista economico non ci sono ritorni sull'investimento.

La gestione è a carico dell'azienda fornitrice del distributore di acqua, la quale sostiene gli oneri relativi a manutenzione e gestione, a fronte di un canone mensile sostenuto dall' Università di Bologna (circa 1200€/anno). L'ammontare viene calcolato considerando un ritorno sull' investimento da parte dell' azienda in 9 anni, relativamente al prezzo di vendita di 10000 €. Inoltre sono da considerare i costi della fornitura di acqua dalla rete pubblica.

Benefici ambientali:
Riduzione dei rifiuti plastici attraverso il minor consumo delle bottigliette d'acqua, che potrebbero essere completamente sostituite dalle borracce o nel peggiore dei casi riutilizzate più volte.
Valorizzazione della risorsa "Acqua". Risparmio energetico e riduzione delle emissioni.

Nome della tecnologia: **Composting toilet, Packaging toilet, Diverting toilet**	**CLASSIFICAZIONE**
Cosa sono: Nuovo sistema sanitario in grado di ridurre, in alcuni casi, o annullare del tutto l'utilizzo della risorsa acqua. Questo tipo di WC sono in fase di sperimentazione, non tutti sono disponibili nell'immediato. Inoltre, le normative in termini di permessi di installazione e quindi utilizzo degli stessi sono in fase di redazione.	**Tema:** Ottimizzazione dei consumi idrici **Tipologia:** Soluzione tecnica **Macroarea:** L'acqua come risorsa
Vantaggi e Benefici: • Consente la totale riduzione del consumo idrico; • Possibile implementazione con altri sistemi di scopi differenti (compostaggio, ecc) • Riduzione notevole delle bollette legate all'approvvigionamento idrico; • Abbattimento dei costi relativi all'assenza di rete fognaria; • Riduzione dell'impatto ambientale dell'edificio; • Conseguente valore maggiore economico dell'immobile.	Risparmio idrico ed energetico: 1 2 <u>3</u> (Basso Medio Alto)
Svantaggi e Limitazioni: • Difficile applicabilità in contesti da adattare; • Spese logistiche per lo smaltimento supplementari; • Assenza al momento di normativa che regola utilizzo ed installazione degli stessi;	Costo di investimento In fase di studio

Gestione e Manutenzione:

- Necessità di svuotare i serbatoi periodicamente;
- Personale specializzato per l'installazione;
- Corretto utilizzo da parte dell'utenza.

Richiesta di Manutenzione
1 2 3
(Basso Medio Alto)

Come funziona:

NB Non si può essere specifici su determinate soluzioni tecnologiche e/o idee di *Business Model* legate alla valorizzazione degli scarti umani, in quanto al momento tali informazioni sono riservate e saranno opera di valutazione nella 12esima "*Global Conference of Sustainable Manifacturing*".

Composting toilet: questo tipo di WC raccoglie in maniera indistinta urine e feci che, poste in un serbatoio interrato locale, forniscono un apporto di biomassa che può essere facilmente utilizzato per scopi successivi (produzione di compost e/o inserimento in un digestore per produzione di biogas);

Diverting toilet: questo tipo di sistema obbliga l'utenza a comportarsi diversamente in funzione delle funzioni corporali, prevede infatti un diverso utilizzo dell'acqua per le distinte funzioni. Nel caso di liquido, un gel di densità minore delle urine permette di non usare acqua nello scarico. Per le feci può essere implementato un compostaggio dello stesso al pari del sistema di composting toilet.

Packaging toilet: del tutto rivoluzionario ed abbinabile ad un sistema diverting, questo toilet permette di creare pacchetti di scarto fecale idonei al trasporto. Il sistema è altamente igienizzato e seppur differente da quello esistente, delega alla busta in plastica (ovviamente biodegradabile e atta allo scopo) la funzione di trasporto (e non solo quella). E' un tipo di soluzione che può avere delle conseguenze che cambiano radicalmente la visione dello scopo dei propri scarti, che possono diventare in questa maniera parte di un ciclo di recupero.

Nome della struttura: **Centro di raccolta RAEE Terracini**	**CLASSIFICAZIONE**
Cosa è:  Luogo utilizzato per raccogliere, smontare, riassemblare o smaltire componenti elettrici ed elettronici. Sarà collocato nel polo ingegneristico di via Terracini.	**Tema:** RAEE (Rifiuti da Apparecchiature Elettriche ed Elettroniche) informatici **Tipologia:** Rigenerazione Recupero Smaltimento **Macroarea:** Ateneo dell'Università di Bologna
Vantaggi e Benefici: • Trasparenza • Recupero/Riciclo • Tracciabilità • Alti volumi entranti • Zona privata e carrabile	Impatto ambientale evitato: 1 2 3 (Basso Medio Alto)
Svantaggi e Limitazioni: • Struttura adeguata • Reperimento risorse • Basso tasso di rotazione • Tecnico specializzato	Costo di investimento 1 2 3 (Basso Medio Alto)
Gestione e Manutenzione: • Verifica dell'integrità e delle funzionalità degli strumenti • Sostituzione degli strumenti in caso di rottura, inefficienza o obsolescenza	Richiesta di Manutenzione 1 2 3 (Basso Medio Alto)

Come funziona:

Il centro di raccolta dei RAEE informatici si propone come obiettivo principale quello di raccogliere apparecchiature informatiche obsolete e/o fuori uso, ormai giunte al termine del loro ciclo di vita, al fine di rigenerarle ed azzerare i rifiuti che altrimenti verrebbero immessi nell'ambiente.

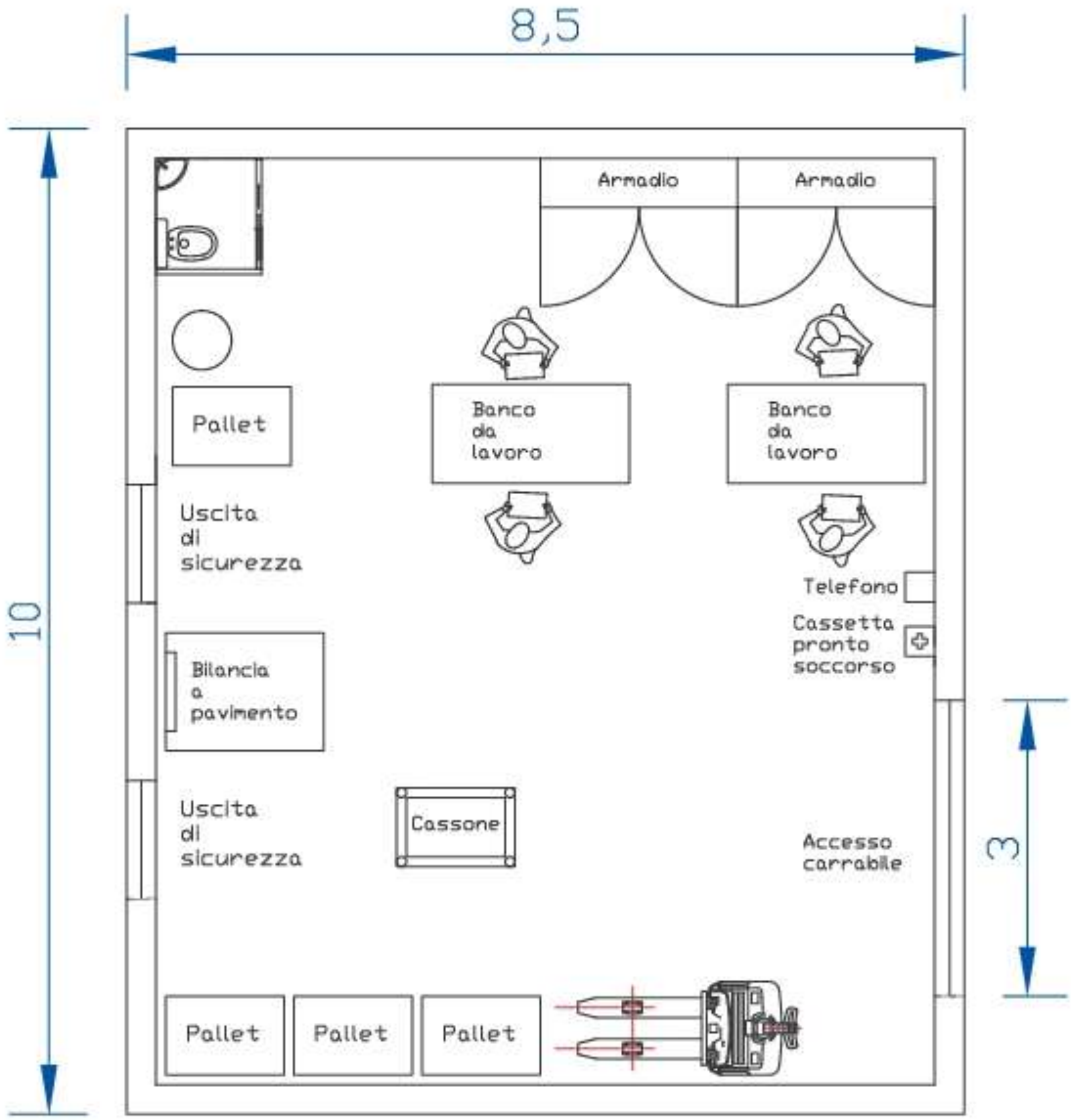
Nel caso in cui non sia possibile effettuare una rigenerazione, nel centro avverrà lo smontaggio dei vari componenti appartenenti alle apparecchiature: una parte sarà immagazzinata, in modo da avere sempre dei pezzi di ricambio, mentre un'altra parte sarà differenziata a seconda dei materiali che li costituiscono.

I materiali differenziati uscenti dal centro, una volta catalogati nel rispetto della normativa vigente, verranno ritirati da Remedia, così come già accade per il centro di raccolta RAEE informatici collocato nella sede storica di ingegneria (viale Risorgimento, 2) .

Benefici ambientali:

- Riduzione delle sostanze pericolose nelle discariche, grazie allo smontaggio e alla differenziazione dei materiali post-smontaggio, il chè comporta minori volumi occupati dai RAEE
- Riduzione della contaminazione delle aree rurali e urbane (falde acquifere, atmosfera)
- Riduzione dell'estrazione di materie prime, conseguentemente al disassemblaggio e al riciclo dei materiali

Pianta del centro di raccolta RAEE informatici Terracini:



Nome della tecnologia: Tetto verde	CLASSIFICAZIONE
Cosa sono:  Un insieme di soluzioni progettuali di "verde tecnologico" che permette di ottenere una serie di benefici ambientali per la gestione delle risorse e la mitigazione dei cambiamenti climatici.	**Tema:** Tetto verde **Tipologia:** Soluzione tecnica **Macroarea:** Verde urbano
Vantaggi e Benefici: 1. risparmio energetico 2. attenuazione del deflusso superficiale 3. mitigazione dell'effetto "isola di calore" 4. rimozione di inquinanti dall'atmosfera 5. trattenimento di polveri e particelle tossiche contenute nell'atmosfera 6. accrescimento della biodiversità urbana 7. riduzione del livello di rumore in città 8. miglioramento del microclima 9. protezione del manto impermeabile dagli sbalzi di temperatura e dall'esposizione ai raggi UV	Risparmio idrico ed energetico: 1 2 3 (Basso Medio Alto)
Svantaggi e Limitazioni: • Costo elevato • Ritorno dell'investimento sul lungo periodo	Costo di investimento 1 2 3 (Basso Medio Alto)
Gestione e Manutenzione: • Monitoraggio dello sviluppo della copertura vegetale • Verifica periodica del sistema di irrigazione e di drenaggio per la tipologia intensiva • Eliminazione delle piante infestanti per la tipologia intensiva. • Sfalcio del prato una volta a settimana per il periodo vegetativo.	Richiesta di Manutenzione 1 2 3 (Basso Medio Alto)

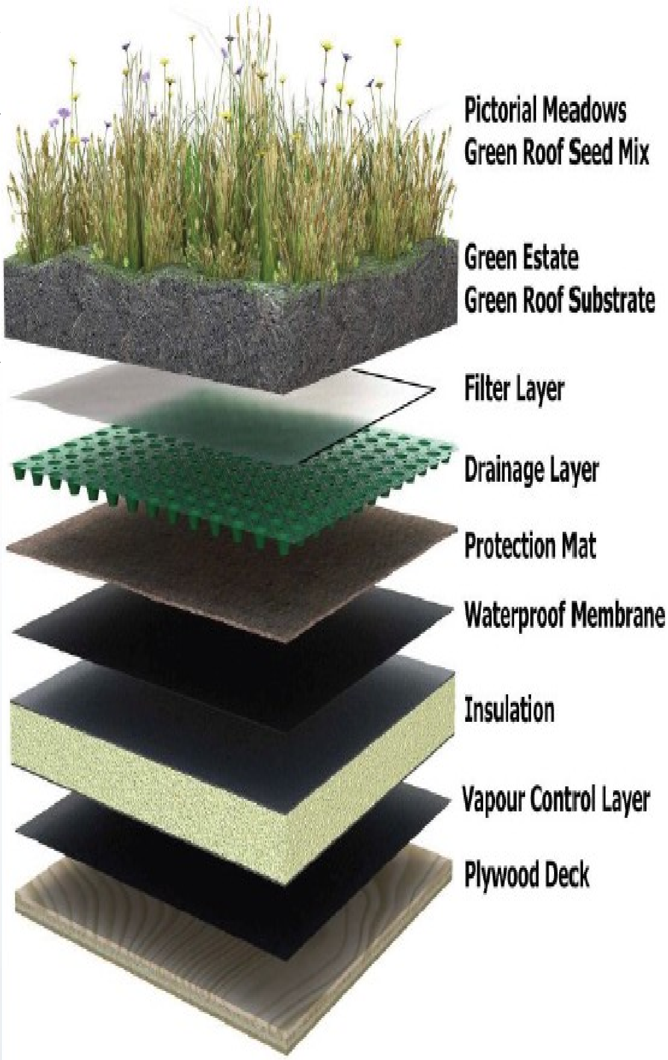
Come funziona:

I tetti verdi possono essere applicati su diversi tipi di coperture, dalle coperture piane ai tetti inclinati delle civili abitazioni, alla copertura dei parcheggi interrati.

I tetti verdi possono essere di tipo *estensivo* o di tipo *intensivo*. Il tetto verde estensivo prevede uno strato di terreno di coltura di circa 10 cm e le piante che vengono utilizzate sono di altezza limitata. Il tetto verde intensivo invece, prevede un maggiore strato di terreno che va dai 40 ai 60/80 cm e l'utilizzo di piante che possono raggiungere anche altezze più elevate.

Per quanto riguarda l'aspetto tecnico il tetto verde si compone di:

- *l'elemento portante,* su cui poggia il tetto verde;
- *una membrana antivapore,* che evita la formazione di condensa e i ristagni di umidità che possono trasmettersi agli ambienti sottostanti;
- *uno strato d'isolante termico,* che evita dispersioni di calore dagli strati sottostanti;
- *una membrana impermeabile,* che evita infiltrazioni d'acqua nelle strutture portanti e negli ambienti sottostanti;
- *una membrana antiradice,* che impedisce alle radici di approfondirsi oltre questo livello per evitare eventuali fessurazioni delle superfici;
- *uno strato drenante e di accumulo idrico,* che ha la funzione di immagazzinare acqua ed allontanare quella eccedente;
- *uno strato o membrana filtrante,* che trattiene le particelle di terriccio evitando così le infiltrazioni negli strati sottostanti;
- *il terreno di coltura,* ovvero terreno alleggerito che ha la funzione di accogliere le piante;
- *la vegetazione vera e propria,* prevalentemente costituita da piante erbacee perenni resistenti alla siccità.



In entrambi i casi, sia per tetti intensivi che estensivi, prima della realizzazione, è bene verificare la portata del solaio sul quale si vuole impiantare il tetto verde poiché i carichi che andranno a gravare su di esso sono nettamente superiori rispetto ad un comune solaio di copertura. Si specifica inoltre che la realizzazione di un tetto verde può implicare o meno l'asportazione delle piastrelle dal tetto.

Confronto costi/benefici con soluzioni convenzionali:

Costo tecnologia:

- *Tipo intensivo*: 150 €/ m^2
- *Tipo estensivo*: 100 €/ m^2

Nel caso in cui fosse già presente sul tetto lo strato isolante, i costi si riducono a:

- *Tipo intensivo*: 100 €/ m^2
- *Tipo estensivo*: 70 €/ m^2

Confronto costi rispetto a soluzioni convenzionali:
Rispetto a soluzioni convezionali il tetto verde permette:

1. la riduzione del fabbisogno di energia per il riscaldamento e il raffrescamento con un risparmio economico sia nei periodi estivi che invernali.
2. L'isolamento acustico che permette maggiore tranquillità negli ambienti interni e all'esterno degli edifici
3. L'aspetto più naturale, infatti il verde contribuisce a incrementare la qualità estetica e trasmette una sensazione di quiete e tranquillità e a valorizzare l'edificio
4. Protezione da sole, pioggia e variazioni della temperatura grazie alla maggiore durata della membrana di impermeabilizzazione del tetto (triplicata rispetto a un tetto non verde)
5. Nessun zavorramento, perciò i tempi d installazione del tetto sono ridotti

Benefici ambientali:

1. Isolamento che permette un risparmio energetico
2. Abbassamento della temperatura dell'ambiente circostante con riduzione degli effetti del fenomeno delle isole di calore urbane
3. Assorbimento di CO_2 con miglioramento della qualità dell'aria
4. Assorbimento delle polveri sottili con miiglioramento della qualità dell'aria
5. Contributo alla biodiversità con miglioramento/difesa dell'habitat naturale di uccelli e insetti
6. Ritenzione delle acque meteoriche con riduzione del carico e dei conseguenti rischi di straripamento
7. Depurazione delle acque meteoriche con miglioramento dell'ambiente

Caso Studio: caso applicativo al Plesso di Ingegneria di Via Terracini

Analisi stato di fatto:
Nel plesso di via Terracini sono presenti poche zone verdi e molte aree in cemento e muratura. Per questo gli edifici dell'università si possono definire un'*isola di calore*, ovvero aumentano l'assorbimento di caldo d'estate causando un maggior utilizzo di aria condizionata e incrementano la dispersione d'inverno provocando un cospicuo innalzamento dell'uso del riscaldamento invernale. La presenza di un tetto verde pertanto porterebbe a una riduzione di questo effetto "isola di calore" conferendo all'ambiente circostante maggior umidità e permettendo di ottenere così un risparmio sull'energia spesa per raffreddare e riscaldare l'edificio, grazie alla capacità di trattenere maggiormente il calore d'inverno e mantenere il fresco d'estate.

Proposta progettuale:
Abbiamo ideato due differenti proposte: nella prima alternativa del progetto abbiamo considerato un tetto verde di tipo intensivo con prato d'erba; nella seconda si è optato per il tetto di tipo estensivo con piante locali.

Principali benefici attesi della proposta progettuale:
Il beneficio principale consisterebbe nel soddisfare l'esigenza degli studenti di avere più spazio verde a disposizione dove consumare il proprio pasto, rilassarsi in attesa della prossima lezione o socializzare con i compagni. Basandosi quindi sulle informazioni ottenute, non ci si è focalizzati solamente sulla realizzazione del tetto verde, ma con esso anche sul fatto di creare uno spazio confortevole in modo da unire i benefici ambientali con quelli degli studenti.

Piano economico e costi dell'intervento:

1) Per quanto riguarda i costi relativi alle due alternative studiate ci si è basati su preventivi forniti dall'azienda Harpo Spa contattata telefonicamente.

Per quanto riguarda la prima alternativa di area =111,54 m^2 il costo del tetto verde intensivo leggero è = 111,54 x 150 = 16731 €.

Per quanto riguarda il costo di installazione dell'impianto di irrigazione, ci siamo riferiti al capitolato dell'azienda Harpo Seic S.p.a al quale abbiamo chiesto un preventivo e dal quale risulta un costo di 12 €/m^2:

Costo impianto di irrigazione = 12 x 111,54 = 1338,48 €

Questo costo non comprende la manutenzione che dipende da molte variabili.

Per la precisione il maggior costo di manutenzione del prato d'erba è dato dallo sfalcio del prato una volta a settimana per il periodo vegetativo. Quindi il costo di manutenzione è dato dal costo orario del giardiniere, più il costo della "chiamata" di cui però non si è tenuto conto.

Per la zona pavimentata si è pensato di acquistare 5 tavoli (inclusi di panche) del costo di circa 150 euro ciascuno e del peso di circa 100 kg. Ciò comunque non influirebbe sulla portata del tetto verde poiché verrebbero posizionati sul piastrellato.

Costo tavoli = 150 x 5 = 750 €

Il costo totale di questa alternativa è quindi pari a 750 + 16731 + 1338 = 18819 €

2) Per la seconda alternativa di area = 120,12 m^2 il costo del tetto verde estensivo è = 120,12 x 100 = 12012 €.

Anche in questo caso non è compreso il costo di manutenzione e di installazione dell'impianto di irrigazione in quanto non previsto per i tetti verdi estensivi.

Il costo totale di questa alternativa è quindi pari a 12012 €.

L'alternativa 1 risulta la preferita dagli studenti del plesso di via Terracini come è stato constatato dal questionario. Tale opzione però potrebbe risultare onerosa per l'università tenendo conto che nel costo complessivo calcolato non sono compresi l'impianto di irrigazione e la manutenzione annua di cui necessita il tetto verde intensivo.

Di conseguenza ragionando dal punto di vista economico converrebbe scegliere l'alternativa 2 per la quale i costi sono inferiori e non occorre manutenzione.

Volendo però tenere in considerazione anche le esigenze degli studenti e l'estetica della terrazza, una soluzione idonea sarebbe quella di mantenere il layout 1 sostituendo però il prato d'erba intensivo con un tetto verde estensivo con piante locali.

In questo modo si riuscirebbe a trovare un compromesso tra i costi sostenuti dall'università e le esigenze degli studenti.

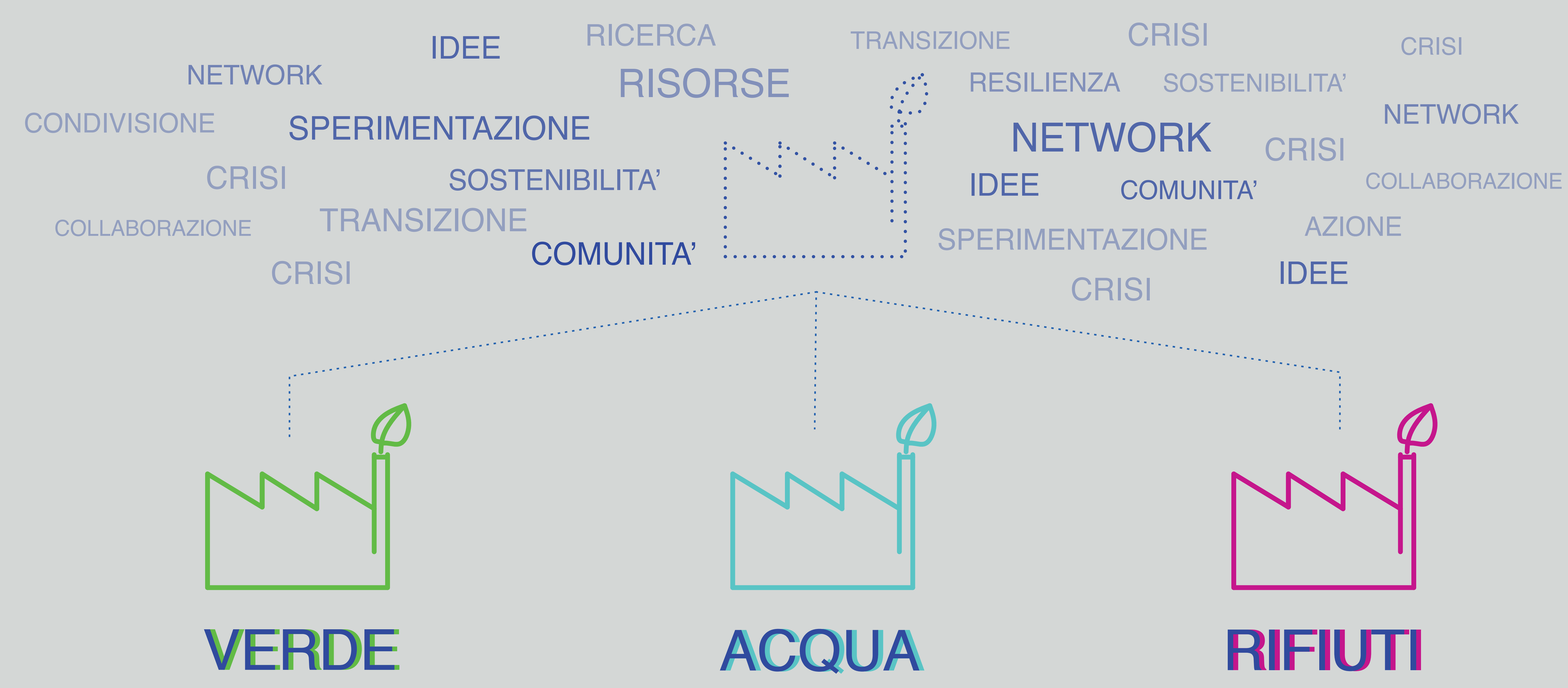
ANNEX III - Terracini Transition Overview

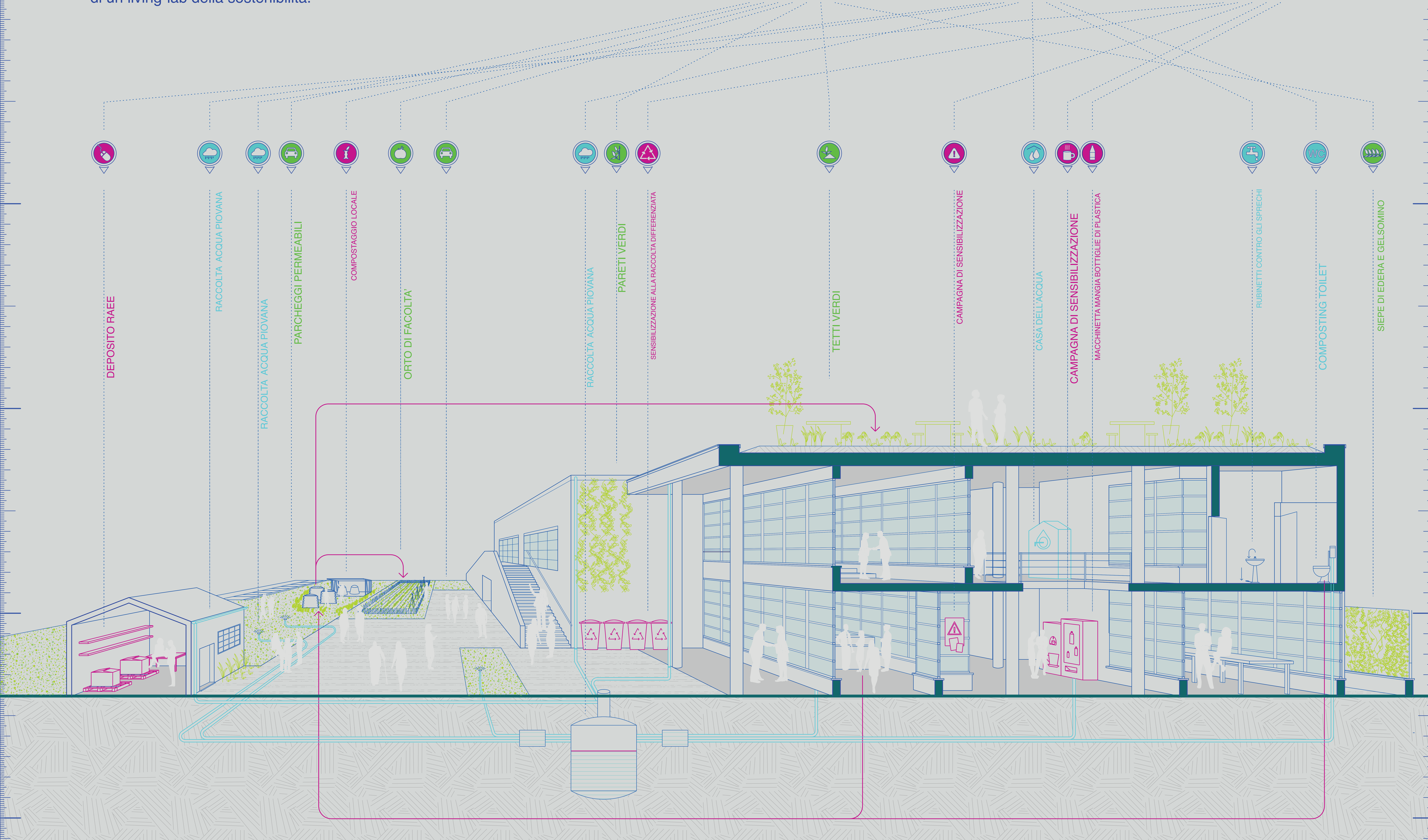
TERRACINI IN TRANSIZIONE

IDEE E PROPOSTE PER LA SOSTENIBILITA' DEL PLESSO DELLA SCUOLA DI INGEGNERIA E ARCHITETTURA DI VIA TERRACINI

PROGETTO DEL LABORATORIO DI TRANSIZIONE SOSTENIBILE
A cura degli studenti del corso di Valorizzazione delle risorse primarie e secondarie

Obiettivo del laboratorio di transizione è l'implementazione di idee e proposte da parte degli studenti del corso di Valorizzazione delle risorse primarie e secondarie per la sostenibilità del plesso della Scuola di Ingegneria e Architettura di via Terracini. La transizione è un approccio emergente per la facilitazione dei processi di cambiamento e di innovazione verso la sostenibilità. Il progetto raccoglie le idee e le proposte per la riduzione degli impatti delle attività del Plesso di via Terracini e la sperimentazione di nuovi modelli di sostenibilità. Il risultato è quello di contribuire alla realizzazione di un living-lab della sostenibilità.





CENTRO DI RACCOLTA RAEE

Luogo utilizzato per raccogliere, smontare, riassemblare o smaltire componenti elettrici ed elettronici. Sarà collocato nel polo ingegneristico di via Terracini.
Vantaggi: recupero/riciclo; tracciabilità; alti volumi entranti.

costo di investimento 1 **2** 3
costo di manutenzione **1** 2 3
impatto ambientale evitato 1 **2** 3

PARETI VERDI

Si tratta di un fronte edilizio ricoperto da specie vegetali rampicanti e/o ricadenti, aggrappate direttamente o indirettamente alla muratura.
Vantaggi: Miglior microclima; mitigazionedel riscaldamento urbano; minor fabbisogno energetico e minori emissioni di CO2, filtra le polveri.

costo di investimento 1 2 **3**
costo di manutenzione 1 2 **3**
impatto ambientale evitato 1 **2** 3

RECUPERO BOTTIGLIETTE

Per incoraggiare alla pratica della raccolta differenziata, proponiamo di ricorrere a macchine per il recupero delle bottiglie in plastica che rilasciano un credito in cambio del vuoto.
Vantaggi: Recupero plastica, incoraggiamento economico.

costo di investimento 1 2 **3**
costo di manutenzione 1 2 **3**
impatto ambientale evitato 1 2 3

CASA DELL'ACQUA

Distributori d'acqua potabile (naturale e frizzante) con un sistema di trattamento e refrigerazione.
Vantaggi: meno rifiuti plastici; basso costo d'acquisto dell'acqua; minor spreco d'acqua per la produzione delle bottiglie; riduzione delle emissioni in atmosfera dovute al loro trasporto.

costo di investimento 1 **2** 3
costo di manutenzione 1 **2** 3
impatto ambientale evitato 1 2 **3**

DISTRIBUTORE BEVANDE

Sostituire le attuali macchine di erogazione di bevande calde con altre che possano permettere di utilizzare un proprio bicchiere per il consumo della bevanda stessa.
Vantaggi: riduzione della plastica consumata; economia nella mancanza del bicchiere monouso.

costo di investimento 1 2 **3**
costo di manutenzione 1 **2** 3
impatto ambientale evitato 1 2 3

TETTI VERDI

Vantaggi: risparmio energetico; attenuazione del deflusso superficiale; mitigazione dell'effetto "isola di calore"; meno polveri atmosfriche e meno inquinamento; più biodiversità urbana; meno rumore in città; un miglior microclima; protezione delle coperture.

costo di investimento 1 2 **3**
costo di manutenzione 1 **2** 3
impatto ambientale evitato 1 2 **3**

COMPOSTAGGIO LOCALE

Sistema di gestione dei rifiuti organici generati nel plesso che prevede il trattamento in loco. Si tratta di un processo di decomposizione di 2 mesi.
Vantaggi: riduzione della spesa per la raccolta dei rifiuti; vantaggi ambientali; funzione educativa e sociale.

costo di investimento **1** 2 3
costo di manutenzione **1** 2 3
impatto ambientale evitato 1 2 **3**

CAMPAGNA DI SENSIBILIZZAZIONE

La campagna di comunicazione e informazione ha la finalità di promuovere e sensibilizzare gli utenti rispetto ad un determinato servizio mettendone in luce aspetti positivi.
Vantaggi: aumento della sensibilizzazione; miglioramento della raccolta differenziata.

costo di investimento **1** 2 3
costo di manutenzione .... **x**
impatto ambientale evitato 1 2 3

RACCOLTA DELL'ACQUA PIOVANA

Sistema per il recupero di acqua piovana attraverso superfici di raccolta; essa è filtrata, trattata e immagazzinata in appositi serbatoi. E' a tutti gli effetti un impianto idraulico che la ridistribuiisce agli apparecchi che la utilizzano .
Vantaggi: riduzione del consumo di acqua.

costo di investimento 1 2 **3**
costo di manutenzione 1 **2** 3
impatto ambientale evitato 1 2 **3**

SISTEMA SANITARIO

WC

Rinnovamento del sistema sanitario per ridurre o eliminare l'uso della risorsa acqua: per esempio con l'installazione di composting/packaging/diverting toilet.
Vantaggi: minor consumo di acqua, non necessita di collegamento alla rete fognaria, compostaggio.

costo di investimento .... **x**
costo di manutenzione 1 2 **3**
impatto ambientale evitato 1 2 **3**

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