

## **Waste management in Smart Cities: the application of circular economy in Genoa (Italy)**

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Summary: 1. Introduction – 2. Analysis of smart practices of waste management – 3. “LiguriaCircular” initiative in Genoa 4. Conclusions - References.

### **Abstract**

The so-called “intelligent bins” represent the more commonly acknowledged, example of feasible waste-related project in the context of Smart Cities. Nevertheless, smart waste management should be intended as well-beyond the simple installation of sensors on bins, and it should embrace an integrated planning strategy tailored for resource recovery and efficiency within a circular economy framework. The present paper reports the findings of an analysis of best practices on smart waste management in Europe and describes the circular economy initiative “LiguriaCircular” developed in Italy. From the findings of this investigation, it can be surely concluded that, on one side, ICT applications, through management of data on all levels by all stakeholders, can smartly enhance the visualization of intelligent waste management systems. On the other side, it can be also underlined that future research should be aimed to broaden the concept of Smart Cities towards full-scale creation of new patterns linking innovation and entrepreneurship for economic growth and value. By taking inspiration from existing experiences in the field of circular economy, the future directions envisaged for Smart Cities should be targeted towards industrial symbiosis, by development and implementation of tools for regenerative systems and symbiotic business links.

**Keywords:** waste management, Smart City, circular economy, forum, best practices, industrial symbiosis, regenerative systems, symbiotic business.

## 1. Introduction

According to the Strategic Implementation Plan of European Innovation Partnership on Smart Cities and Communities, “Smart Cities should be regarded as systems of people interacting with and using flows of energy, materials, services and financing to catalyze sustainable economic development, resilience, and high quality of life; these flows and interactions become smart through making strategic use of information and communication infrastructure and services in a process of transparent urban planning and management that is responsive to the social and economic needs of society” (EC, 2013a). Smart Cities are doubtless considered as a hot topic indeed among policy actors, technology experts, management practitioners and academia; nevertheless, a wide set of definitions of the Smart City concept in literature is retrievable (Elmangoush et al., 2013). It was even judged as a fuzzy concept, since several examples of self-defined Smart Cities were traceable (Hollands, 2008). Different acceptations such as “intelligent city”, “information city”, “knowledge city”, “digital city” and “ubiquitous city” in fact have some common characteristics and individual elements, while definitions encompass a different scope and place different emphases (Lee et al., 2014).

The orientation on specific priorities by European Commission is described in the Operational Implementation Plan (OIP), companion document to the Strategic Implementation Plan (SIP) of the European Innovation Partnership on Smart Cities and Communities (EC, 2013b). Several areas of interests and recommendations are analyzed in detail, together with examples aimed to inspire interested parties responding to the Commission's 2014 Invitation for Commitments, as well as address further implementation actions that may be launched at a later stage.

In the Priority Area “Integrated Planning and Management”, a spatial, temporal and technical coordination of diverse policy areas is stressed, planning resources to achieve defined goals using specified financial instruments. The focus on this area is aimed to foster implementation of local policies leading to innovative smart integrated solutions for mobility, energy, buildings, water and, in fact, waste management. Besides, in the Priority Area “Integrated Infrastructures”, new joined-up approaches with employment of modern technologies, are promoted, by exploring how both active and passive infrastructures in cities may be improved and exploited in a more integrated way to add value on the three dimensions of sustainability. Among the potential actions proposed within OIP, “Intelligent Bins” are proposed for implementation. The installation of sensors on bins can enable cities to communicate within the waste collection system, in order to optimize truck routing, minimize energy consumption and congestion, and satisfy customers (EC, 2013b).

Intelligent bins indeed represent the first, and probably the more commonly acknowledged, example of feasible pattern aimed to the engagement of different layers of government, industries, civil society and city residents for value-adding purposes with focus on waste-related themes. Nevertheless, smart waste management should be intended as well-beyond the simple installation of

sensors on bins, and it should embrace an integrated planning strategy tailored for resource recovery and efficiency within a circular economy framework.

This perspective is in line with the idea of a Smart City as a “system of systems”, where the integrated systems forms a closed loop and are characterized by functions. Along this interpretation, each system produces its own information and consumes the output information from the other ones in a well-defined urban planning (Naphade et al., 2011). In fact, the concept of circularity has been described as a tangible driver of innovations and value creation for the 21st century global economy, dealing with the complex issues of waste, economic growth and sustainability (Greyson, 2007). Recent assessments of good governance highlighted the possible links between urban ecosystems and innovative processes for the development of greener economy for cities, by reducing their ecological footprints and increasing circulation of material and economic resources (de Oliveira et al., 2013).

In this context, smart waste management is a key issue for translating integrated strategic approaches for Smart Cities to the wider idiom of circular economy, transcending the urban dimension. The present paper reports the findings of an analysis of best practices on smart waste management in Europe and describes the circular economy initiative “LiguriaCircular” developed in Italy.

## **2. Analysis of smart practices of waste management**

This section is aimed to investigate smart practices in the field of waste management, firstly among the projects already tested for implementation within European Smart Cities, and successively among the documented experiences of circular economy at project level in Europe.

When examining the distribution of existing projects through different fields of application among Smart Cities at global level, a recent report (GMA, 2013) highlighted that transportation sector accounts for most projects, followed by energy/environment sector, and municipal infrastructure services, including water and waste management. In a recent review study (Piro et al., 2014), analyzing the investigated use-cases by the most important EU projects, only 1 project out of 19 is classified to be focused on the topic of waste management, under the category of smarter building and urban planning. This is the case of OUTSMART project, where it is explicitly stressed that, within efficient urban planning, the management of waste is an emerging issue for modern urban areas. Here, the modeling process is about an user wishing to know the waste container where to throw the waste, thus releasing a so called “interest packet”, aimed not only for the position of the bin, but also to understand if it is empty or not. The bin should provide these details within a so-called “data packet”, also communicating to a remote data center its filling level. Thus, the waste management data center is able to reply with a “data packet” of confirmation and then properly react to the information, by planning the emptying of the bin (Grattard et al., 2013). In fact,

several integrated sensing systems and algorithms for solid waste bin automation have been recently analyzed by the scientific community through experimental setup (Mamun et al., 2015), aimed to develop efficient and dynamic waste management systems.

Nevertheless, as stated previously, an integrated approach for smart waste management may be intended also beyond the concepts of intelligent bins. Some experiences on how Smart Cities are being practically addressed are recorded by OIP (EC 2013b) in “Country Landscaping” annex for five EU Member States. In Finland, among Public Sector City Initiatives about governance theme, the “National Waste Management Plan” in 2008 established a target for 50% of waste to be recycled and 30% to be used as energy by 2016, with 20% of waste to dumping grounds. This theme is included in the implementation plan as an illustrative driver that can help countries for comparing context, supporting dialogue, and informing action for Smart Cities, thus waste management is explicitly quoted as a key topic indeed.

In this sense smart waste management is not only addressed to operational procedures but also to development of decisional strategies. Thus here a list of best practices of circular economy approaches is analyzed and evaluated from a “smartness” perspective, through the classification of the experiences retrieved from the three last reports of Ellen MacArthur Foundation (EMF 2013a, 2013b, 2014). In table 1 the case studies of best practices are evaluated in relation to a set of criteria proposed by EMF, i.e. *New business model*, *Reverse logistic*, *Cross-sector collaboration*, *Tighter regulation*, *Enabling technology* and *Radical design*. These parameters are addressed to represent different aspects related to circular economy, in order to inform, inspire and stimulate innovative research.

The first criterion is *New business model*, defining if a better design can result in attractive value propositions, e.g. transforming the consumer in user or converting products in services. For instance, Mud jeans developed a method to improve the recovery rate of fabric, through the implementation of a new selling strategy.

*Reverse logistic* is the second criterion taken into account in this study, assessing if a cost-efficiency analysis is implemented to improve the quality of collection and treatment systems in order to avoid leakage of components and materials out of the system. An example is represented by Rype office enterprise, which applied a scheme for trade office furniture that will result in the re-collection off all the sell material at their end of life.

**Table 1. Case studies – EMF parameters**

Case studies	New business model	Reverse logistic	Cross-sector collaboration	Tighter regulation	Enabling technology	Radical design
Rype office	x	x				
Coca-cola		x	x	x		
Villa Welpeloo					x	x
Bunge	x		x			
Splosh	x			x		
Caterpillar	x	x				x
Philips & Turntoo	x		x			
Maersk Line			x			
Mud Jeans	x	x				
Wear2			x	x	x	x
Autocraft Drivetrain		x		x		
Kalundborg Symb.	x	x	x	x		
Refuse vehicle		x		x		
FLOOW2	x		x			
Ricoh	x	x		x		
Desso	x					x
GameStop	x	x		x		
Aquafil		x	x	x		
Active disassembly					x	x
Ecovative						x
Mazuma Mobile	x	x		x		
Digital Lumens	x				x	
Brocklesby		x	x			

**Table 2. Case studies – waste related parameters**

Case studies	Internal loop	External loop	PSS application
Rype office	x		x
Coca-cola enterprise		x	
Villa Welpeloo		x	
Bunge	x		
Splosh			
Caterpillar	x		
Philips & Turntoo			x
Maersk Line			
Mud Jeans	x		x
Wear2		x	
Autocraft Drivetrain Solutions		x	
Kalundborg Symbiosis	x		
Refuse Vehicle Solutions		x	
FLOW2		x	x
Ricoh	x		x
Desso	x		x
GameStop		x	
Aquafil	x	x	
Active Disassembly		x	
Ecovative		x	
Mazuma Mobile		x	
Digital Lumens			x
Brocklesby		x	

*Cross-sector collaboration* is used as parameter to define if effective cross-chain and cross-sector collaboration are implemented towards a large-scale establishment of a circular system. For instance, Coca-cola company made agreements with two recycling companies to improve European collection and valorization of plastic waste.

Some products or services need to strictly involve decision makers to guarantee a faster and shared agreement on their goodness, or to be better understood by the market. Thus, a binary criterion, defined as *Tighter regulation*, outlines when a product or a service needs or suggests a better resource scarcity regulation and tighter request on environmental standards, in order to be adopted as virtuous practice. The final effect will be to reward circular business over 'take-make-use-dispose' businesses; e.g. WEAR2 developed a yarn that dissolves under the influence of micro-wave; in this way the clothes can be processed to

eliminate the brand and be re-sold. With a tighter regulation more companies may be able to adopt this technology, resulting in an increase of recovered cloths.

*Enabling technologies* criterion gives information about the need of advanced technologies. Digital Lumens offered a service that is classifiable under this parameter, as this company developed an integrated intelligent lighting system combining LEDs, networking and software to reduce consumers' related energy use.

Besides, products that present improvements in design and material selection, reducing the cost of moving products into ever tighter reverse cycles, were marked with the criterion named *Radical design*. Caterpillar can be quoted along this line, since this company designed an engine that permits to recovery the pistons' cylinder extending the overall life of the machine.

Beyond the classification proposed by EMF, further investigation on waste-related patterns was performed. For this purpose, a set of criteria was here defined, on the basis of the criteria of Extended Producer Responsibility in supply chains (Rizzi et al., 2013) and service-dominant logic (Lusch and Vargo, 2006). Thus, here three additional parameters are outlined in order to evaluate the different practices presented by EMF, as shown in table 2, i.e. *internal loop*, *external loop* and *PSS application*.

*Internal loop* parameter assesses the reuse by the same enterprise of a waste process or product, to transform it into main product or by-product. For instance, Desso - an enterprise producing carpets – started to withdraw its own old carpets to disassemble them and produce new ones.

On the other hand, *External loop* criterion assesses if the enterprise main product is generated by the collection of scrap materials from other systems, resulting in a minor use of raw materials; e.g. Brocklesby is a company that collects waste oil and fats from restaurants and food industries, producing fuels.

The last criterion is called *Product Service Systems (PSS) application*. PSS have been heralded as one of the most effective instruments for moving society towards a resource-efficient, circular economy and creating a much needed 'resource revolution'. PSS aim is to change the user behaviors from ownership to access. The arising of this pattern in the market can be seen in the increase of shared cars, machinery and articles of daily use (Tukker, 2015). For instance, "pay per lux" is a project of the joint-venture of Philips and Turntoo aimed to radically change the ownership of lighting systems. Philips maintains ownership of the materials, while costumers benefit from maintenance and service, as well as the option to adapt or upgrade the setup, with the manufacturer able to recover the materials when necessary.

Among all the proposed case studies, Villa Welpeloo project is here judged as the most easily reproducible practice to be effectively replicated in a Smart City context, such as the initiative described in the next section. Villa Welpeloo is a building situated in Netherlands, designed by a team of architects, assembled with waste and scrap materials found in the construction area. This building became a flagship to develop a new project, i.e. a web portal that tracks and tags waste and scrap materials, giving geographical information of where it is possible

to find them. This portal is an excellent example of how a simple project of sustainability can be developed within a regional scale, multiplying its virtuous impact and becoming a standard of good practice.

### 3. “LiguriaCircular” initiative in Genoa

Among the best practices related to circular economy reported by EMF, the unique case study in Italy is represented by Aquafil experience, with the establishment of the Econyl Reclaiming Programme, a tool to facilitate reverse supply chain and ensure reliable materials inputs, by taking advantage of the depolymerisation feature of Nylon 6.

When investigating the global scenario for waste management in Italy, wide differences emerge in the governance arrangements in the various regions of the country (Citroni and Lippi, 2009). In certain regions the operative rules of the system have been established by the legislator on the basis of the structural features of the firms active in the area. This was sometimes exclusively aimed to maintain the status quo, nevertheless in virtuous cases this solution was tailored in order to add value to some existing organizations for the creation of a “regional sample” to face the evolving free market with sensible hopes for success (Paci and Becagli, 2009).

In 2014 a permanent forum related to circular economy, named “LiguriaCircular” started in the municipality of Genoa, northern Italy, from an initiative of the Municipal Urban Health Enterprise (AMIU S.p.A.) aiming to promote and manage circular economy initiatives in the Ligurian territory.

Smart Cities can benefit from the transition from ‘take-make-use-dispose’ economy to the new concept of circular economy. The idea of improving circular economy in a metropolitan city is addressed to overtake linear economy patterns that usually transform every product in waste at the end of its life. On the contrary circular economy is a system where every product, from the design to the end of its life, is organized to avoid any possible waste of resources, and to transform refuse and scrap in resources instead. The aim of circular economy is to get the maximum value from every product, both in use and at the end of their life. The forum is organized in four different thematic areas.

The first area was developed to reverse the trend of the food waste. As stated by (Godfray et al., 2010), continuing population and consumption growth will result in a highly food demand in the next decades. The savage spoil of land, water, and energy, in addition to the tremendous mistreatment of the sea, will affect our ability to produce food, as will the urgent requirement to reduce the impact of the food system on the environment. Finding a solution to this problem is possible by leading an improvement of good practices in the food supply chain. Some of them are really simple actions, such as pushing the food producers to introduce flexibility in size, color and weight of fruit and vegetables. This will help



to avoid the waste of less attractive foods, and can be developed by introducing new promotions for misshapen products.

**Figure 1. LiguriaCircular Model**



The second area of interest for LiguriaCircular forum is to enhance resource efficient buildings. According to the European Union, due to energetic inefficiency systems, buildings are responsible for 40% total carbon-dioxide emissions in Europe (Huovila, 2007). The building design stage is a key factor to new opportunities for cutting energy, waste, water and carbon impacts. A strong link with many actors of the construction sector will enable to bring whole supply chains together, towards circular patterns. For this thematic area, LiguriaCircular forum is intended to be a facilitator between government and industry, helping to catalyze collective actions.

The hub of the third area is in the sustainable products design. The traditional 'make, sell and dispose' model is resource intensive. The design of better products starts from the development of new ideas, and new technologies. Research and development (R&D), society and university are the leaders in the innovation field, while companies can improve their production thanks to the link with these realities. Through this approach, the creation of better-designed products or services will respond to market opportunities while cutting carbon, waste and water impacts. Encouraging re-use and repair does not only benefit the environment; it saves businesses money, can generate jobs and has social benefits too.

Although the design of complex products that can be simply dismantled to recover the reusable raw materials is one of the main concerns manifested by the last of the four operating areas of the forum, focused on waste as a resource. The ongoing research within this thematic area deals with the issue of feasible recover of material and value when products reach the end of their useful life. Smartphone, televisions and all the sort of household electrical appliances are composed by treasure of scarce and precious materials, rare heart and valued metals. The collection of those materials is becoming a political and economic concern, where circular economy may play a fundamental role. Improvements of the collection systems and working with recycling and re-use businesses help to create new markets for its outputs. Clothes, electrical and furniture can be refurbished and reused; the forum will enable partnership projects among local authorities, waste management companies and third sector organizations that increase re-use within a local area, making the disposal a beginning and not the end.

In addition to Genoa municipality and AMIU, LiguriaCircular involves many different companies as responsible actors for improvement, such as associations based in Genoa and the local University. A total of 43 enterprises, 30 different organization and public body, 9 research institutes and 34 among consortia, groups and consultants constitute a total number of 116 actors working within LiguriaCircular. As notable in figure 1, the target of LiguriaCircular model is to create mutual help by all the represented realities. LiguriaCircular's results and projects will help in creating feasible solutions in the transition to a circular economy as a useful tool to create a smart community, firstly in the local context and successively in the regional area.

As a validation test of the classification criteria proposed by LiguriaCircular forum, these ones can be applied to the analyzed case-studies within EMF. Three and four projects can be respectively assigned to food waste and resource efficient buildings categories, whilst thirteen projects are ascribable to sustainable products design, and the wide majority, i.e. eighteen out of twenty-three, is related to the area of 'waste as a resource'.

#### **4. Conclusions**

The analysis of existing experiences and guidelines about smart waste management performed in this paper suggests that innovative rethinking process about urban waste management infrastructures is not the only path for cities to reap the benefits of turning waste into a resource.

Coordinated initiatives, such as the investigated case of LiguriaCircular, are able to effectively promote broad awareness of reuse and recycling through engagement of all the stakeholders in the urban context, from local and regional authorities to industry, from decision makers to citizens. The exchange of best practices between public authorities and stakeholders involved shall be

supported in order to increase preparedness and planning capacities of all the relevant actors.

It can be also underlined that future research should be aimed to broaden the concept of Smart Cities towards full-scale creation of new patterns linking innovation and entrepreneurship for economic growth and value. By taking inspiration from existing experiences in the field of circular economy, the future directions envisaged for Smart Cities should be targeted towards industrial symbiosis, by development and implementation of tools for regenerative systems and symbiotic business links.

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