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ECO-INNOVATIVE STRATEGIES TOWARDS PERI-URBAN SUSTAINABILITY: THE CASE STUDY OF THE METROPOLITAN AREA OF NAPLES

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Abstract. Across Europe, the current system of waste management is responsible for environmental pollution, leading to the need of a transition towards a circular economy model, and towards systemic approaches for achieving sustainable objectives. Interpreting waste as resource – through the development of eco-innovative solutions – can play a positive impact on the quality of life and of the environment. REPAiR[1] research project proposes eco-innovative strategies, in order to co-design and assess solutions, involving a series of decisional problems that require the development of Spatial Decision Support System, described in their general structure and with a focus on the REPAiR project.

Keywords: circular economy, eco-innovation, environment, wastescapes, urban living lab, waste, co-design, co-evaluation.

Introduction

The transition from a linear to a circular model of (economic) growth is one of the most important challenges that the contemporary society need to face. The use of non-renewable resources at global level, the progressive shortage of raw materials, the need to reduce the impact caused by waste contamination and its defective management, require a rethinking on production cycles, lifestyle choices and cultural models. Being a focal point of the European policies[2], Circular Economy (CE) becomes a crucial element for sustainable urban developments. In this way, the traditional negative perception of waste is reversed, with the possibility to consider it as a resource for an innovative way of planning. New economic and social models, supported by eco-friendly

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[2] Framework Directive 2008/98/CE enforced with Legislative Decree 205/2010; *Towards a circular economy: A zero waste programme for Europe*. COM(2014) 398; Law no. 221/2015 on *Environmental provisions to promote green economy measures and to contain an excessive use of natural resources*.

technologies, are thus essential to address the main environmental challenges; this is embodied in the eco-innovation concept (EC 2012). With the aim to achieve sustainable environmental goals through innovation, the European Commission elaborated the Eco-Innovation Action Plan[3]. In addition to that, the Eco-Innovation Observatory monitors and reviews the measures undertaken by the Member States assessing their environmental performances through a reliable verification system, the Eco-Innovation Scoreboard[4]. European Union also drew up research programs as Life+ and Horizon 2020 to encourage funding to support research and innovation projects. The first one, Life+[5], develops political approaches and innovative technologies and tools for the public sectors, while the second, Horizon 2020[6], supports the research for new solutions and related experimentation, demonstration activities and market introduction. To that end, these measures in addition to an optimization of the resources, are necessary requirements for a reduction of environmental impacts and for implementing a more sustainable economic growth.

From innovation to eco-innovation. Towards new and more sustainable models

Compared to the concept of Innovation, firmly established in the economic policy initiatives[7], the concept of eco-innovation is still in a developmental phase. In particular, the OECD Oslo Manual shows differences between the two notions arguing that "*Eco-Innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations"* (OECD 2005: 394). In sum, the main distinction is that the definition of eco-innovation includes also the social and institutional dimensions that are related to the environment. In this sense, changes in socio-cultural rules and institutional structures are guaranteed, through a win-win strategy able to ensure satisfactory solutions for each part involved in the setting process. In addition to the reduction of environmental hazards, to implement an eco-innovation there is the need to innovate also the current economic framework increasingly transforming the production and/or market models for the achievement of environmental sustainability objectives. In this light, the support to new processes, technologies and services is essential for a greater respect of the environment by enterprises in order to optimize European growth potential. These concepts are underlined by Environmental Technology Action Plan of the EU Commission in which eco-innovation is defined as "*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 risks, pollution and other negative impacts of resource use"* (OECD 2009: 11) and by the Industrial Science Technology Policy Committee that defines eco-innovation as "*a new field of techno-social innovation focused less on product's functions and more on environment and people*" (OECD 2009: 12). However, in order to encourage a transition towards sustainable approaches, it is important to adopt radical rather than incremental solutions, in order to achieve significant effects locally, as well as, at the global level. In this sense, within governance processes, it is necessary to relate political, technological, social, economic and organizational components through a holistic approach. According to the Or-

[3] Communication COM(2011) 899 *Innovation for a sustainable Future – The Eco-innovation Action Plan (Eco-AP)*.
[4] *Eco-innovation Observatory,* http://www.eco-innovation.eu.
[5] *Life+ Programme*, http://ec.europa.eu/environment/life/about/index.htm#lifeplus.
[6] *Horizon 2020 Programme*, Ahttp://ec.europa.eu/programmes/horizon2020/en.
[7] *European Commission,* Innovation Policies, https://ec.europa.eu/growth/industry/innovation/policy_en.

ganisation for Economic Co-operation and Development eco-innovations have three dimensions (OECD 2009):

- *targets*, as the main focus of eco-innovations and they include products, processes, marketing methods, organizations and institutions;
- *mechanisms*, that are at the bottom of eco-innovations: modification, re-design, and implementation of alternatives;
- *impacts*, investigating on possible environmental repercussions through the lifecycle of Eco-Innovative Solutions (EIS).

Starting from these indications on the dimensions of eco-innovation, it is possible to provide their classifications, related to the systems on which they act, and to the changes that they generate. The following scheme aims to provide a synthesis of these distinctions (Fig. 1). Consequently, eco-innovations constitute in general a change or an improvement of an environmental, economic or social existing situation; this could have significant effects as eco-efficiency, reduced energy consumption, reduced waste, polluting emissions and water uses, lower producing costs, greater competitiveness, cooperation and partnership, less environmental impacts by production system, higher quality of life and employment opportunities.

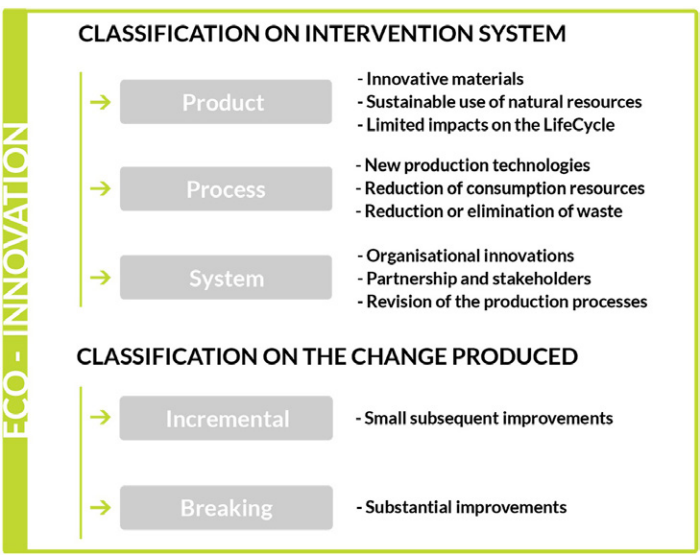


Figure 1. Classification and impacts of eco-innovations
Source: V. Vittiglio, re-drafted from "Eco-innovation and Green Economy" (Green Jobs) [https://www.cliclavoro.gov.it/Progetti/Green_Jobs/Documents/Eco-Innovazioni]

Defining eco-innovative solutions for wastescapes

According to the European directives mentioned above, and within the framework of Horizon 2020, the REPAiR project (REPAiR 2015), through a circular approach, aims to develop EIS, creative, transferable and smart ideas aimed to innovate and improve a specific and fixed process in relation of the management of waste as a resource and wastescapes (REPAiR 2018a), integrating them into systemic and territorial Eco-Innovative Strategies, within the peri-urban areas of two pilot cases: Naples and Amsterdam. EIS are the result of a co-creation process deriving from case-specific

problems. They cross the multiple scales, the different dimensions of the peri-urban territories investigated, assuring the reciprocities between the natural and the built environment (EC 2016: 153). EIS are not just changes in current technologies, but also process innovations "*contributing to the EU's ambition of a paradigm shift towards Circular Economy and a near-zero waste society*" (EC 2016: 153). In the end, they are based on the key environmental principle "Reduce-Reuse-Recycle-Recover" (REPAiR 2018a). Conversely, an Eco-Innovative Strategy is an alternative course of a combination of two or more elementary actions, namely EIS, aimed at addressing both the objectives and challenges and develop a more CE in peri-urban areas (REPAiR 2018a).

In Italy, peri-urban areas (Viganò 2001) are those especially affected by waste management pressure. Located in between the urban-rural gradient, these areas are featured by not-planned and chaotic land use, mixing together urban uses and the former rural areas, so generating a new form of geographies, defined in REPAiR as wastescapes (Amenta & Attademo 2016)[8]. Wastescapes are related to the spatial effect of material waste flows on the territories and to the configurations of the infrastructures for their management. From a spatial, environmental, and social point of view, wastescapes can represent challenging spaces (REPAiR 2018b), spatial/landscape resources for the planning of the fringe areas that could regain their dignity, becoming public spaces connected to infrastructure and services, through combined management of waste flows and improved quality of life for the inhabitants. The research focuses, with a multi-scale approach, on the individuation of adaptive solutions to case-specific problems to be developed within a co-creation process implemented in the Peri-Urban Living Labs (PULLs) environments. With this purpose, REPAiR project applies a variety of methodologies; among them, the Quadruple Helix (QH) model (Arnkil et al. 2010) that ensures the achievement of innovations through the interaction between knowledge and information, human resources, financial capital and institutions (Carayannis & Campbell 2006). This model is implemented in the REPAiR project through PULLs (Steen & van Bueren 2017), that represent a system of dialogue able to involve users in the innovation activity of both public and private organizations (Arnkil et al. 2010). Indeed, QH is characterized by the collaboration among universities, public administrations, companies and citizens (Fig. 2).

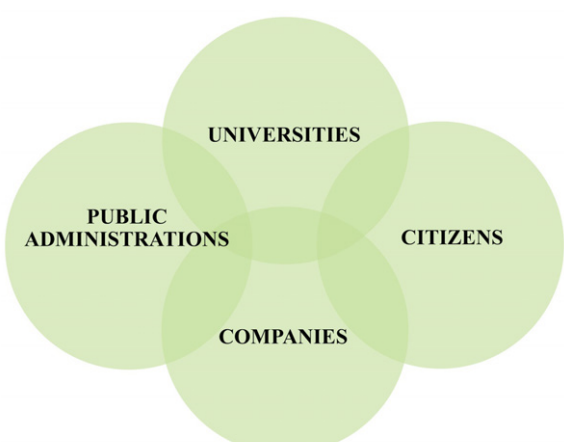


Figure 2. Quadruple Helix
Source: S. Iodice, modified from Lindberg et al. (2014)

[8] For further information on the definition of wastescapes, see REPAiR (2018b).

In this way, users that are mainly represented by citizens can be highly involved in the innovation activity and, more in general, all the stakeholders have the possibility to become active players in the joint creation and experimentation of new ways of doing things and in the creation of new services and products (EC 2015). Therefore, users play an active role in all the phases of EIS development, from the early ideation to the co-creation of solutions. This determines a strong link among resources, local societies and territorial identities, moving beyond the functionality of products in order to add new values for citizens and society (EC 2015). In this model, industries have to develop integrated solutions in the form of products and services, combining the support from University and Public Administrations, and overcoming the concept by which innovation is only performed by experts (Afonso & Montiero 2011). Furthermore, the QH emphasizes a broad cooperation in innovation, shifting towards systemic, open and user-centric innovation policy (Arnkil et al. 2010). The QH applied in REPAiR is supporting the interactions of waste management and urban regeneration to improve the functionality of the urban metabolism processes (Swyngedouw 2006; EC 2011, 2014; Allen et al. 2012; Golubiewski 2012; Ibañez & Katsikis 2014), as well as considering CE as a basic framework. In order to achieve these purposes, REPAiR specifically focuses on the following aims:

- testing out new practices for collaborative problem solving, through the implementation of six PULLs (Mitchell 2003; Bilgram et al. 2008; Steen & van Bueren 2017) across Europe;
- supporting decision-makers, through the delivering of innovative tools, running within a Geo-Design Decision Support Environment (GDSE) (Steinitz 2012; Campagna 2014);
- providing more sustainable waste management systems, based on Life Cycle Thinking;
- providing new planning approach and design solutions for regenerating and recovering wastescapes in peri-urban areas.

The importance of stakeholders' participation in Peri-Urban Living Labs

REPAiR PULLs are the instrument that allow the dialogue among all stakeholders. This is actually compliant with the logic of the QH. A Living Lab (LL) in general can be defined as an "*user-centered, open innovation ecosystems based on a systematic user co-creation approach in public-private-people partnerships, integrating research and innovation processes in real life communities and settings*" (García Robles et al. 2015: 12). It is crucial that all stakeholders are involved in the planning process within a creative space in which they can be able to develop design ideas that can lead to societal changes. To do so, common knowledge and expert knowledge represented by public and private stakeholders is integrated. In this way, the emergence of breakthrough ideas will be enabled, bringing up new concepts and scenarios towards the identification of a first set of EIS (Pallot et al. 2011); the latter will be further analysed in the PULL process, in order to select the most suitable ones, according to the territorial context under exam. Evaluating alternative scenarios, based on the implementation of EIS, becomes a complex decision process, characterized by multidimensional perspectives that comprise both technical aspects based on empirical observation as well as non-technical aspects characterized by social visions, preferences and feelings (Munda 2004).

The PULL methodology for developing EIS and strategies is characterized by 5 main phases (REPAiR 2017c):

- *co-exploring*, i.e. analysing the territory from different perspectives, to identify the most relevant issues;

- *co-design*, i.e. designing concepts, working together to achieve common targets and to propose actions on the territory that could activate a virtuous process;
- *co-production*, i.e. designing tactical actions and eco-solutions;
- *co-decision*, i.e. designing rules systems;
- *co-governance*, i.e. the set of rules and procedures that guide the participatory construction of choices.

The last three phases represent the test of the EIS, to be able to prove their effectiveness or the possible criticalities and potentialities, with the aim of making them replicable also in different contexts.

The PULLs of the Metropolitan Area of Naples

Within the Metropolitan Area of Naples, the EIS are tested in contexts in which waste flows and wastescapes can be considered as the main drivers of the configurations of the contemporary peri-urban territories (Forman 2008).

The defined area is an environmental, physical and socio-economic sample for the issues of waste and resource management, located in the South of Italy. More in depth, the Italian study area is a sprawling urban area, located at the margins of the compact cities, and it has a chaotic structure derived also from illegal building processes. Density and dispersion of settlements are mixed in this territory. Historical centres are connected with each other through a continuous urban pattern, where hybridization exists between urban and rural landscapes. There is not an acclaimed tradition of spatial planning on regional and municipal levels. Conversely, it is made of a combination of different implications coming from several sectorial policies and projects: such as infrastructures, production settlements, shopping malls, and so forth, not integrated in the landscape planning. Residential settlements are separated from urban public spaces, as for example parks, public facilities, open public spaces, etc. This phenomenon generated a territorial fragmentation with spontaneous and low quality urban patterns (Russo 2012).

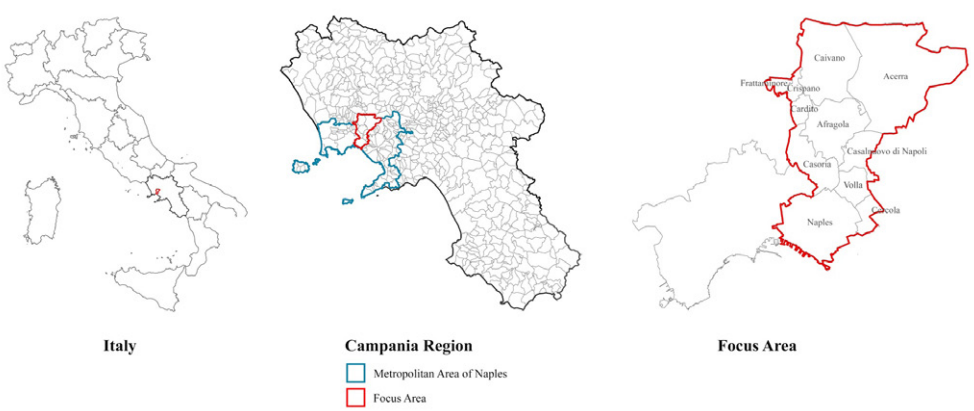


Figure 3. Focus Area within the Metropolitan Area of Naples
Source: S. Iodice elaboration

Starting from the urban peculiarities of this area, one of the main challenges to face is represented by the research of site-specific EIS. The latter should be respectful of the local specificities of the urban context; this is one of the reasons why these solutions need to be co-designed by local actors operating on the territory and with a precise knowledge of the examined area. Furthermore, it is important to define a spatial boundary that could help in the identification of some central issues. Indeed, the Italian focus area (FA) (Fig. 3) is identified through a process of spatial analysis and it is "*supportive for the definition of Eco-Innovative Solutions*" (REPAiR 2017c: 14), whose implementation could generate multi-dimensional impacts. The changes deriving from the implementation of EIS can be monitored through a combination of hard and soft data, the first in the form of indicators and the latter through perceptions and visions of the main stakeholders.

So far, the PULL workshops carried out in the Metropolitan Area of Naples have been characterized by the involvement of the most relevant local stakeholders, in relation to the role that they play within the territory, specifically into the waste management sector. They are represented by the Campania Region Authority[9], by representatives of the Metropolitan City and the Homogeneous Territorial District ('*Ambito Territoriale Ottimale'*), and by the representatives of the Municipalities of the REPAiR focus area, the waste management companies, as well as the researchers from the University of Naples Federico II, partner of the project.

The first PULL workshops have been mostly characterized by an informative structure, in order to present the main targets of the project and to identify the key challenges that the research intends to tackle, as well as to collect general information on the waste management systems and on the possible data availability. In particular, the key waste flows: Organic Waste (OW), Construction and Demolition Waste (CDW) and wastescapes have been described and presented to the participants.

Regarding CDW, REPAiR focus area is characterized by the presence of many illegal settlements and one of the challenges is to propose EIS for the re-use of demolition materials coming from abandoned buildings, in the framework of CE.

From the interaction with other stakeholders it was also possible to understand other potentialities and possibilities of development for REPAiR focus area:

- regional financing for the realization of 13 new composting plants serving the separate waste collection as well as the strengthening of the existing plants for shredding and packaging of waste (*'Stabilimenti di Tritovagliatura e Imballaggio Rifiuti'*)[10];
- regional financing of EUR 24 million for a first realization of 189 community composting plants managed by the homogeneous territorial districts[11].

Regarding OW flow, the main problem is related to the lack of local plants able to treat it, and most of this fraction is now sent to the Venetian Region, in the North of Italy. For this reason, the Regional Urban Waste Plan[11] estimates the processing requirements of the organic fraction, in order to reach higher differentiated collection rates (recycling rate of 50%). An important policy regards the community composting plants, reducing biodegradable waste landfilling. The objective is to achieve a self-sufficiency treatment and a stable integrated management of urban waste, starting from the organization of "Manifestations of interest" (i.e. public call for intention to support) by individual or associated municipalities for the composting on their own territory. These composters are halfway between the large plant and the domestic one and are characterized by an accelerated aerobic process. For this reason, Campania Region, in order to inte-

[9] The PULL workshops have been organized in collaboration with Campania Region Authority, that is one of the partners of the REPAiR project.

[10] Campania Region public announcement n. 402, *I dati ISPRA sui rifiuti 2016: Bonavitacola: la realtà è più forte delle mistificazioni*, http://www.regione.campania.it/.

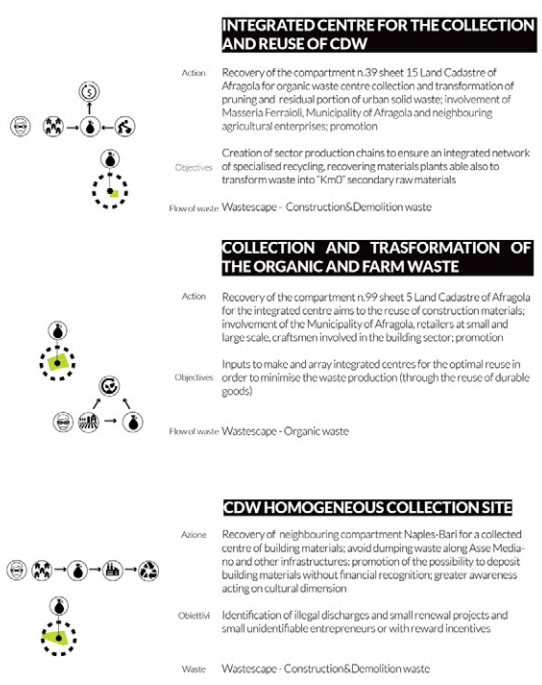
[11] Regional Urban Waste Plan no. 685/2016.

grate the waste management system with a network of small plants, needs to identify the most suitable sites where to locate these community plants, according to the territorial peculiarities and to the identified wastescapes. In particular, these plants must be located in public areas or, if managed by the municipalities, they should be located in areas open to the public; anyway it is necessary that the municipality identifies the legal availability of the foreseen localizations. Furthermore, the plants will have small dimensions, allowing the localization in outdoor spaces as well as in small prefabricated buildings. The improvement of the separate waste collection, in order to reach higher recycling rates, as established in the Regional Urban Waste Plan, could be done including citizens in the waste management, through the introduction of monitoring and information tools and through the establishment of future goals in order to reach a high-quality compost. During PULLs it will be possible to improve the knowledge of the focus area and the mapping process of wastescapes, collecting useful feedbacks from the stakeholder interactions.

In particular, in the last PULL workshop, the categories of wastescapes were presented with the idea of starting a collaborative process to collectively update the maps. With this purpose, three work-tables were organized with local stakeholders whose interaction has generated three different territorial strategies. Each territorial strategy has been developed with the aim to identify specific local strategies and subsequently the elementary EIS for the specific problems related to wastescapes and connected waste flows. The first strategy, *Homogeneous collection site*, attempts to solve problems related to the illegal dumping of waste (CDW) in abandoned areas along the infrastructures and in which there are some confiscated properties, owned by criminal organization, to be recovered (Fig. 4). The second strategy *Green Mile,* aims to recover the existing pedestrian and cycle path along the provincial road connecting Acerra and Pomigliano. This strategy aims to involve the local community, as well as the university, the local schools, and the citizens' associations. Specifically the associations are willing to make a commitment for the implementation of the strategy, facilitating the involvement of the citizens and the other stakeholders (Fig. 5). The third and last strategy *New lands* concerns the necessity to control the flow of CDW coming from the realization of the new railway connections (in several point of the territory) with the high-speed train station of Afragola. This first aspect of the strategy aims to implement a local reuse of these CDW fractions. Secondly, this strategy focuses on the regeneration of the abandoned productive area of the municipality of Acerra (Area PIP; Fig. 6). According to the developed strategies, a list of EIS has been drawn up from literature or discussion in the PULLs and subsequently grouped in four complex local strategies, listed below[12]:

- *RECALL: REmediation by Cultivating Areas in Living Landscapes*. Reclamation of polluted soils and water, and restoration of the former agricultural tradition to promote new forms of circular economy for the wastescapes located into the Metropolitan Area of Naples. Furthermore, this eco-innovative strategy seeks to promote an improvement of the employment situation involving the local community in the agricultural activities.
- *Re-compost Land. Short supply chain of organic waste*. Regeneration of wastescapes, buffer areas, agricultural fields, through an innovation process which works on the short supply chain, thanks to the regional aids to trigger the use of community composting plants. The short supply chain allows to collect and treat organic waste in the REPAiR sample area, in order to create: on the one hand, top soils for the new morphologies of the terrain, along roads, and around the recycling areas, and, on the other hand, to recover the agricultural soils.
- *Beyond INERTia. Circular supply chain for C&D waste*. Beyond INERTia strategy introduce a set of EISs to trigger specific weak points in current supply chain of recycled aggregates production

[12] For further information on the following strategies, see REPAiR (2018a).



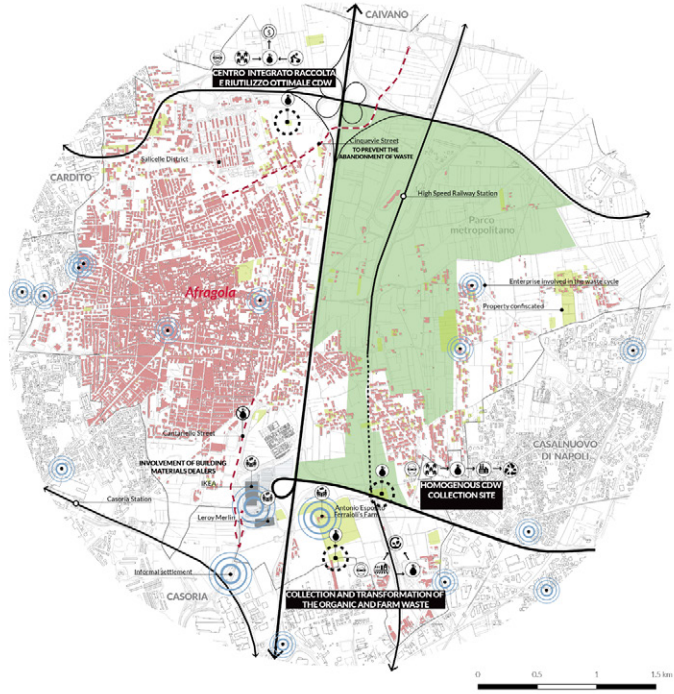


Figure 4. Homogeneous collection site Strategy
Source: F. Vingelli elaboration

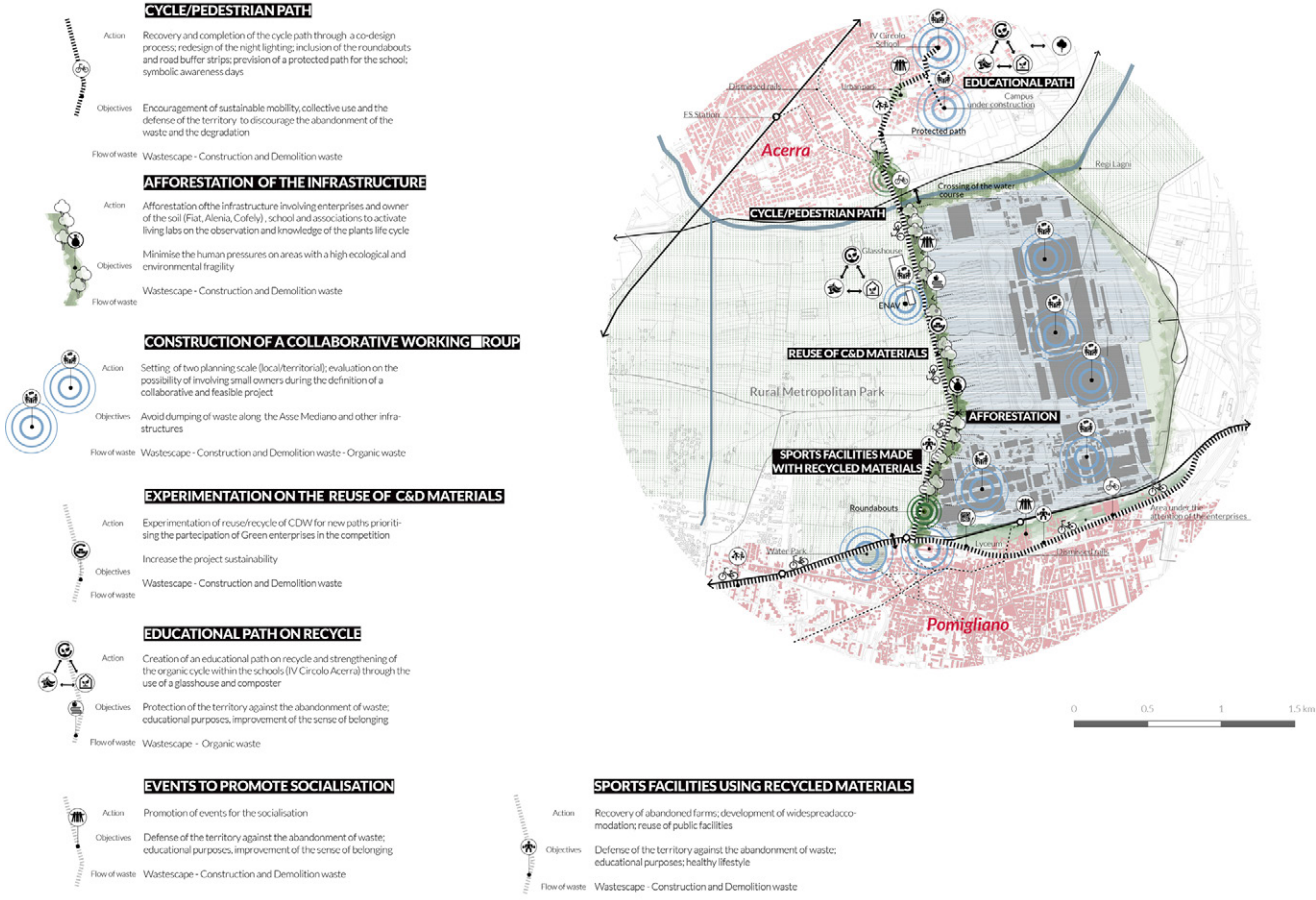


Figure 5. Green Mile Strategy
Source: F. Vingelli elaboration

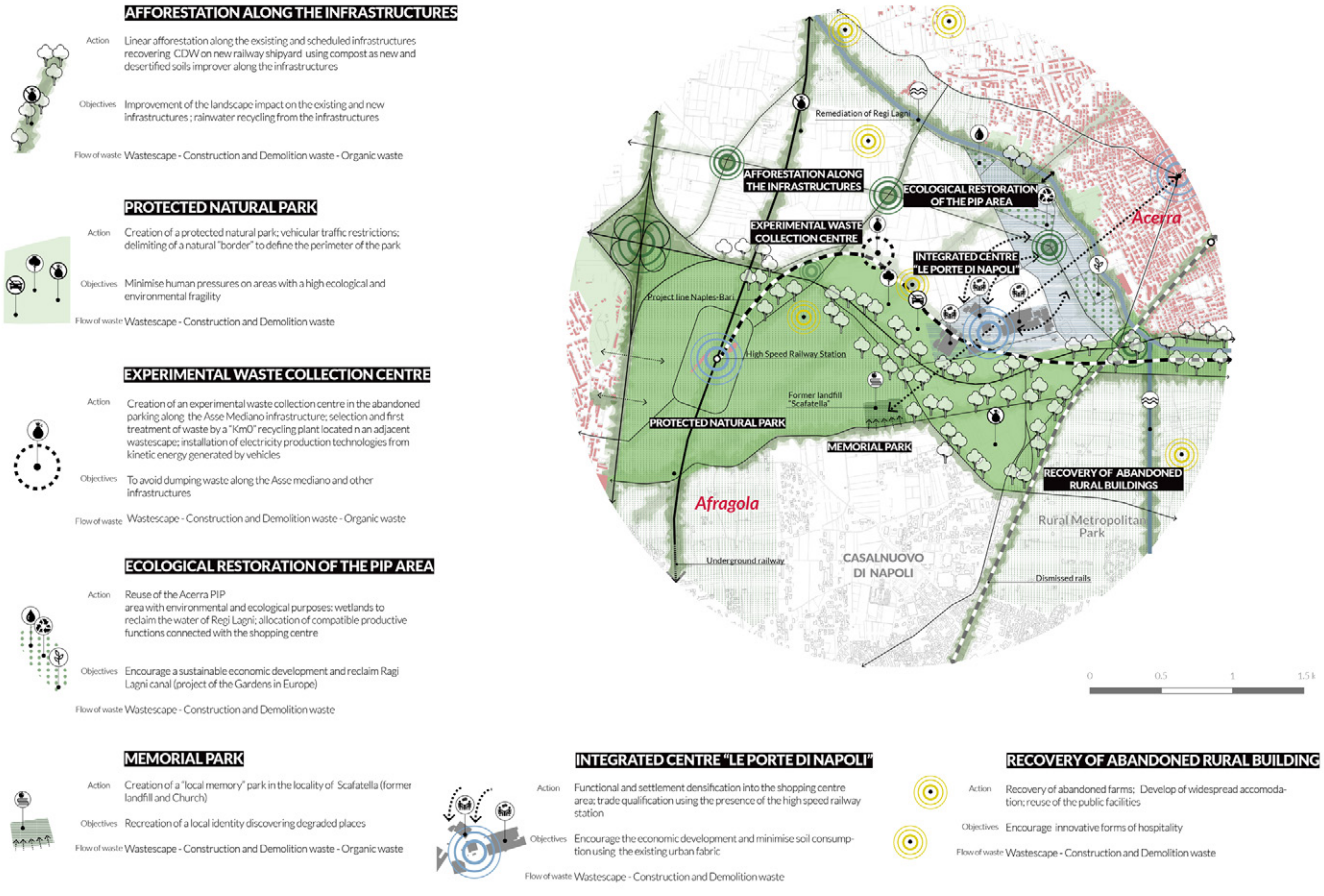


Figure 6. New Land Strategy
Source: F. Vingelli elaboration

and reuse and to create services that aims to improve the recycle of inert waste.

- *CIRO. Integrated Center for Optimal Reuse of durable goods from demolition activities.* Avoid illegal dumping of durable goods from private disposals. Create a new circular supply chain for the refurbishment and up-cycle of durable goods.

In order to ensure their transferability to the other contexts, eco-innovative Strategies were unpacked into elementary EIS and submitted to a co-evaluation aimed to analyse the process, the involved parties and the form of action, the degree of eco-innovation and the ways of improvement. Afterwards, EIS are submitted to the stakeholder to identify the operative relevance and the possible weaknesses of the selected EIS for the pilot case of Naples in order to update them. The dialogue among stakeholders within the PULLs for the identification of EIS is supported and guided by two Decision Support Systems (DSS) (Simon 1960), represented by a Geo-Design Decision Support Environment (GDSE) and by Life Cycle Assessment (LCA). In the following paragraphs GDSE and LCA are described in relation to the utility they play within PULL workshops and the first results of the baseline scenario of LCA related to the treatment of CDW are presented.

Decision Support Systems in the Decision Analysis

The core objective of REPAiR is to promote waste as a resource, establishing a CE and improving the territorial impact of waste flows, analysing territorial metabolic processes of peri-urban areas (REPAiR 2015). This challenge involves a series of decisional problems that require the development of appropriate DSS that can allow a rational analysis of the issue under exam, by structuring a logic framework of evaluation. The concept of DSS is part of the decision analysis and decision theory fields, that represent their theoretical premise.

A typical and important part of DSS is characterized by a spatial component, forming the so called Spatial Decision Support Systems (SDSS), often supported by the use of GIS (Malczewski 1999, 2006). This type of integration has proved to be very useful in the field of urban planning, considering the spatial connotation that characterizes the choices of land use (De Toro & Iodice 2016; Carone et al. 2017). SDSS can address multi-criteria, semi-structured spatial decision problems, combining both soft and hard information (Irfan et al. 2017). Soft information in REPAiR are collected through the interaction with the main stakeholders operating in the focus area, while hard information refer to appropriate indicators, arising from different databases. The territorial component in REPAiR is a fundamental prerogative for the identification of spatial development strategies, the definition of territorial impacts as well as the regeneration of wastescapes. This is compliant with the purpose of applying SDSS for the reduction of waste flows in peri-urban areas, improving also the impacts that waste flows generate on the territory. During PULLs it is possible to use some evaluation instruments that can facilitate the structuring of the decisional problems. An example is represented by the value tree, according to which it is possible to represent the decisional problem in a hierarchical structure, evaluating the first sets of EIS through a set of established criteria.

As previously specified, REPAIR adopts two kinds of DSS that have spatial implications on the territory: a GDSE and LCA, that will support the development of spatial strategies, defining a combined approach to co-design solutions and strategies. GDSE is a decision model based on the concept of Geodesign (Steinitz 2012) in order to elaborate some scenarios based on the implementation of EIS. Geodesign means "changing geography by design" and more specifically it is a "*design and planning method which tightly couples the creation of design proposals with impact simulations informed by geographic contexts*" (Flaxman 2010: 29). In this way, a possible

solution is supported by geospatial knowledge, integrating context analysis, design and evaluation, that in traditional planning are treated as separated steps, generating a more robust and context-sensitive design solution (Lee et al. 2014). In such a framework, the patterns of change play a very relevant role, reflecting different strategies and decisions, as well as the interrelation of the EIS with their spatial component. One of the main potentiality of this instrument is due to the possibility to increase the level of collaboration and interdisciplinarity, bringing together specialists from different fields, allowing a comprehensive understanding of the impacts. GDSE will be implemented in the PULLs, with the aim of providing local and regional authorities with a tool able to support the reduction of waste flows in the strategic interface of peri-urban areas. This tool is represented in the form of a computerised platform able to implement an interactive communication among stakeholders. Therefore, GDSE will support the identification of integrated, place-based, eco-innovative spatial development strategies (REPAiR 2015), helping the finding of scenarios of development. These scenarios could lead to an alteration of the material flow, to a change on the impact ratios, or also change on the land use (REPAiR 2017b). GDSE is integrated with LCA in order to simultaneously monitor the impacts coming from the scenarios of development. In the next paragraph, it will be presented a small focus on the LCA model and on the result that it has already been possible to obtain from the assessment of the baseline scenario, i.e. the actual scenario before the alterations that will arise after the implementation of EIS.

Life Cycle Assessment as a Decision Support System in REPAiR

After the identification of the scenarios of transformation through the use of GDSE by stakeholders, the change in the environmental impact categories will be assessed using LCA model, that will be integrated in a simplified way in the GDSE platform. According to the International Standard ISO 14040 (2006)[13], LCA can be defined as a set of procedures for compiling and examining the inputs and outputs of materials and energy and the associated environmental impacts directly attributable to the functioning of a product or service system throughout its life cycle. This procedure allows the description of the complex and multidimensional impacts related to human activities, providing quantitative information aimed at facilitating sustainable choices (Helling 2017). LCA process is divided in some precise steps (Fig. 7), articulated as follows (European Commission et al. 2010):

- *goal definition*: during this phase it is established the decision context and the intended application of the study, together with the addressees of the results;
- *scope definition*: during this phase the object of the study is defined in detail. Furthermore, this phase is characterized by the Functional Unit (FU) and the reference flow definition. FU becomes the reference to which the other data in the assessment are normalized. In REPAiR, FU is represented by the treatment of a certain waste typology (A) generated by (B) in the focus area during one year (REPAiR 2017a), with the aim of comparing the impacts related to the status quo to the impacts related to the implementation of the EIS. The latter, as already underlined, will be identified through the stakeholder involvement within the PULLs;
- *inventory analysis:* this is the phase during which all kind of data are collected. This phase is one of the most demanding, and it is in progress in REPAiR, in relation to the collection of quantitative data regarding the OW and CDW flows;
- *impact assessment:* during this phase it is possible to establish a link between the inventory of elementary flows and its potential environmental impacts (Hauschild & Huijbregts 2015), analysing the effects of substances on the environment and on human health;

[13] ISO 14040, 2006, *Environmental management – Life cycle assessment – Principles and framework.*

- *interpretation of results,* during which it is possible to collect some useful recommendations for decision makers, in order to facilitate the choice of the best scenarios for the implementation of the EIS. It is important to express the results in an understandable way, in order to facilitate the dialogue with non-technical stakeholders.

In general, it is desirable that the implementation of these solutions leads to a significant reduction of environmental impacts. In this perspective, LCA becomes a monitoring tool, stimulating the dialogue among stakeholders as well as making the selection of the best performing scenarios.

Definitely, LCA in REPAiR is used in order to "*analyse the sustainability of waste management in the present urban metabolism and the influences of EIS in a spatially differentiated and transdisciplinary way. Assessing environmental/social/economic consequences associated with potential changes to the current system towards increased sustainability performance is going to be used for decision making support*" (REPAiR 2017a: 8). The most important challenge is the collection of useful feedback for the entire life cycle of matter, not only in the focus area but also generating positive multi-scale repercussions. LCA has often been used in the waste management field in order to prevent or minimize negative impacts through the selection of the best performing scenario. In particular, at the current state, the model for the environmental assessment linked to the treatment of the CDW flow of the status quo has been almost completed. The CDW flow, usually generated during the life cycle of projects at the construction scale, is part of the special waste category and can be divided into hazardous and non-hazardous. According to the Regional Plan for the Management of Special Waste in Campania '*Piano Regionale di Gestione dei Rifiuti Speciali*'), CDW is produced in large quantities and for this reason the Directive 2008/98/EC[14] establishes the necessity to reach a recovery of about 70% of this flow by 2020. Analysing the results of the environmental assessment carried out for the baseline scenario both of Campania Region and of the focus area, it is possible to identify some possible strategies for the reduction of en-

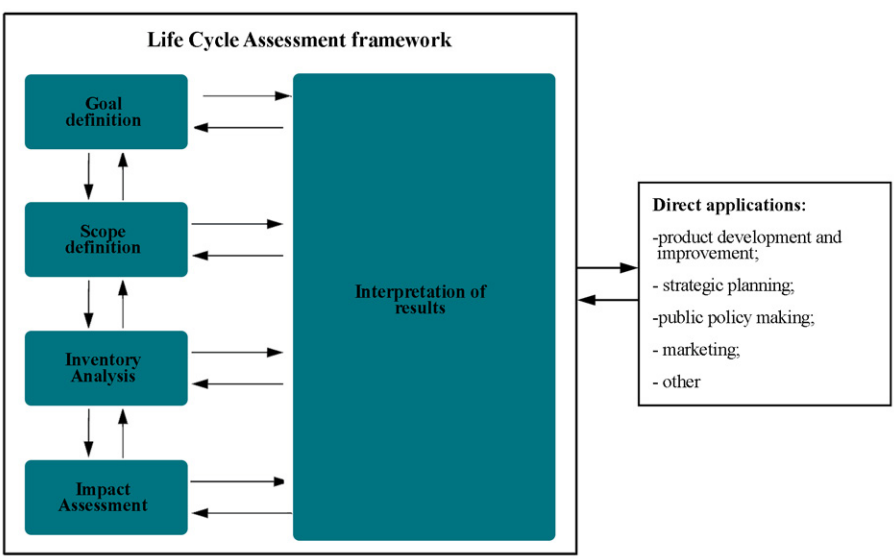


Figure 7. Framework for Life Cycle Assessment
Source: S. Iodice, modified from ISO 14040:2006

[14] Waste Framework Directive, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32008L0098.

vironmental impacts in a CE perspective. These strategies can be summarized by the following recommendations, that arise from the results interpretation:

- the necessity to reduce the impacts associated to transport, considering that currently a huge quantity of the flow produced inside the region is treated outside the same, generating the necessity to distribute the flow on the territory in a more functional and sustainable way;
- the necessity to improve the recyclability of materials from the beginning, through the application of the practice of "selective demolition", according to which the CDW flow is already separated at the origin, reducing the level of impurity of the flows conveyed to the various plants;
- the importance of improving the quality of recycling aggregates, which usage could reduce the intensity of mining activities;
- the general importance of reducing as much as possible the quantity of flow to be sent to landfill through the implementation of an integrated management.

Finally, in REPAiR, LCA is not an isolated evaluation tool, but it is part of a methodological framework interacting with PULLs and GDSE. More in depth, it is possible to collect information from the co-exploration phase of PULLs for the goal and scope definition; the first three phases of GDSE (representation, process and evaluation) can converge in the inventory analysis and the impact assessment is strictly linked and integrated to the impact phase of GDSE. Finally an important link is created among the co-decision phase of PULLs, the decision phase of GDSE and the interpretation of results in LCA, in order to identify useful strategies to be implemented by the decision makers involved in the territorial regeneration. After the baseline scenario evaluation, the same model will be used for the environmental evaluation of EIS, in order to monitor how they are able to modify the current flow and to influence the lowering of environmental impacts.

Conclusions

The main opportunities and criticalities related to CE are present in cities, which can be considered as priority sites to implement innovative change models. To do so, new uses and consumption models of resources through innovative methodologies and technologies are promoted, to be applied in contemporary cities.

Co-creation dissemination and implementation of EIS, in addition to a pro-active involvement of public institutions, citizens, enterprise and researchers in PULLs, can have a heavy impact on the environmental, cultural and social quality of peri-urban contexts. However, this is only possible through strategic management approaches coherent with the European directives in order to define a new and more sustainable planning model.

The conversion of natural resources in goods, services and eventually in waste is related to the metabolic functioning of the territory. This unsustainable and linear metabolic processes can cause the exhaustion of resources as well as multi-scale impacts on the environment. This generates the necessity to transform the relationship between urban growth and natural environment into an opportunity (Conke & Ferreira 2015). Starting from this assumption, a transition towards a CE is strictly necessary. For these reasons REPAiR aims to develop EIS and strategies aiming at the reduction of the negative impacts of waste on the territory. In order to reach this goal, REPAiR uses a methodological framework formed by three instruments, namely: Peri-Urban Living Labs (PULLs), Geodesign Decision Support Environment (GDSE) and Life Cycle Assessment (LCA). They are interrelated with each other and are based on the involvement of public and private lo-

cal stakeholders, who are asked to focus their attention on the peri-urban areas of the examined territory, combining common knowledge and expert knowledge. These integrated methods have the goal of developing different resource management options, as well as territorial regeneration processes.

Definitely, only through the development of more sustainable ways of re-using (many times) resources throughout their life cycle, it will be possible to decouple economic growth from resource dissipation and its environmental impacts (EEA 2015). This process can lay the foundation for the development of resource-efficient cities, improving the cross-scale interactions among the natural system, the trans-boundary engineered infrastructures and the involvement of different stakeholders (EEA 2015), as well as ensuring an improved spatial and functional relationship among urban and peri-urban areas.

References

Afonso O., Montiero S., 2011. *A growth model for the quadruple helix.* Journal of Business Economics and Management, vol. 13, no. 5, pp. 849-865.

Allen A., Broto V. C., Rapport E., 2012. *Interdisciplinary Perspectives on Urban Metabolism. A review of the literature.* Journal of Industrial Ecology, vol. 16, no. 6, pp. 851-861.

Amenta L., Attademo A., 2016. *CIRCULAR WASTESCAPES. Waste as a resource for peri-urban landscapes planning.* CRIOS Critica degli Ordinamenti Spaziali, vol. 12, pp. 79-88.

Arnkil R., Järvensivu A., Koski P., Piirainen T., 2010. *Exploring Quadruple Helix. Outlining user-oriented innovation models.* Final Report on Quadruple Helix Research for the CLIQ project, Yhteiskuntatutkimuksen instituutti.

Bilgram V., Brem A., Voigt K.-I., 2008. *User-centric innovations in new product development – systematic identification of lead users harnessing interactive and collaborative online-tools.* International Journal of Innovation Management, vol. 12, no. 3, pp. 419-458.

Campagna M., 2014. *Geodesign: dai contenuti metodologici all'innovazione nelle pratiche*. Proceedings of the XVII National Conference SIU, Società Italiana degli urbanisti, *L'urbanistica italiana nel mondo*. Milan, Italy, pp. 71-76.

Carayannis E., Campbell D. F. J., 2006. *"Mode 3" and "Quadruple Helix": towards a 21st century fractal innovation ecosystem*. International Journal of Technology Management, vol. 46, no. 3-4, pp. 201-234.

Carone P., De Toro P., Franciosa A., 2017. *Evaluation of urban processes on health in historic urban landscape approach: Experimentation in the metropolitan area of Naples (Italy).* Quality Innovation Prosperity, vol. 21, no. 1, pp. 202-222.

Conke L. S., Ferreira T. L., 2015. *Urban metabolism: Measuring the city's contribution to sustainable development.* Environmental Pollution, vol. 202, pp. 146-152.

Cowen D., 1988. *GIS versus CAD versus DBMS: what are the differences? Photogrammetric Engineering and Remote Sensing*, vol. 54, pp. 1551-1555.

De Toro P., Iodice S., 2016. *Evaluation in Urban Planning: a multi-criteria approach for the choice of alternative Operational Plans in Cava De' Tirreni.* Aestimum, vol. 69, pp. 93-112.

EC, 2011. *A resource-efficient Europe - Flagship initiative under the Europe 2020 Strategy.* Communication COM(2011)21.

EC, 2013. *Life +Programme,* http://ec.europa.eu/environment/life/about/index.htm#lifeplus [27 November 2018].

EC, 2014. *Towards a circular economy: A zero waste programme for Europe*, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52014DC0398 [15 November 2018].

EC, 2015. *Open Innovation 2.0.* Yearbook 2015.

EC, 2016. *Eco-Innovation Observatory,* http://www.eco-innovation.eu. [12 November 2018].

EEA, 2015. *Urban sustainability issues – What is a resource-efficient city?* EEA Technical report, no. 23.

European Commission, Joint Research Centre, Institute for Environment and Sustainability, 2010. *International Reference Life Cycle Data System (ILCD) Handbook – General guide for Life Cycle Assessment*

- *Detailed guidance*. Luxembourg: Publications Office of the European Union.
Flaxman M., 2010. *Fundamentals of geodesign*. Anhalt University of Applied Science, Berlin, pp. 28-41.
Forman R.T.T., 2008. *Urban Regions. Ecology and Planning Beyond the City*. Cambridge University Press.
García Robles A., Hirvikoski T., Schuurman D., Stokes L., 2015. *Introducing ENoLL and its Living Lab community,* https://www.iemed.org/recursos-compartits/pdfs/ENOLL%20introduction.pdf [13 November 2017].
Golubiewski N., 2012. *Is there a metabolism of an urban ecosystem? An ecological critique.* Ambio, pp. 751-764.
Grabher G., 2004. *Learning in Projects, Remembering in Networks? Communality, Sociality and Connectivity in Project Ecologies.* European Urban and Regional Studies, vol. 11, no. 2, pp. 103-123.
Hauschild M. Z., Huijbregts M. A. J., 2015. *Life Cycle Impact Assessment. LCA Compendium – The Complete World of Life Cycle Assessment*, Dordrecht: Springer Science+Business Media.
Helling R. K., 2017. *The Role if LCA in Sustainable Development*. Encyclopedia of Sustainable Technologies, Reference Module in Earth Systems and Environmental Sciences, pp. 237-242.
Ibañez D., Katsikis N., 2015. *New Geographies 06*. Grounding Metabolism, pp. 2-10.
Irfan M., Koj A., Sedighi M., Thomas H., 2017. *Design and development of a generic spatial decision support system, based on artificial intelligence and multicriteria decision analysis*. GeoResJ, vol. 14, pp. 47-58.
Kemp R., 2010. *Eco-Innovation: Definition.* Measurement and Open Research, vol. 3, pp. 397-420.
Lee D. J., Dias E., Scholyen H. J., 2014. *Introduction to Geodesign Developments in Europe.* Berlin: Springer.
Lindberg M., Lindgren M., Packendorff J., 2014. *Quadruple Helix as a Way to Bridge the Gender Gap in Entrepreneurship: The Case of an Innovation System Project in the Baltic Sea Region.* Journal of the Knowledge Economy, vol. 5, no. 1, pp. 94-113.
Malczewski J., 1999. *GIS and multicriteria decision analysis*. New York: John Wiley & Sons, Inc.
Malczewski J., 2006. *GIS-based multicriteria decision analysis: a survey of the literature*. International Journal of Geographical Information Science, vol. 20, pp. 703-726.
Mitchell W. J., 2003. *Me++ : the cyborg self and the networked city.* Cambridge, Mass.: MIT Press.
Munda G., 2004. *Social multi-criteria evaluation: Methodological foundations and operational consequences.* European Journal of Operational Research, vol. 158, pp. 662-677.
OECD, 2005. *The Measurement of Scientific and Technological Activities: Guidelines for Collecting and Interpreting Innovation Data: Oslo Manual, Third Edition* prepared by the Working Party of National Experts on Scientific and Technology Indicators, OECD, Paris.
OECD, 2009. *Sustainable Manufacturing and Eco-Innovation. Framework, Practices and Measurement*, www.oecd.org/sti/innovation/sustainablemanufacturing [November 2017].
Pallot M., Trousse B., Senach B., Scapin D., 2010. *Living Lab Research Landscape: From User Centred Design and User Experience towards User Cocreation.* First European Summer School "Living Labs", Paris, France.
Rennings K., 2000. *Redefining innovation – eco-innovation research and the contribution from ecological economics.* Ecological Economics, vol. 32, pp. 319-332.
REPAiR, 2015. *Report of the Horizon 2020 Project Proposal*.
REPAiR, 2017a. *Analysis of data-availability at regional level pilot cases*. REPAiR Deliverable 4.1. [typescript].
REPAiR, 2017b. *Data Requirement Description and Data Delivery Plan for the Case Study Areas*. REPAiR Deliverable 2.2. [typescript].
REPAiR, 2017c. *Introduction to methodology for integrated spatial, material flow and social analyses*. REPAiR Deliverable 3.1. [typescript].
REPAiR, 2018a. *Eco-Innovative Solutions Naples*. REPAiR Deliverable 5.3. [typescript].
REPAiR, 2018b. *Process model for the two pilot cases: Amsterdam, the Netherlands & Naples, Italy*. REPAiR Deliverable 3.3 [typescript].
Russo M., 2012. *L'esperienza come progetto: conoscere l'area est di Napoli,* [in:] R. Lucci, M. Russo (eds.), *Napoli verso oriente*, Napoli: Clean, pp. 144-163.
Simon H. A., 1960. *The new science of management decision.* Upper Saddle River: Prentice Hall.
Steen K., van Bueren E., 2017. *Urban Living Labs. A living lab way of working*. Amsterdam: AMS, Amsterdam Institute for Advance Metropolitan Solutions.

Steinitz C., 2012. *A framework for GeoDesign: Changing geography by design.* Redlands: Esri Press.
Swyngedouw E., 2006. *Metabolic urbanization. The making of cyborg cities*, [in:] N. Heynen, M. Kaika, E. Swyngedouw (eds.), *In the Nature of Cities – Urban Political Ecology and the Politics of Urban Metabolism*. London: Routledge, pp. 21-40.
van Rooijen T., Nesterova N., 2013. *Applied framework for evaluation in CIVITAS PLUS II.* Deliverable no. 4.10, https://civitas.eu/content/applied-framework-evaluation-civitas-plus-ii [November 2018].
Viganò P., 2011. *Territories of a new modernity*. Napoli: Electa.