WASTE MANAGEMENT IN (PERI-)URBAN AREAS: integrated assessment of environmental, social and economic sustainability in a collaborative decision support environment

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SUMMARY: *Waste management is an important function of a city government and a key utility service on which the inhabitants depend. The main purpose of waste management technologies and policies are to protect human and environmental health by reducing the negative impacts of waste and finding beneficial reuses for it. In light of the on-going initiatives of the European Commission towards establishing a strong circular economy, a project named REPAiR (REsource Management in Peri-urban Areas: Going Beyond Urban Metabolism) was able to start in 2016. The core objective of REPAiR is to provide local and regional authorities with an innovative transdisciplinary open source geodesign decision support environment (GDSE) which will be implemented in living labs in six metropolitan areas (Amsterdam, Naples, Hamburg, Ghent, Lodz, Warsaw). The GDSE aims at creating integrated, place-based eco-innovative spatial development strategies to quantitatively reduce waste flows in the strategic interface of (peri-)urban areas. These strategies will promote the use of waste as a resource to achieve enhanced spatial quality, living conditions (health, well-being) and sustainable urban development. Therefore, the integration of life cycle thinking, urban metabolism, material flow analysis, stakeholder participation and geodesign plays a crucial role in the iterative development and validation of the GDSE. An essential part of the GDSE is establishing a multidisciplinary sustainability framework that allows the assessment of environmental, social and economic consequences of the present urban waste management system and the influences of eco-innovative solutions in a spatially differentiated and transdisciplinary way. This will be achieved by quantifying and tracking essential resource and emission flows, mapping and quantification of negative and positive effects of present and future waste management scenario's not only at a*

global/regional scale but also on a local scale, and the determination of a set of (semi-) quantitive indicators to inform decision makers concerning the optimization of (re-)use of waste.

1. INTRODUCTION

A booming economy, increasing world population, rapid urbanization and improved living standards have greatly accelerated waste generation (Lehman, 2011). On average, about 16 tonnes of material are used per person per year in the European Union (EU), which is a reflection of consumption patterns and economic wealth of this territorial area. Of the 16 tonnes of materials used, about 6 tonnes become waste (EC, 2010a). There is a limited ability to use resources efficiently; raw materials are extracted, products are produced and after usage, they become waste. This linear model has been considered as a successful and effective approach in the past, able to manufacture products at very low prices, boosting the economies of developed industrialized countries, and encouraging human consumption. However, lately, concerns about the continued use of natural resources, and harm to the environment and human health (e.g., causing pollution and greenhouse gas emissions) have brought more attention to the way we must use them (Ekvall et al. 2007).

The linearity of material flows is one of the profound problems EU countries are up against today. Especially densely populated European cities are large consumers of goods and services, including the utilization of primary energy, and producers of waste. Because of an increasing consumption of resources within an urban environment, and growing dependencies on trade, the impact of European cities extends beyond their geographic locations (Zaman and Lehmann, 2013; Claudia et al., 2011). Sustainable urban development and local waste management should therefore not only improve the quality of life in a city, including ecological, cultural, political, institutional, social and economic components but also the life in regions outside the city boundary (Doughty and Hammond, 2004). The assessment of such interactions and impacts is not straightforward, but rather challenging because not one method or tool is available to comprehensively assess the sustainability (with all its aspects) of local waste management.

Transitioning towards a more circular economy is crucial and follows the efforts at the European policy level which resulted in a series of environmental action plans, directives, reports and a framework of legislation that aims to reduce negative environmental and health impacts of waste and improve Europe's resource and energy efficiency (EC, 2010a). Some examples are the EU commission's directives in waste (2008/98/EC), packaging (94/62/EC), landfill (1999/31/EC), electronic waste (2012/19/EU), batteries (2006/66/EC), end-of-life vehicles (2000/53/EC), the analytical note on waste management targets (EC, 2015), the reports on the EU approach of waste management (EC, 2010a), cities of tomorrow (EC, 2011b), the implementation of the Circular Economy Action Plan (EC 2017) and Europe 2020: a strategy for smart, sustainable and inclusive growth (EC, 2010b). The REPAiR project develops, in the context of reshaping policies towards a circular economy, the possibility for public and private local waste management actors to simulate and assess projects, policies and spatial plans towards a more resource efficient Europe (EC, 2011a, 2014).

Although multiple waste policies and targets are established since the 1990s, at the moment, the EU remains far from a circular economy. Improvements can be made across the full product

lifecycle, at the choice of materials, the design phase, or the end-of-life phase (EEA 2015). For example, the development of an open source platform for innovation of resource and waste management, considering a holistic sustainability aspect from a life cycle point of view, could stimulate the current and future developments in the field in the direction of the targeted circular economy objectives. The REPAiR project includes the required cross-disciplinary expertise to develop and create such a platform.

2. The REPAiR project

The project started in September 2016, has a duration of 48 months, and is funded by the Horizon 2020 EU Research and Innovation programme, under the WASTE-6b-2015 - Eco-innovative strategies topic.

2.1 Overall concept and objectives

The core objective of REPAiR is to develop an innovative transdisciplinary open source geodesign decision support environment (GDSE) which provides local and regional authorities with integrated, place-based eco-innovative spatial development strategies aiming at a quantitative reduction of waste flows in the strategic interface of especially peri-urban areas. There areas are landscapes characterised by a patchwork of dispersed urbanised areas, agricultural land, open space and high density residential areas within a discontinuous countryside, i.e., both urban, rural and hybrid spatial characteristics are present. Peri-urban areas are particularly relevant as a source of waste management problems, but their specific spatial configurations also offer a range of possibilities to develop sustainable stategies. These strategies will promote the use of waste as a resource, thus support the on-going initiatives of the European Commission towards establishing a strong circular economy.

The integration of life cycle thinking, geodesign, reversed material flow accounting and urban metabolism is key to identify the place-based eco-innovative strategies or solutions. Data collection, tracking of flows, impact assessment and model development are crucial to allow quantification and validation of alternative solution paths and therefore promote sustainable urban development. The GDSE will be available on an open source platform and the approach is by definition transdisciplinary, i.e., including economic, social and environmental dynamics. To successfully develop, test and implement the GDSE, the following project (sub-) objectives have been defined (REPAiR Grant Agreement):

- To provide decision-makers with comparative assessments of different integrated spatial resource management strategies by combining forecasting methods, strategy conceptualisations and an integrated assessment of economic, environmental and social sustainability in a collaborative decision support environment.
- To develop an understanding of the characteristics, mechanisms and dynamics of European resource management systems by analysing the relations between waste flows, environmental and spatial quality, allocation and governance in six peri-urban areas using life cycle thinking.
- To better interpret the link between metabolic flows and urban processes, by extending the assessment of urban metabolism to include urban driver concepts and urban patterns, as well as environmental and spatial quality, and co-benefits.
- To improve the knowledge and reliability of waste related data by reversed material flow accounting.

• To implement living labs in peri-urban areas across Europe in order to develop, test, implement and assess place-specific eco-innovative solutions for resource management to improve environmental and spatial quality and quality of life.

• To understand decision making structures and processes in the case study areas with regard to interests and priorities of different stakeholders in order to add transparency to the decision making process.

• To develop a framework for transferring (a) the key modules of the GDSE itself; and, (b) the solutions and change models that it will produce across differentiated peri-urban areas.

• To disseminate and ensure the further uptake of the project's insights on aspects of resource management and GDSE development by including local and regional planning authorities, NGOs, public and private waste management companies, and future urban planners in the project.

These objectives may boost the development of eco-innovative solutions to prevent waste generation and promote the use of waste as a resource. The aim is to enhance the natural and living environment in urban and peri- urban areas and assure that developing and demonstrating eco-innovative solutions in real-life environments will enhance their market uptake and contribute to sustainable urbanisation worldwide. REPAiR uses two pilot studies in Naples and Amsterdam (case study areas) to develop the GDSE. The rationale behind this being that the Naples case focuses on territorial and landscape questions, whereas the Amsterdam case focuses on waste/resource flow optimisation and business development. The follow-up studies (Ghent in Belgium, Hamburg in Germany, Łódź in Poland and Pécs in Hungary include both challenges (Figure 1). The wide array of characteristics within this set of cases makes them representative for many other European metropolitan regions.

Figure 1. The six case study areas of REPAiR; Amsterdam and Napels (pilot cases) and Ghent, Hamburg, Lódź and Pécs (follow-up cases). *Source: REPAiR Grant Agreement*

2.2 Consortium

The REPAiR consortium consists of a good balance of partners with different expertises, e.g., expertise in waste and resource management, spatial decision support, territorial governance, spatial planning and urban design. In total 18 companies or institutions are part of the REPAiR consortium (Table 1). The project is coordinated by TU Delft, which acts as the intermediary between the partners and the European Commission (Funding Authority). The Executive Board (EB) consists of Work Package (WP) leaders (see Section 2.3) and peri-urban living lab (PULL) leaders. Also, a User Board (UB) has been established (13 members in total, spread over different European countries) and will be steered by the Executive Board. The UB shall support the work of the consortium, and shall assist and facilitate the decisions made by the project partners. The UB will play a crucial role in testing and further developing the GDSE and will therefore be invited to join the regular project meetings.

Table 1. Consortium members within REPAiR and their location (country). *Source: REPAiR project handbook*

Participant (Acronym)	**Country**
Delft University of Technology (TUD)	Netherlands
Ghent University (UG)	Belgium
DiARC UNINA - University of Naples Federico II (UNINA)	Italy
HafenCity Universität Hamburg (HCU)	Germany
Institute for Regional Studies, CERS of HAS, MTA KRTK (RKI)	Hungary
Institute of Geography and Spatial Organization Polish Academy of Sciences (IGiPZ)	Poland
Joint Research Centre (JRC)	Italy
Geo-Col GIS and Collaborative Planning (Geo-Col)	Netherlands
Delta Development Group (DELTA)	Netherlands
BIOKOM Nonprofit Ltd (BIOKOM)	Hungary
Gertz Gutsche Rümenapp Stadtentwicklung und Mobilität GbR (GGR)	Germany
Public Waste Agency of Flanders (OVAM)	Belgium
Municipality of Haarlemmermeer (GHM)	Netherlands
Campania Regional Authority (CRA)	Italy
Pheno horizon (PHH)	Poland
Bauer Umwelt GmbH (BMU)	Germany/Italy
IVAGO (IVAGO)	Belgium
Stadtreinigung Hamburg (SRH)	Germany

2.3 Work packages

REPAiR's structure is built upon 9 work packages (WPs). Work packages 1, 2, 7, 8 and 9 manage different aspects across the cases and coordinate activities related to knowledge dissemination and data management wheareas WPs 3 to 6 develop territorial metabolism models, evaluation and impact models, decision models and a knowledge transfer methodology (Figure 2). The paragraph below describse more in detail the goals of the different work packages and the interlinkage amongst them.

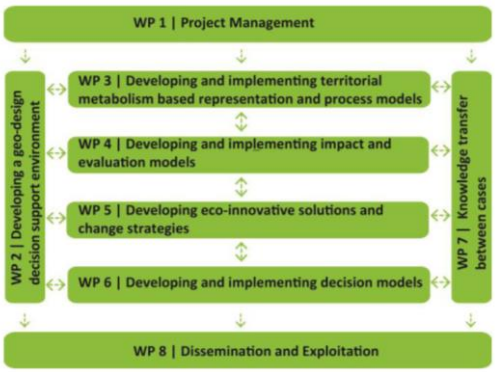

Figure 2. The workpackages and their interaction within REPAiR. WP 9 is not vizualized but is an overaching WP (similar to WP2 and WP7) about ethics requirements. *Source: REPAiR Grant Agreement*

WP 1 involves the project management, WP2 develops the final GDSE, based on the output of WP3 to WP6. The main objective of WP3 is to collect primary and secondary data of the different case study areas in terms of material and mass flow balances, but also socio-economic aspects with regard to spatial and temporal dimensions. The collected data will be used by WP4, who is responsible for the development of a sustainability framework, including transdisciplinary impacts (economic, social, and environmental) in a spatially-differentiated way. The generic framework has to be applied to the different case study areas, both to assess the current waste management situation as the proposed eco-innovative solutions. The latter will be generated within WP5, for each case study area, and data collection of these solutions is again based on the methodology developed by WP3. Decision models are then developed by WP6 based on the outcomes of WP3-5 in connection with the analysis of the decision making landscape. WP7 is responsible to develop a methodology for knowledge transfer that can be used by the different case study areas. There is a clear link with WP8 that develops dissemination strategies, so the results of REPAiR can be communicated to a full range of target groups. A last WP9 sets out the ethics requirements that the project must comply with.

3. RESULTS AND CONCLUSION

Local waste management is a complex process with a range of positive and/or negative consequences for the involved stakeholders and is a key element in ensuring resource efficiency and the sustainable growth of European cities. Decision making in waste management requires clear goals, appropriate methods and reliable data. However, currently, there is no consensus on how to assess the sustainability of urban waste management. The objectives of waste management must be multidisciplinary: safeguarding human health and the environment, conservation of resources and no transfer of waste problems to future generations as this does not contribute to sustainable management (Stanisavljevic and Brunner 2014). In addition, an important point of attention is the fact that the waste management system is spread over different geographical locations, i.e. to optimize urban waste management, also the burdens (and/or credits) associated with the treatment of the urban waste must be taken into account to avoid burden shifting amongst different regions. Equally important is to include a life cycle perspective, to minimize burden shifting among the involved processes (waste management processes and the supporting processes such as energy production).

A framework to support decision making in waste management must be able to cope with environmental, engineering, technical, socio-economic and spatial aspects. In fact, the sustainability framework for local waste management must include the methodological basis for assessing multi-scale (different geographical locations), multi-size (micro to macro) and transdisciplinary (environmental, economic and social) impacts, in order to support quantitative modeling in current and future research. The aim is to contribute to a comprehensive sustainability framework for waste and secondary resource management able to cope with local (spatial) differences, for which a variety of methods and tools need to be used (e.g., material flow analysis (MFA), energy balances, spatial analysis, life cycle assessment (LCA), social LCA, life cycle costing (LCC), etc.). A fundamental challenge is to overcome the limitations of each concept and to coherently integrate the basic principles into a comprehensible framework for REPAiR. This framework allows a comparison between the current urban waste management system, and possible eco-innovative solutions which may incorporate circular economy approaches. It envisions to provide local and regional authorities with strategies to use waste as a resource towards establishing a strong circular economy.

At the moment, further details regarding ongoing work cannot be spread towards a broader public because of confidentiality issues and non-public deliverables. However, the main ideas and broader vision of especially WP4 was explained.

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