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Innovation and Technical Change in the European Municipal Waste Industry

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Abstract

Municipal Waste (hereafter MW) sector is commonly considered an industry dominated by the collection segment and by labour intensive activity, with almost no room for innovation apart from waste-to-energy incinerators. In this work we intend to argue this perception, demonstrating that even when focused on labour intensive activities such as selection and recycling, MW sector is interested by innovation and technical change. But we claim that standard innovation theory developed by Neoclassical economics miss to represent a useful theoretical framework, and that Complexity Theory allows to better interpret innovation in this field.

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Key words: Solid Waste, Waste Management, Technical Change, Complexity Theory

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Introduction

Innovation in MW Industry is a quite neglected issue in both economic and waste management literature.

Definitions of eco-innovation (Kemp, 1997, 2010) highlight the ecological attributes of individual new processes, products and methods from a technical and ecological perspective. The Measuring Eco-Innovation research project defines eco-innovation as the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life-cycle, in a reduction of environmental risks, pollution and other negative impacts of resources and energy use compared to relevant alternatives. The inclusion of new organizational methods, products, services and knowledge oriented innovations in this definition differentiates from the definition of environmental technologies as all technologies whose use is less environmentally harmful than relevant alternatives (Kemp, 2010).

Several papers investigate eco-innovation drivers. These include Parry (2001), which argues on the impact of environmental policies on technological innovation, Horbach *et alia* (2012), who focus on the German regulated industry to assess the drivers of eco-innovation, claiming that the existence of consumer demand for environmental quality boosts eco-innovation in the areas of recycling and use of materials; Kneller and Manderson (2012), which examines the link between eco-innovation and regulation in the United Kingdom; Rehfeld *et alia* (2007), concluding that the relevance of demand pull factors for eco-innovation is mixed. Another research line investigate the role of policy schemes and regulation on the so called Porter hypothesis (Ambec and Barla, 2006, Popp *et alia*, 2009; Costantini and Mazzanti, 2012).

Applying more specifically to innovation in MW management realm, Managi et alia (2012) analyse the technology adopted by municipalities in Japan, suggesting that inappropriate incentives for technology adoption can arise. Nicolli and Mazzanti (2011) explore the existing relation between environmental policy implementation and the patent application in the area of European Union recycling and waste management technologies, obtaining that regulation does seem to play an important role in the promotion and diffusion of innovation, even though from 1990s its effect is less pronounced. Cainelli et alia (2015) develop a joint theoretical-empirical investigation, with a model including idiosyncratic institutional and economic features of the territory, to find the key elements of regions that foster waste and resource use related innovations; in line with the emphasis on external innovation as more important than classic drivers of innovation, such as R&D, they conclude that firms located in regions where commitment to waste management to increase recycling is stronger are more likely to adopt innovations aimed at reducing waste and materials, while waste related innovation seem not to be sensitive to the presence of R&D.

In this work we claim that technical and organizational change is an issue in MW, and that the theoretical framework of Complexity theory seems to fit better than mainstream innovation economics to illustrate and study it.

The paper is organized as follows: Section 1 outlines a brief literature review on innovation; Section 2 is devoted to describe the kind of innovation that belongs to MW industry. In Section 3 and 4 we analyse the MW sector with the theoretical frameworks of neoclassic innovation economics and complexity theory respectively. Section 5 resumes the main drivers of innovation in MW industry. A final section summarises the main results.

1. Innovation and Technical Change: a Literature Review

Technological and organizational change is defined as innovation when the introduced novelty entails increased efficiency.

Given that innovation has become the "industrial religion since the end of 20th century"[2], Economics of innovation has gained new prominence in last decades.

[2] The Economist, *Survey of Innovation in Industry*, 20th February 1999.

At the dawn of the economic discipline, Adam Smith and David Ricardo focused on the technical change embedded in goods and on its influence on productivity, some topics that would have been rescued by neoclassical economics in more recent years. A different point of view on technical change was proposed by Marx, who emphasised the social dimension of innovation, to be seen as the result of relationships and conflicts among economical and social groups (Malerba, 2000a).

For many years, the same issue of economics of innovation has been associated to the figure and the studies of Joseph Schumpeter. Schumpeter is the first to provide a definition of innovation as the exploitation for economic purposes of a scientific or technical knowledge internal (through Research and Development activity, hereafter R&D) or external (through acquisition on the market) to the firm (Schumpeter, 1919). In the same study, Schumpeter offers a taxonomy of innovation, described as the introduction of a new good (product innovation), of a new production or sale method (process innovation), and of a new organization or market form (organizational innovation).

In his wide-spreading work, Schumpeter calls the attention on the discontinuous nature of innovation, with waves of disruptive technological change that sweep away old goods and the industry producing them (Schumpeter, 1935). At first, he identifies in the single entrepreneur and in its “animal spirit” the driving force of innovation, the agent able to move forward the technological frontier searching for market benefits; later, he turned to the preeminence of big and monopolistic firms, exploiting economies of scale related to R&D investments, and the existence of “strategic” industries, characterized by a higher technological content and positive spillovers on the whole economy of a country (Rosenberg, 1983).

The studies of Schumpeter have been seminal for the following Economics of Innovation, both of neoclassical and heterodox orientation. We can see the influence of Schumpeter on neoclassical theory in the accent on drastic innovation and in the substantial scepticism on the innovation aptitude of small-medium enterprise; at the same time, his emphasis on the innovative force of non-competitive market and on the uncertainty affecting the entrepreneur, incapable to grasp all the implications of the innovation he introduces, put Schumpeter in the mark of heterodox innovation frameworks, such as evolutionary and complexity theories.

In more recent years, neoclassical economics of innovation focuses on a set of fundamental issues, neglecting others: the stress on process innovations and the consequent cut in production costs and price reduction, rather than on product innovation compatible with price differentiation; the attention for equilibrium conditions (optimal length of patents, firms winning a patent race and gaining the market), rather than for adjustment processes; the interpretation of innovation as the product of information accumulation and learning by doing, rather than as a new way to watch at artifacts; the willing to increase market quotas and gain extra-profits as the driving force of innovation; the role of technical change and technological progress in Gross Domestic Product (GdP) growth.

A huge neoclassical literature descends from the mentioned Schumpeter's intuition on the relation between market structure and incentives to innovate. A new beginning, in this sense, is given by Arrow (1962a), who concentrates on process innovation reducing the unit cost of production entailed by different kinds of agent, namely a monopolist, an oligopolist and a social planner. The final outcome of this influential work is the so called "Arrow's argument": in both cases of drastic innovation (i.e. a technical change that produces higher profits for an outsider rather than for an incumbent) and of non-drastic innovation (conversely), the total benefit of innovation is increasing with the number of competitor and it is the highest for a social planner. The adducted reason is that the incentive to innovate is lower for the monopolist, that would end "replacing himself", while an outsider or a competitor would replace the former incumbent (a situation labelled as "leapfrogging") or at least increase its market share.

Starting from Arrow's study, a new generation of models wondered on the results of non-cooperative and cooperative R&D activity. The first line of works is the so called "patent race" family of models, where innovators participate in a winner-takes-all competition to gain a leader position in both R&D and final product markets.

Relevant patent race models are provided by Loury (1979), Dasgupta and Stiglitz (1980), Lee and Wilde (1980), Gilbert and Newberry (1982), Reinganum (1982), Grossman and Shapiro (1987), Scotchmer and Green (1990), De Fraja (1993), Denicolò (2000), Stein (2008).

The first contributions share the same framework given by firms with symmetrical costs structure and expected benefits from innovation. Considering fixed upfront R&D costs, Loury (1979), and Dasgupta and Stiglitz (1980) show that the effort in R&D is lower when competition increases, but competitive equilibrium is affected by over-investment in R&D. The picture changes in Lee and Wilde (1980), where firms pay a variable cost that falls to zero when they cease to invest in R&D; in this case, the outcome is the opposite and R&D effort at equilibrium increases along with the number of agents operating in the market.

The assumption of symmetry is abandoned with the second group of patent race models, rooted in a game theory framework. Gilbert and Newberry (1982) introduce a sequential game with an incumbent leader and an outsider follower competing to reach a non-drastic innovation: the final result is that incumbent wins the patent race (monopoly persistence), but an "efficiency effect" arises, i.e. consumers of the final product can exploit the benefits from innovation. Reinganum (1982) considers a simultaneous game with stochastic achievement of drastic innovation by incumbent and outsider; she obtains that incentive to innovate is higher for outsiders (leapfrogging), but no benefit for consumers is generated, so that the final outcome is just the replacement of the former monopolist with a new one (replacement effect). Finally, in the same line of research, Denicolò (2000) considers a simultaneous game *à la* Reinganum (1982), with a non-drastic innovation *à la* Gilbert and Newberry (1982); he shows that the effort in R&D is a strategic complement for both incumbent and outsider, and that the final results in terms of persistency of the incumbent or leapfrogging, and of replacement or efficiency effect are ambiguous *a priori*.

A different branch of studies, midway between non-cooperative and cooperative R&D, focuses on multi-stage research activity. Pioneered by Grossman and Shapiro (1987), this group of models consider the cases when intermediate technological knowledge is the input for the final achievement of sequential innovation, and the implementation of a weak patent regime leads to faster technical change. In this mark, Scotchmer and Green (1990) consider the role of disclosure, i.e. placing new findings in the public domain, as a prominent tool to spread the knowledge necessary to promote the diffusion of inventions. De Fraja (1993) shows that a firm might find it profitable to help the rival in achieving the innovation, if there are enough benefits from finishing "second" in the innovation race; Stein (2008) shows that a spontaneous collaboration will arise if firms have the opportunity to share repeatedly their own progress when facing multi-step sequential innovation (Blasco, 2012).

Cooperative R&D is debated by Katz and Shapiro (1985), Grossman and Shapiro (1986), D'Aspremont and Jacquemin (1988), Kamien *et alia* (1988), Leahy and Neary (1997), Salant and Shaffer (1998), Belderbos *et alia* (2004).

Katz and Shapiro (1985) focus on licensing agreements, i.e. the transfer of technology from an innovator to one or more licensee firms for a fixed-fee or royalty; they conclude that licensing can have important effects both on the development of innovations and on total surplus for society as a whole, but even that minor innovations are more likely to be licensed than major ones. Grossman and Shapiro (1986) apply to Research Joint-Venture (RJV), i.e. the creation of a new economic agent aimed at developing R&D activity and owned by at least two firms, to find out that RJV benefits are given by scale returns (economies of joint research), elimination of duplicate costs in R&D, spillovers from dissemination of results (ex-post dissemination), and capability in stimulating R&D investments (ex-ante incentives). Contributions by D'Aspremont and Jacquemin (1988), and by Kamien *et alia* (1992) belong to the so called "non-tournament literature"; the two studies argue that R&D always leads to lower production costs, benefiting all firms of an economy. The latter model, in particular, analyse the effects of RJV on welfare under Cournot and Bertrand competition, coming to the conclusion that in both cases a RJV cartel yields the highest per-firm profit. Generalizing D'Aspremont and Jacquemin (1988) results, Leahy and Neary (1997) find that when they do not act strategically, firms sharing a RJV agreement achieve higher levels of both R&D effort and final production. Salant and Shaffer (1998), show that RJV increases social welfare even in case of lack of technological spillovers. Finally, a more recent contribution to cooperative R&D literature is given by Belderbos *et alia* (2004) in an empirical work on Dutch firms: they find that R&D collaboration with competitors and universities increases sales attributable to market novelties, while cooperation with suppliers and competitors leads to a growth of value added per employee.

Another typical neoclassical argument on innovation is the optimal design for intellectual property rights (IPR) reward and patent protection. The issue deals with both the rightful size of breadth and length shelter and with the comparison between prizes, patent protection, contests and other rewarding schemes as the best remuneration system for innovation.

On the first issue, a seminal contribution is given by Nordhaus (1969), who wonders on the existing relationship between duration of protection and social welfare, finding non conclusive arguments in favour of a length limitation. Incorporating even the breadth of protection, i.e. the allowed degree of "invention around the patent", Klemperer (1990), Gallini (1992), Denicolò (1996), Maurer and Scotchmer (2002) suggest that the best protection design for IPR and patent in terms of social welfare is based on a restricted breadth conjoint with a quite long length.

Several economic history contributions explore the efficiency of prizes as a reward method for innovations (Porter, 1994; Zuckerman, 2003), while other works focus on the comparison among different incentive mechanisms for innovation (Kremer, 1998; Foray, 2004; Scotchmer, 2004). Scotchmer (2004) argues that the best incentive scheme changes with respect to the considered research environment: in places where research ideas are scarce, patents seem to fit better, while public prizes could be the best solution whenever it is able to set up a rivalry among potential innovators, even though intellectual property is more effective in relating the reward with the social value of the innovation.

The last neoclassical topic we consider is on the contribution of innovation to GDP growth. With respect to this issue, the point of departure is undoubtedly the Total Factor Productivity model by Solow (1957), who introduces in economic literature the role of technological progress, giving birth to modern Growth Economics. Studying time series of US economy from 1909 to 1949 applying a Cobb-Douglas function to estimate the growth dynamics, Solow realizes that GDP is systematically and heavily under-rated when considering the National Account values for labour force and capital factor; Solow explains this residual value with the increase in productivity of inputs made possible by technological progress. In the line of Schumpeter (1919, 1935) and Kuznets (1930), he suggests that technical change, acting as a factor productivity multiplier, is the main driver of economic growth. In addition, in his model Solow stresses the parametric nature of growth, replicable in any economy throughout the world, destined to converge in the long-run to the same natural and common growth rate.

Albeit preserving the rationale and the technical set up of Solow's model, Arrow (1962b) claims that, rather than parametric, growth is fuelled by endogenous drivers, that reflects the disparity existing among different national and economic systems. Following this intuition, the new paradigm of "endogenous growth" arose, with several studies emphasising alternately the main contribution of various factors to growth: human capital investment (Lucas, 1988), learning by doing that increase workers' skill and productivity (Grossman and Helpman, 1991), investment in R&D (Romer, 1990; Aghion and Howitt, 1992).

Focusing on the contributions more directly concerned in the role of R&D, Romer (1990) builds up a model where GDP growth relies on the increase in the availability of new capital goods, made possible by the investment in human capital in R&D sector. Aghion and Howitt (1992) propose a very technical model, where investment in R&D influences the availability of intermediate goods, regulated by a stochastic mechanism *à la* Poisson. The new intermediate good drives the older and less efficient out the industry, increasing the productivity of intermediate sector and – as a consequence – of the whole GDP.

Many assumptions of neoclassical economics of innovation are challenged by new paradigms arisen in last few decades and labelled as "heterodox approaches": starting from the paramount point of refusing the alleged full rationality of economic agents (Simon, 1962), new theories disclaim the fact that most of innovations are incremental and cumulative, not disruptive, until a technological discontinuity appears; the fact that innovations are characterized by learning by using and they are historically and socially determined; finally, the fact that any innovation generates uncertainty in the agents' space and the main role of Public sector is to reduce that uncertainty.

The relevance of the historical pattern that leads to innovation has a launch in Nelson and Winter (1982) and a climax in David (1985)

Nelson and Winter's volume outlines a new evolutionary theory of the behaviour of firms operating in a market environment, with respect to economic change and innovation. Borrowing from biology the notion of natural selection, they highlight the importance of adjustment processes and the sequence of historical occurrences in market equilibria, following in their argument the line of many technical change scholars, who recognized the role of bounded rationality (Rosenberg, 1976; David, 1975; Mansfield *et alia*, 1977; Pavitt and Wald, 1971). From their work, a new family of "history friendly" models on industrial organization and innovation arose (Malerba, 2000a)

In one of the most famous works of last years, Paul David introduces the well-known example of the diffusion of typewriting on QWERTY keyboard. He illustrates how a chain of almost accidental historical facts could create a rigid condition that blocks the system on a less effective solution difficult to be overcome.

In another influential work, Arthur (1989) labels these dynamics as "path dependency", that could end in a "lock in" condition, i.e. a situation that, albeit improvable, stands unchanged for a long while when not irreversible. According to Arthur (1989) the reasons for path dependence could be the existence of sunk costs to be recovered, such as the learning costs depicted by David with QWERTY, or the existence of norms and habits difficult to overcome, or even the presence of network effects (Katz and Shapiro, 1985 and 1994; Economides, 1988).

Evolutionary economics is the inspiring theory of a new branch of studies in innovation: it is the so called National Innovation System (NIS), considered an empirical development of the former. In the US version, NIS investigates the role of formal institutions in supporting innovation (Nelson, 1993), while in the European version, the so called "Aalborg school", the focus is on how institutional framework (both formal and informal) and industrial organization affect the innovation attitude of a country (Lundvall, 1993)[3]. In a North (1990) perspective, the Aalborg version of SNI considers institutions as a set of habits, routines and norms regulating interactions among bounded rationality agents in a state of instability and uncertainty.

The same accent on uncertainty and the role of institutions to support agents affected by it, is well rooted in another heterodox approach: the innovation economics according to Complexity (or Chaos) theory. Developed by Santa Fe Institute's scholars, Complexity thinking is a systemic and dynamic approach considering the outcome of the behaviour of each agent and of the system where the agent is embedded is intrinsically dynamic, and it can only be understood as the result of multiple interactions among agents operating in evolving structures (Antonelli, 2011a).

Complexity Economics relies on a set of assumptions: the relevance of agents' space of interactions (considered as a pure and non-interesting virtual perimeter by neoclassical theory), and of the hierarchical organization of interactive agents: the continuous adaptation of agents to external context, through evolution dynamics and learning processes; the incessant raise of new products, markets, technologies, behaviours creating niches in global and local systems; the existence of multiple equilibria and the implausibility of a global optimum to be achieved (Arthur *et alia*, 1997). The final scenario emerging from these assumption recovers the Marxian intuition of innovation as a social driven event.

Because of the coexistence of previous characters in many economic systems, standard empirical techniques such as econometric approaches are no longer applicable; they are replaced by computer

[3] The same emphasis on the empirical aspects is the base for another model of innovation of growing reputation: it is the "triple helix" approach, stating that innovation spreads out by the simultaneous action of firms, universities and institutions that – as the blades of a helix - change their position playing the role of counterparts, so that university support the birth of innovative start ups to fill a supply lack, firms contribute to design innovation policies and programmes, while institutions experiment new solutions in market burdened by uncertainty (Leydesdorff and Etzkowitz, 1998).

simulations addressed to cover the whole set of relevant hypothesis and of the available adaptation trajectories (Rosser, 1999).

According to this approach, innovation is a property emergent when complexity is organized (Antonelli, 2011a). This intuition, joint with the perception of uncertainty as a central issue of the Complexity paradigm, suggests a fundamental role for institutions in implementing stabilization from erratic dynamics and coordination policies.

Lane and Maxfield (1997, 2005) identify three types of uncertainty, intrinsic to the transforming action of agents. They are: epistemological uncertainty, related to the real existence of the phenomenon (is a phenomenon true or not?); semantic uncertainty, related to the interpretation of the phenomenon by interacting agents (are we giving the same meaning to the phenomenon?); finally, ontological uncertainty, related to the vision of the world and the categories to describe it (is my representation of the state of the world still plausible, after the evidence of the phenomenon?). The latter one is the most problematic, since innovation changes the state of the world and prevents agents to foresee the consequence of their own actions.

This means that innovation, besides of its positive potential, generates primarily an ontological instability that ought to be guided, and that guidance role is upon institutions. As a matter of facts, there are two main instruments to deal with ontological uncertainty according to the authors: the first ones are the “narratives”, i.e. a cognitive process to give rationality to what is happening, to compare different points of view and to set medium- long-run objectives of change; the second one are the “scaffolds” (or “scaffolding structures”), i.e. institutions of various kinds (public administrations, research and support centres, universities, scientific reviews, employers associations, trade unions, …) entrusted to mediate among agents and innovations, and to act as a point of reference in the natural condition of uncertainty generated by a changing environment. The role of scaffolds is to sustain and to strengthen network linkages, exploring new opportunities, circulating novelties, proposing new functions to products, addressing the stream of information and steering R&D activity.

Another distinctive construct of economic complexity of innovation and technological change is given by the notions of "artifact". Lane and Maxfield (1997), and Lane (2006) label as artifact any manmade object able to embed technical or social change, or to achieve some particular attribution of functionality. The emergence of a new artifact generates a new uncertainty to be handled by agents in a system: as a consequence, they change their scale values, behaviours, and actions; many of them are driven out of equilibrium and react to achieve a new one in a complex setting. A higher degree of organization of complexity, usually related to the role played by institutions, allows to convert more easily the change in growth. Conversely, both disruption (because of insufficient organization) or dissipation (because of rigid path-dependency) could arise.

The combination of the agents (firms, individuals, and institutions) organized around a set of evolving artifacts, and involved in recurrent interactions is labelled as "market system". It can be associated to a given artifact, for instance "the market system of printed book" (Bonifati, 2008), or to an industry, such as "the market system of Municipal Waste" (see *infra*).

Through interactions, agents commission, design, produce, trade, provide, use and upkeep artifacts, generate new attribution of functionality and develop new artifacts to achieve the attributed functionality (Lane, 2006). All those actions are not driven by atomistic choices, but they are socially determined, being the outcome of the social features of the system populated by agents, and innovation a cognitive act, given by the building of an agents/artifacts space that creates a new market system.

Other topics belonging to the complexity approach to innovation are the relation between technical change and knowledge (Antonelli, 2005) and – as for neoclassic theory - the contribution of technical change to economic development.

Saviotti (2011) gives a deep insight in the notion of knowledge and its features. Rooting in Informational Theory (Shannon and Weaver, 1949), he describes knowledge as a co-relational structure and as a retrieval or interpretation structure.

In the first sense, knowledge is the product of the mental association among observables detected in the external environment and different variables to represent and measure them; this association generates a theoretical framework where a reduced number of entities are the fundamental determinants of a large range of phenomena. On the other hand, knowledge is the outcome of an uninterrupted exchange between internal and external information, with internal knowledge (what is already known) determining the ability to learn external knowledge and to use existing information.

As a consequence of previous considerations, knowledge is representable as a network with the nodes given by concept and variables, and the links given by the joint-utilization of them (Saviotti, 2011). A common character of a systems like this is to be "local", i.e. not fully connected, since: (i) the creation of new nodes precede the creation of links between them and between them and the old ones; (ii) knowledge can provide co-relations only over a restricted number of variables at a time; (iii) knowledge can provide co-relations only over a limited range of values of variables; (iv) the probability of the holder of a given internal knowledge to learn some piece of external knowledge is inversely proportional to the distance between the two kinds of knowledge in the total observable space of knowledge.

Starting from this theoretical and definitional framework, Saviotti (2011) use social network analysis to represent knowledge and innovation networks involving firms and organizations of biotechnology industry. It allows to bring out a high degree of structural change in the sector, with new knowledge (i.e. molecular biology) and consequent technological classes emerge in substitution of older ones (namely traditional chemistry).

An interesting review in this field is provided by Cantner and Graf (2011), who emphasise the inter-disciplinary nature of innovation networks studies, a research area that have management (Powell *et alia*, 1996), sociology (Granovetter, 1973), economics (Nelson and Winter, 1982), and geography (Saxenian, 1994) contributions as inspirers.

Following the line of the relevance of interaction in the study of innovation, in contrast with the attention to individual nodes, Consoli and Patrucco (2011) explore the relevance of innovation platforms, i.e. systemic coalitions, hierarchically organized, for the coordination of distributed capabilities and knowledge processes with high degrees of complexity.

Finally, Bodas Freitas *et alia* (2011) investigate the different forms of governance of university-industry collaboration that allows the best performance of university as knowledge producer and provider for private sector.

With respect to the relation between innovation and development, complexity theory approach stands on the legacy of unbalanced growth and post-keynesian school, and remarks the role of product, rather than process, innovation and of "mesonomic" architectures.

Robert and Yoguel (2011) mention Myrdal (1957), Hirschman (1958), Prebisch (1959), and Kaldor (1972) as precursors of development factors related to macro-complexity, due to their emphasis on the relevance of economic structure, the existence of divergent dynamics between countries and regions reinforced by feedback effects, attention for disequilibrium conditions, and the role of institutional change. The authors merge this approach with emerging literature on micro-founded development (Amsden, 2004; Ocampo, 2005a, Cimoli and Porcile, 2009) to identify industrial policies as the main tool for the processes of creative destruction and structural change, fostering absorption and connectivity capacities.

The multi-dimension nature of innovation processes is stressed by Dopfer (1994, 2011). Paying a deep tribute to Metcalfe (1998) and evolutionary economics, he depicts economy as an evolving process where the rule trajectories (the meso elements of the economy) are embedded in a process structure (the macro element) and affects the behaviour of firms (the micro elements). Addressing the complexity of the environment, meso-economics provides a useful analytical platform for theoretical explorations of economic issues. Not coincidentally, a strand of literature with strong connection with knowledge and innovation studies points up the role of meso-institutions for local development (Nonaka and Takeuchi, 1995; Brusco, 1989; Arrighetti and Seravalli, 1999; Becattini and Rullani, 1993).

Frenken and Boschma (2011) consider economic development under the influence of complexity theory being characterized by a joint process of economic growth and qualitative change (Saviotti, 1996), uneven development across regions and countries (Boschma and Frenken, 2006), and driven by local agents such as firms and cities (Frenken and Boschma, 2007). In addition, they stress the relevance of product innovation in generating growth dynamics in firms and urban structures, allowing the integration of insights from Industrial Organization and Economic Geography in a single theory.

Comparing mainstreaming and heterodox approaches, we see pronounced differences in interpreting innovation and technical change. While neoclassical economics of innovation is interested mainly in process innovations that allow cost reduction and price cut, patent protection, and equilibrium conditions, heterodox theories are more concerned in cumulative innovations that are historically and socially determined, out of equilibria conditions, and agents reaction to the uncertain framework generated by innovation.

Complexity theory, in particular, considers change intrinsic to a system characterized by the variety and creativity of their components, and by the degree of heterogeneity of operating agents. The actual directions of change are determined by the interaction between creative agents rooted in a well-defined space, exposed to endogenous events that alter expected conditions on products and factor markets, and external knowledge. Interaction between local action and external knowledge generates a complexity that could produce new knowledge and innovative effort by firms. Persistence, resilience and innovation forces interact, with characters of both path-dependency and development, the latter due to the degree of organized complexity of the system. In this sense, mesonomic institutions enable in a better way the dynamics of positive feedbacks and the successful recombinant generation of new knowledge (Antonelli, 2011a).

2. Process, Product, and Organizational Innovations in the MW Industry

As illustrated in previous Section, since Schumpeter (1919) technological change can be labelled as process, product, or organizational innovation. When applied to MW industry, this classification allows to clarify the nature of innovation for many practices and artifacts.

Process innovation deals with capital intensive plants in the segment of disposal, aimed at reducing wastes by incinerating, pyrolyzing or composting them to generate energy and products that can be used for other activities, even combining all these techniques to optimize waste minimization (Dunmade, 2013).

With respect to downstream technologies, there exist three main innovation fields: the most mature one, with a technology developed around 30 years ago, is the procedure to obtain Refused-Derived Fuel (RDF) from waste; more recent are the technologies to get thermal and electric energy from waste incineration, currently joint with the progressive reduction of ashes and particulate matters in the fume emissions; finally, the highly advanced plasma torch incineration, a technology that do not generate toxic gas emissions, particulates nor slag, but still too costly to be exploited in waste industry. Other innovative techniques involve biological and mechanic treatments of MW, aimed at reducing the amount of biodegradable waste to be addressed to landfill.

Process innovation are mostly but not exclusively connected with end-of-the-pipe disposal, regarding even waste selection and recycling. New techniques with different technology contents are pre-paid waste bags, in some cases equipped with transponders, street dumpsters with electronic scales and skullcaps, or underground collection points.

Pre-paid waste bags are an instrument at the intersection between process and organizational innovation, invented in Switzerland in mid-1990s. The rationale is to sell plastic bags, validated by the local body responsible for MW management, as the ones and only accepted for the conferring of non-recyclable waste, while selected MW can be conferred in free transparent bags. Because of the expenditure in waste bags, households pay inversely to the effort in selection they make, being motivated not only to sort final MW but even to reduce the purchase of goods with higher "content of waste" (non-recoverable materials and packaging).

To make more accurate the identification of the amount of unsorted MW produced and to charge households punctually, new tracking systems have been introduced in last years. They are based on the application of an electronic chip with transponder to plastic bags, to identify and automatically memorize searchable data tagged through radiofrequency devices positioned on the waste collection vehicles or remotely controlled. This technology, called Radio Frequency Identification (RFID), allows the storage of data on the number of purchased bags, the weight of conferred sacks, the number of conferment/emptying (when the tag is associated not to waste bags but to dump bins), and the geographical provenience of unsorted MW, all information useful to make MW management more effective. Other ICT applications to the MW field call into question the implementation of software and the use of electronic devices to track and measure garbage, and to dematerialize and simplify the billing system.

Another technique to deter the conferment of unsorted waste, especially in settings characterized by non-domestic users such as shops and offices, is the electronic and skullcaps equipped street dumpster. It is a common dump for street MW collection with a reduced insertion compartment to limit the conferring of bulky materials, and a magnetic opening key that permits the user's identification and association with the conferred waste.

In last years, it is increasingly spreading the installation in city centres and downtowns of a complete series of collection dumps (the so called "ecological islands") under the street level, with a pneumatic or mechanical elevator system to rise them at the moment of the waste bestowing. The rationale of this technique is to make more efficient waste selection in constrained areas, for instance downtowns, avoiding both the soil occupation and the visual impact of street dumpsters.

Product innovation in the field of waste means using new concepts in producing consumer goods. It is an issue that calls into question the activity of eco-design, i.e. the new habit of designing objects assuming the purpose of minimizing environmental impact both during their use and after end of live.

This claims for dematerialization, i.e. the reduction of the amount of materials used per unit output and the minimization in packaging, a waste stream accounting for between 15% and 20% of total MW in different countries (Nicolli and Mazzanti, 2011). The reduction of packaging could be considered in a wide sense, meaning both the reduction of the wrappings associated with the product and the establishment of refills and recharges in products as detergents, beverages, ink cartridges, and so on. Being strictly related to a new way in organizing retail segment, this novelty stands at the ideal intersection between product and organizational innovation.

Besides of dematerialization, product innovation even takes the form of a configuration for disassembly, that gives performing results at the moment of dismantling and disposal, when many parts and components can be recovered as raw materials, and of a conception for repeated use of the good. Finally, product innovation in last years even means a design that fosters energy efficiency and energy saving, especially with respect to electronic devices.

The last family of innovation that we consider is of organizational kind. It deals with two conceptions in waste collection and service charging: the first one, anticipated in the Introduction, reflects the approach of many multi-utility throughout Europe, that launched a relevant mergers campaign and modified the organizational scenario of the industry in last 20 years. The second one consists in implementing collection schemes based on door-to-door, kerbside or proximity collection when the other two are made difficult by logistic features related to altimetry or urban sprawl, with a source separation process that begins inside the households, or even more sophisticated systems like the one-on-one pick up for Waste Electrical and Electronic Equipment (WEEE), committed to electrical and electronic device retailers and sellers. More rare and ingenious methods are the use of "eco-mobiles", i.e. multi-compartment vehicles temporarily located in places to provide the services normally covered by collection centres for materials such as exhausted oils, bulky MW, and WEEE; another unusual system implemented in perched villages, characterized by narrow streets and space constraints, is the garbage separate collection with donkeys that substitute vans and minivans. It must be pointed out that many techniques can be perceived equally as either organizational or process innovations, and an exact classification in this sense is difficult.

Strictly related with different MW selection organization systems and processes, there exist new methods for the service financing, all aimed at charging the user for the real amount of generated waste, or for a good proxy of it. They are methods often at the status of experiments, that in many cases still mix together a flat rate based upon parametric calculations (related with the number of members of the household or the habitation size) and a direct measure of the conferred waste. The most common are the so called Pay As You Throw (PAYT) tariffs, and other kind of unit pricing such as the Italian Environmental Hygiene Tariff (*Tariffa d'Igiene Ambientale*, TIA).

Another interesting innovation belonging to the organizational category are product leasing schemes developed by some provider: manufacturers who prefer to manage goods throughout their products' service life with the customers; at the end of it, they retrieve and either upgrade or remanufacture the goods.

3 The Innovation in the MW Industry as a Market-driven Process: a Neoclassical Perspective

According to neoclassical theory, innovation is pushed mostly by market forces. The standard situation in which innovation spreads is when an outsider wants to enter a new market occupied by an incumbent to substitute or to flank him. The reason that makes it possible for the outsider to challenge the incumbent is innovation, i.e. proposing a new product more appreciated by consumers or the same product at a lower unit cost and at a consequent lower market price.

As anticipate in Section 1, neoclassical economics label as "leapfrogging", the situation when the outsider is able to send the former incumbent off the market thanks to the introduction of an innovation, that in this case is called of "drastic"; on the opposite, "incremental" innovations allows the outsider to enter the market just to cohabit with the incumbent.

In MW Industry, drastic innovations are quite rare and mostly related to the introduction of end-of-the-pipe facilities of a new generation. In this sense, the main innovation of last years has been the introduction of waste-to-energy technology, with the first full-scale commercial facility, the Arnold Chantland Resource Recovery Plant in Ames (Iowa), that started the operation in 1975 (Sovacool and Drupady, 2011). The technology earns credit in the disposal market at the end of 1990s, substituting slowly in many districts the former disposal landfills.

The recourse to waste-to-energy incinerators can act both as a drastic innovation, with the new technology that leapfrogs the old landfill, and as an incremental one, meaning the fact that the two technologies keep on co-existing in the disposal segment. The discriminating factor between leapfrogging and cohabitation is the unit revenue extracted from the technological change, given in the prospected case by the market value of recovered energy, so that when it is higher than a particular threshold, exclusionary price by innovator for the service of disposing is favourable; on the opposite, the energy revenues are not so promising to make it advantageous a price cut in the provided service, and no efficiency effect comes into action.

In the current MW industry, the state of the art seems much more addressed to cohabitation of landfills and waste-to-energy plants, rather than to leapfrogging and substitution of old technologies with more innovative ones. Besides of an insufficient extraction of value from energy generation, a reason that can be sought in the lock-in effect of the sunk costs borne by operating facility: even though it is higher for incineration plants than for landfills, the latter ones need initial investments to be written off in 10 years or more.

A further assumption that is typical of regulatory economics postulates that the absence of competition will reduce the incentives to operate efficiently, especially when facilities are allowed to charge their full cost to customers. The argument, deeply rooted in the Arrow's intuition on incentive to innovate (Arrow, 1962a) is not frequently analyzed with MW industry, but there is some empirical evidence that confirms it (Massarutto, 2015).

Another topic that usually belongs to neoclassical innovation theory is the study of R&D dynamics and incentive to innovate. In the waste industry, the degree of investment in R&D is quite low, and technological change is mainly embodied in capital equipment, rather than in the waste management sector itself (Nicolli and Mazzanti, 2011). This is someway surprising, considering that the evolution of the industry is in the direction of the rise of bigger and more capitalized firms, with higher investment capacity. Nonetheless, in a market heavily regulated and characterized by non-drastic innovation, the incentive to innovate is insufficient, and Denicolò (2002) shows that even incumbents' interest in R&D is very low in industries characterized by non-drastic innovations and low propensity to invest (see Section 1).

It is a long debated question whether innovation is a public or a private good and under-provided R&D must be considered a market failure (Griliches, 1958; Jaffe, 1986; Levin, 1988; Klette *et alia*, 2000). If so, public intervention can allow a satisfactory level of R&D and innovation; the theoretical literature on the relationship between environmental policy and technical innovations has claimed for the superiority of market-based instruments such as taxes, subsides and tradable permits (Downing and White, 1986; Milliman and Prince, 1989). In the waste management industry for a long time this has taken the form of incentives and green certificates emission on energy produced from waste incinerators.

Recent studies confirm the superiority of market-based instruments with perfect competition and full information, but they maintain that the situation changes when firms gain strategic advantages from such innovations (Carraro, 2000; Montero, 2002); in those cases, standards seem to be a more appropriate policy (Rennings *et alia*, 2006).

Mergers between operators of MW industry, in both forms of vertical mergers between collector and disposer, and horizontal mergers between firms of the same segment, are one of the most relevant organizational innovations affecting the waste industry in last 20 years. Since Williamson (1968), economic theory pointed out the potential relationship existing between firm concentration and efficiency gains. Farrell and Shapiro (1990) develop a smart analysis on horizontal mergers, highlighting that the efficiency gains generated can exceed the gains from market power. The sources of potential efficiency gains from mergers are related to the capture of economies of scale and of scope (the latter quite typical with the transformation of municipalized waste firms in modern multi-utilities involved in gas, water and electricity provision as well), and cost savings generated by rationalisation of distribution, administration and marketing activities, with the relevant notation that their impact on market prices, i.e. on the consumer surplus, is related to the possibility of reducing variable rather than fixed costs (Motta, 2004).

Mergers have been identified by competition theory as a possible tool for market monopolization because of the opportunity for the integrated operator to provide the good/service at a price lower than rivals: vertical mergers because of the elimination of the double marginalization problem; horizontal because of the exploitation of efficiency gains. At the global level, we see that this organizational innovation have moved a formerly very fragmented system towards a concentration, rather than a monopolization, with bigger and more efficient operators competing in wider markets, with potential positive feedbacks on the total price of waste management and, as a consequence, on consumer's surplus.

In conclusion, assuming a neoclassical perspective on the issue of the role of innovation in the waste management industry means to focus mainly on process innovations in the end-of-the-pipe segment. As a matter of fact, neoclassical theory is more comfortable in treating drastic innovation inducing technological change, R&D investments and patent applications to win a market competition. This hardly fits with a sector as waste management industry, where innovation are mostly non-drastic, R&D is low and policy driven, and the market is both highly regulated and progressively more concentrated, so that the incentive to innovate could affect the once in a while competition for the market, rather than the day-by-day competition in the market.

4. The Innovation in the MW Industry as a Social Process: a Complexity Perspective

In last 30 years neoclassical economics of innovation has been challenged by new theories that rescue the Marxian intuition of innovation not being the result of individual ingenuity of isolated inventors nor, in a more modern acceptation, the outcome of specialized R&D units, but as a matter involving the whole society: a social interaction and a historical process, rather than a market one.

These theories start from the observation that the majority of innovations in history have been non-drastic, and even technological discontinuities have been the result of incremental changes, rather than of disruptive ones (Rosenberg, 1983), and focus on the notion of uncertainty as the most relevant in treating the issue of changing. To reduce the degree of instability that invariably accompanies innovation, a prominent role is played by institutions, that support firms and economic operators in facing the "ontological" uncertainty related to change.

4.1 Heterodox approaches to waste economics

As pointed out in previous Section 1, heterodox approaches to economics of technological change have two main strands in the National System of Innovation studies (Nelson, 1992; Lundvall, 1993), and in Complexity Economics (Arthur *et alia*, 1997).

National System of Innovation studies concentrate on idiosyncratic features of a country and on existing relationships internal to it affecting generation, diffusion and selection of skills and knowledge useful to the economic system.

A similar approach is applied to waste management by Cainelli *et alia* (2015), even though at the regional instead of the national level. They investigate the drivers of environmental innovations in institutional and economic features of the territory, searching for the key elements of regions (policies, infrastructures, social capital, firms' organization, sector and geographic policy based factors) that foster waste and resource use related innovations. They find that, given the public good nature of MW management, market forces are not sufficient to ensure the deployment of a satisfying level of innovation in that sector, and policy content of regional frameworks, along with firm-related factors, matter more than R&D investment to explain the adoption of waste technologies (Cainelli *et alia*, 2015).

According to this framework, the national industry characteristics and its historical evolution are at the origin of the innovation trajectories of different countries; for instance, the early implementation of prevention inspired principles or extended producer responsibility schemes such as German or Danish Duale Systems are at the basis of the organizational innovations entailed by shifting from landfill to MW selection (Silvestri, 2014).

Complexity Economics focuses on non-equilibrium dynamics and adaption strategies by heterogeneous agents, agents' interactions, role of institutions in addressing the system to one of the multiple available equilibria, multilevel decisions. Lane and Maxwell (1997) apply the complexity framework to the issue of innovation.

To our knowledge there is no complexity study exploring the waste industry yet, but we claim that complexity is the most promising theoretical framework to deal with the non-drastic, organizational and non-technological innovations that characterize waste management.

4.2 Market Systems in MW Industry

In Section 1 we have illustrated the fundamental definitions of the complexity economics innovation theory; maybe the most relevant among them is the notion of "market system", meaning not the simple and aseptic neoclassical concept of place where demand meet supply, but "a set of agents involved in recurring interactions, and organized around a family of artifacts. Through interactions agents require, design, produce, trade, provide, install, use and preserve artifacts, generate new assignments to functions and develop new artifacts to confer them the assigned functions" (Lane and Maxfield, 1997).

A market system differs from the standard notion of market because of the emphasis on the fact that interpretation of the social environment, and not hedonistic behaviour, drives individual action and choices. It is a notion that, besides of agents considered with their different features, involves institutions, social and legal norms, fads, geographical characteristics, technological *status quo*, firms organization, property system, and so on. A generic market system of MW can be outlined as follows:

Categories	Items
Agents	European/National law- and policy-makers Regional planners District organizers/controllers Municipal policy makers Collection operators Disposer operators Equipment suppliers Product designers Production chain consortia Households and assimilated (offices, retailers, shops)
Artifacts	Waste bags Transponders Waste tracking electronic equipment Domestic bins Street dumpsters Subterranean dumpsters MW depot (ecological islands) Collection means Waste-to-energy plants Incinerators Landfills RDF
Interactions in the space agents-artifact	Types of collection Street collection Kerbside Mixed (Some materials collected at home, other with street dumpsters) Light multi-material (mixed collection of paper, plastic, tetrapak and metals) Heavy multi-material (as above + glass) Types of disposing Landfilling Incineration Incineration with energy recovery Mechanical sorting and materials recovery Types of charging Waste tax PAYT Mixed (Waste tax with discounts and variable charges)

Table 1 The market system of European MW

The chronological evolution of MW sector calls into question the notion of market systems. Albeit the framework of integrated waste management nowadays is emerging throughout Europe, different MW market systems still coexist, each of them using a proper set of artifacts, assigning new functions to them, and being characterized by particular kinds of interactions.

Based upon the classification in Table 1, we can identify at least four market system in MW industry:

1. a "traditional" system, totally landfill oriented;
2. a "waste-to-energy" system, deeply incinerator oriented;
3. a "light recycling" system, with integrated solutions and selection percentages lower than 50%;
4. a "hard recycling" system, addressed to selection percentages higher than 50%.

Even though still relevant, the traditional system is bound to disappear in next years. It can call for either integration or separation of collector and disposer, and it is usually based upon street collection, and the bestowing of MW to landfills. The relevant artifacts for this market system are street dumpsters, truck compactors and landfills, the interactions are monopolized by street collection and landfilling, while the substantially nil involvement of households in collection does not call for any PAYT charging system.

According to Complexity economics, a necessary condition to observe the rise of innovations in a market system is to have "generative relationships" among the agents; in the traditional market system the nature of interactions is quite barren: relations are minimized and based on commercial or technical basis (the public tender to find the collection or the integrated operator, the organization of collection by the entrusted operator, the contract between collector and disposer), while participation by household is absent.

As a consequence, it is not surprising that innovation in this market system is depressed and dating back to 20 or 30 years ago, regarding operations to make landfills safer (new coating solutions, abating systems for dioxin), and for the automation of street collection (CCTV for a better approach of truck compactors to dumpsters, mechanical solutions for dumpsters' lifting and emptying).

The "waste-to-energy" market system is based on end-of-the-pipe facilities, as the previous one, but represented in this case by incinerators revamped and upgraded to the version of energy recovering plants. It is a "hard industrial" market system, where the incinerator is the key artifact, often characterized by the presence of vertically integrated operators. The whole MW chain is oriented to feed the end-of-the-pipe incinerator to its minimum optimal size; this means that the collector will not be induced to a sophisticated selection that would subtract raw materials to the plant, and that the system as a whole is not addressed to recycling. As a consequence, the collection phase is mainly drawn upon undifferentiated street dumpsters[4]. Being no interest in rewarding a reduction in MW, "virtuous" schemes such as PAYT are useless, and standard taxes or fees are the common tool.

As for the previous market system, the relationships among agents are infrequent, and limited to procedural exchanges that involve experts and technicians; innovation in this market system is not the result of generative liaisons between agents, but of the technology embedded in incinerators, its origin is placed in a sector external to MW industry.

The "light recycling" system is maybe the natural outcome of the integrated approach to MW management. It involves both recycling and end-of-the-pipe disposal, so that the key artifacts range from waste bags, domestic bins and ecological points of collection to street dumpsters and incinerators. The collection phase normally is run through a mixed system of street and kerbside collection, even inside the same municipality, with different numbers of materials that are selected.

Being a very assorted market system, the interactions among actors are frequent and varied: collectors and municipal policy makers debate stably to fit the recycling targets of EU, improving the separate collection; the MW management involves quite deeply household asking for an increasing effort in waste sorting and proposing to them evolving schemes of collection (separation of new materials, scheduled retreats, use of admitted plastic bags). The higher involvement of citizens claims for more sophisticated payment schemes, so that PAYT tariffs progressively replace the waste tax. This asks for a change in the common artifacts, for instance in the street dumpsters, that are equipped with scales, skullcaps and electronic keys that allow to register more precisely the quantity of MW conferred and to match it to the real deliverer. But the existence of a wider network

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[4] This description of the market system has been rejected in last times by proponents of a "mixed" vision, suggesting that the primary need of waste-to-energy plants is not the fulfilling of the minimum optimal size, but the search for efficiency, this argument claims for the selection of higher calorific materials and the discarding of others streams, in particular wet waste. This is the point of view proposed by the "Zero landfill" narrative (see *infra*).

of agents favours the rise of innovation even in the form of assignment of new functions to existing artifacts: this is the case of RFID and transponders, commonly used in electronic ticketing systems and in logistics, applied to waste bags; the same happens with underground dustbins, whose technology belonging to firms operating in construction of garages and parking lots, and proposed as a solution to locate dustbins avoiding the soil occupation in urban environments.

Finally, the "hard recycling" system is the market system of the integrated approach once addressed to the target of a MW selection higher than 50-60%. Hard recycling is the market system that fulfil the prospected evolution of MW management according to the EU Priority Ladder Principle.

Banning the landfill and considering the incinerator a residual and temporary option, means to elect as central agents collectors and the production chain consortia; the involvement of households is the most, regarding not only the awareness on the best way to select MW, but even the education in choosing goods with lower contents of packaging. Interactions are characterized by the kerbside collection method and by PAYT charging, with artifact such as pre-paid waste bags and tracking equipments. Besides of the previous, other innovations in this market system are of organizational kind: the need to reach higher performances in collection and selection drives the introduction of minute solutions, such as the eco-mobiles and the cited use of donkeys as collection means in perched urban centres.

4.3 Narratives and Scaffolding Structures in MW Industry

According to Complexity theory innovation is mostly a cognitive act, given by a representation of the space shared by agents and artifacts that generates a new, socially determined, market system. This one is subjected to pressure of both internal and external factors, produced by the interaction among agents and in turn generating instability on the assignment of functions to artifacts and to social conventions that regulate interactions on agents; the pressure rise until a new market system replace the old one.

Going back to MW industry, the internal changes are given by the mentioned new artifacts that arise: the refinement of the waste-to-energy technology, the availability of low cost RFIDs and transponders, the underground or the scale equipped dustbins. The external one dealt with the EU regulation, in the form on one hand of distinction between services of General or Economic Interest (Silvestri, 2014), and on the other of the mentioned emphasis on the Priority Ladder Principle; watching at Italy, a relevant external change has been given by the direct election of majors, that changed the relationship between Municipality policy makers and the community, with the formers compelled to seek new indicators to measure their political performance and to ask the vote on it; recycling addresses this need, and as a matter of fact the target in terms of MW selection has been turned in an issue that characterizes the political orientation of a Local Council.

The interaction of internal and external changes generates "ontological uncertainty" and instability on agents that have to update their behaviours to the new market system. Examples of instability in the Italian MW realm are given by the case of the Municipality of Melpignano (Province of Lecce), where the Local Council, that decided to join the hard recycling market system, unsatisfied with the results so far, decided to force the situation removing completely the street dustbins in a few days, producing in the community a deep disorientation; a similar example is given by the Municipality of Casalecchio di Reno (Province of Bologna), where since 2013 the street collection has been banned, and the movement for abandoning the rigid door-to-door collection has given rise to a political coalition for 2014 municipal elections.

To deal with instability and to confine the ontological uncertainty naturally generated by innovation, agents can draw upon to the two kinds of instruments given by "Narratives" and "Scaffolding Structures", both fundamental notion in the Complexity framework.

Since uncertainty prevents agents from seeing the consequences of their actions, thanks to the Narratives they are able to give a rationale to what happens. In this sense, a Narrative identifies the cognitive process that allows agents to orient their future actions, to compare it with other point of views, even to change the Narrative while working, so to address their action to medium- and long-run objectives.

In MW management there exist different recognizable Narratives, some of which playing relevant roles in justifying and supporting some of the market systems illustrated in previous section. The most famous are the “Zero waste”, and the “Zero landfill” Narrative.

Zero waste is the name of the MW management approach that claims for the feasibility of an almost complete elimination of MW disposed in either landfill or incinerators. It is supported by an international network of non-profit associations, the Zero Waste Alliance (ZWA), that helps industry and communities to pursue “a future without waste and toxic materials”.

According to the claim of the ZWA: “Zero Waste is a goal that is both pragmatic and visionary, to guide people to emulate sustainable natural cycles, where all discarded materials are resources for others to use. Zero Waste means designing and managing products and processes to reduce the volume and toxicity of waste and materials, conserve and recover all resources, and not burn or bury them. Implementing Zero Waste will eliminate all discharges to land, water, or air that may be a threat to planetary, human, animal or plant health”[5].

The Zero Waste Narrative sets an ambitious future objective (closing the loop of materials phasing out toxic ones and emissions) giving to the community of participants, made of business agents and municipalities, a ten-steps road map to achieve it. In this sense, the Zero Waste strategy calls for the following actions:

1. community involvement for the implementation of waste selection (waste management as an organizational rather than a technological issue);
2. implementation of kerbside or door-to-door collection (only collection method deputed to get a 70% recycling target);
3. creation of a compost machinery, in particular in rural areas (closing the loop and shortening the use chain);

[5] www.zerowasteeurope.eu/about/principles-zw-europe, consulted November 21st 2014.

4. creation of recover and recycling platforms (selecting materials to be re-used in the production process);
5. reduction of waste (through consumption of tap water, refillable bottles, banning of throw-away products);
6. creation of repair and re-use centres (second hand and flea markets, repair laboratories and workshops);
7. implementation of price uniting in waste tariffs (rewarding virtuous behaviours and supporting responsive purchase decisions);
8. creation of a second inspection recover and selection machinery (recovering further materials that escaped the first selection, stabilizing the residual organic waste fraction);
9. creation of a research and design centre to run studies and analysis on the residual waste from selection, the industrial design of products, the corporate social responsibility of firms);
10. final cancellation of waste, to be reached within 2020.

The Zero Waste network conjoins several associations throughout the world. In Italy, it associates more than 200 municipalities committed to undertake a process that, even though hardly leading to the cancelation of waste within 2020, could allow a 70-80% of MW selection and recycling.

Another prominent Narrative in the MW realm in the Zero Landfill option. Experienced as a deception by Zero Waste advocates, this Narrative claims for an integration among different waste management methods to achieve the objective of dismantling landfills in favour of a mixed system of recycling and waste-to-energy plants.

On a global scale, the incineration segment still exhibits significant growth trends (Eckhard, 2013), mostly in EU countries experiencing a transition dominated by the aim of phasing out landfills as much as possible. There is a clear correlation between incineration, recycling and landfilling: countries that divert less than two kilograms/year per capita adopt a balanced combination of incineration and material recycling, while countries that do not incinerate rely on landfill for more than 30% of their MW. According to proponents of this Narrative, this is a hint that incineration is complimentary, rather than opposite, to recycling in the effort of phasing-out landfills (Massarutto, 2015). At the same time, countries that achieved a higher share of incinerated MW show a mature situation, fostered by the decoupling trends of waste generation from economic growth (Mazzanti *et alia*, 2012), generating an excess of supply during the last decade and a foreseeable further limitation to the expansion of this market.

Both technical (Cossu, 2011; Brunner and Rechberger, 2015) and economic literature (Massarutto *et alia*, 2011) look at MW incineration as a key element of an integrated MW management strategy, emphasising complementarities, rather than antagonism, between recycling and energy/heat recovery from MW.

The energy issue is stressed by the promoters of the Zero Landfill Narrative as a relevant positive environmental outcome of this approach, since energy from waste is 50% due to renewable materials contained in the waste flow (Manders, 2009), while estimates claim for a potential doubling of energy generated from waste by 2020 (Massarutto, 2015).

On the other hand, incinerators are challenged on the basis of environmental and health arguments, related to air pollution, GHG emissions and disposal of by-products. Zero Landfill advocates maintain that epidemiologic studies in this sense are not conclusive, being fettered by methodological weaknesses and lack of a serious consideration of confounding factors (Hu and Shy, 2001; Cordioli *et alia*, 2013): as a matter of fact, most of the studies showing adverse effects on human health were actually based on the analysis of older facilities to date completely phased-out by new ones.

According to recent literature (Schrenk, 2006; Federico *et alia*, 2010), emission targets imposed by EU Incineration Directive and by stricter national standards on precautionary principle basis would show that the impact above the bottom threshold of a standard urbanized area are almost nil, and the same happens for risk of damages to health (UBA, 2008; WHO, 2007).

This official position is not shared by environmental activists and NGOs, claiming the existence of micro-pollutants conveyed by nanoparticles, while incinerator champions remark the higher nanoparticles emissions of urban traffic, traditional industry, and so forth (Cernuschi, 2013; Buonanno and Morawska, 2015).

Finally, Zero landfill Narrative protest the presumed superiority of pure recycling on integrated methods relying even on waste to energy. From an economic perspective, the increasing marginal costs of MW selection, conjoint with the lower quality of materials collected for higher separation ratios and with imperfections and bottlenecks in the downstream segment of second hand raw materials, suggest that recycling is not a viable option at any cost: extreme recycling scenarios claim a kerbside systems reaching 75% or more of separate collection, a realistic assumption for small cities and rural areas, but not for urban ones (Massarutto, 2015). Jamasb and Nepal (2013) discuss the UK waste management strategy, comparing a ‘‘business as usual’’ setting with the full implementation of the EU waste directive, finding that waste-to-energy is the dominant MW management technique in terms of social cost-benefit.

On this bases, recycling is not a viable solution for all contexts - a point of view that is opposite to Zero Waste’s one, whose objective is to generalize a source separation level of 80% or more to all communities – addressing the non-recycled quota to incinerators. In this sense, Zero landfill Narrative stands up the complementarity of the two MW management solutions, since they address different flows of the same materials: recycling suits those that are easier and cheaper to select, while waste to energy better suits the others (Massarutto, 2015)

According to Complexity theory, another useful tool are the Scaffolding Structures (or Scaffolds). Scaffold are organizations of different nature, platforms, scientific and popular science journals, international fairs, mediating between agents and innovation, and playing in this way the role of supporting agents in facing ontological uncertainty. If Narratives give a medium-long run objective to agents, leading the way to a possible change, Scaffolds back them in the day-by-day relationship with an ambient pressured by internal and external change.

Their main role is strengthening network ties among agents and artifacts through actions such as exploration of options, dissemination, interpretation, and circulation of information, experimentation of solutions, and so on.

In the waste management field we can see the existence of relevant Scaffolding Structures. The most prominent one is probably the EU LIFE Programme. The LIFE programme is the European Union's funding instrument for the environment and climate action, aimed at contributing to the implementation, updating and development of EU environmental and climate policy and legislation by co-financing projects with European added value. LIFE began in 1992 and to date there have been four complete phases of the programme (LIFE I: 1992-1995, LIFE II: 1996-1999, LIFE III: 2000-2006 and LIFE+: 2007-2013), while the fifth LIFE wave is next to be inaugurated for the period 2014-2020. The LIFE Programme has always been divided in two strands at least: the first one activated to finance the European nature conservation strategy, and the second one for other environmental projects with the obliged requirements of being replicable in any EU region and being innovative (Silvestri, 2005). In addition, any LIFE financed project must include a communication plan to disseminate the main results achieved. In this sense, EU LIFE Programme is a relevant tool to support experimental projects and to circulate information on new viable products, processes and methods.

Since 1992, numerous LIFE projects dealt with the technical feasibility and financial viability of methods and technologies to enhance environmental performance in the waste sector. According to the LIFE Programme database[6], from 1992 to 2013 there have been 579 out of 4.171 (13%) financed project focused on waste management issues; 369 of them are related to non-industrial waste, and 101 are marked with the label "Municipal Waste".

[6] Website: http://ec.europa.eu/environment/life/project/Projects/index.cfm, retrieved November 25th 2014.

Nearly half of the LIFE Programme's beneficiaries were private firms, underlining the strong economic interest existing in the waste industry.

Prominent MW Scaffolds can be identified in common platforms such as the just mentioned Zero waste organization, and in other initiatives implemented by environmental NGOs.

As pointed out in the previous section, Zero Waste is an international network, born in the US and counting to date supranational, country and regional ramifications (13 in Europe), of non-profit associations conveying the Zero Waste Narrative and helping firms and local communities to increase the percentage of recycling and to reduce source waste. The aim of the network is to circulate information, best practices and standards to the community of actual and potential members. The Zero Waste Italy organization associates even a think tank and research centre in a full sense: it is the Rifiuti Zero Research Center in Capannori (Lucca).

Similarly, many environmental NGOs act as Scaffold in different European Country. This is the case of the Italian Legambiente, that since 1994 ranks Italian municipalities based on percentage of MW selection achieved and organizes an annual national prize to award the most virtuous. The prize have won a relevant fame throughout years, generating a tangible emulation effect among Italian municipalities. Besides of the separate collection prize, Legambiente publishes many annual reports on the waste issue (among the other, an annual dossier on criminal activities related to environment and waste diversion), and circulates information on the waste issue.

Another important scaffolding role is played by international fairs on waste management. The most relevant in Europe are the biennial fair of Munich (IFAT - International Trade Fair for Environment, Waste Water and Waste Disposal), and the annual fair of Rimini (Ecomondo), while importance is raising for Istanbul (REW Recycling) and St. Petersburg (Waste Management - Technology And Equipment).

Finally, there exist international multidisciplinary journals that disseminate information and update the debate among researchers and practitioners on innovation and technical change in the waste industry.

5 Drivers of Innovation in the MW Industry

According to Complexity theory, agents' interaction generates the development of new artifacts and new functions, transforming the existing market system in a new one.

In previous section we illustrated four market systems in MW industry characterized by different artifacts. It is worth asking which kind of dynamics drives the passage from one system to another or, put in another way, which motivations lead interactions to change the artifacts and to generate a new market system.

Both the mentioned Nicolli and Mazzanti (2011), and Mazzanti and Zoboli (2006) focus on technical change in the MW industry, reaching the conclusion that a relevant driver for it is environmental regulation.

Using empirical data from the EPO Worldwide Patent Statistical Database, they observe the existing relationship between environmental policies and patent applications in waste-related technologies over the period 1970-2007, providing interesting insights on the role of policy stringency on the waste management sector. The study shows that policy standards such as national directives on packaging reduction in Denmark, Germany, and Korea really affected the spread of technological change in the sector, offering an indirect suggestion on the active role of policies as innovation driver. In particular, the older wave of policies, implemented between end of the 1980s and beginning of the 1990s, produced a technological shock in the system, while now their effect is less pronounced in terms of patenting activities, suggesting that the waste sector entered a status of technological maturity.

Following this mark, we identify three main policies that stimulated innovation in MW industry in last 30 years: the first one are the national packaging regulations, strengthen in by the EU Beverage Directive (339/1985) and the Second Packaging Directive (62/1994), that introduced *de facto* the Extended Producer Responsibility principle in the EU regulation (Silvestri, 2014). As a consequence of this set of policies, recycling entered powerfully in local MW agendas, leading to the emergence of new market systems.

A second relevant policy is given by the so called EU Landfill Directive (31/1999), that set stringent technical requirements for landfills and the activities of landfill diversion with the aim of reducing their environmental impact. Among the others conditions, the directive obliged to reduce the amount of biodegradable waste landfilled to 35% of 1995 levels by 2016, fostering the innovation related to selection technologies. The implementation of national landfill taxes and the consequent rise in landfill disposal tolls gave a further impulse to a set of artifacts related to both waste-to-energy and recycling market systems, putting the adopting countries progressively on the track of the complete landfill abandonment.

The third policy, again deeply rooted in the EPR principle, is the Waste Electrical and Electronic Equipment Directive (96/2002 amended in 19/2012), that introduced organizational innovations such as the private European Recycling Platform, implemented by four big electronics makers (Hewlett-Packard, Sony, Braun, and Electrolux), working in 2007 with more than 1.000 companies in 30 countries and recycling about 20% of the equipment covered by the WEEE Directive (Nidumolu *et alia*, 2009).

In situations characterized by the implementation of price uniting, a driver of innovation is given by the search for higher productivity by operators. As a matter of fact, the price uniting fosters recycling ratios (Silvestri and Ghinoi, 2015), reducing the revenues from unsorted collection; a way to restore the profit for Collector is to raise productivity thanks to innovation of different kinds.

Finally, a last source of innovation is given by the technology embedded in equipments provided by suppliers. Studying pollution abatement in the pulp industry, Popp and Hafner (2008) find that the innovations only rarely originate from the regulated sector itself. In some of those cases, innovation is in the availability of producers of artifacts normally employed with other functions: this is what happened with dumpster positioned under the street level, a technology proposed to MW industry by constructors of underground garages.

Conclusions

Innovation in MW is quite neglected by mainstream economics. The neoclassical technical change framework, focused on drastic innovation, leapfrogging, and R&D investments, is not comfortable with an industry where innovation deals mostly with organizational changes.

Cainelli *et alia* (2015) remark the low impact of R&D for innovation in MW industry, while Nicolli and Mazzanti (2011), conveying a perception *à la* Porter and Van der Linde (1995), highlight the impact of regulation for the few patent applications registered in the sector.

Nontheless, the explanatory contribution of Complexity Theory seems sharper: concepts such as market system, narrative, scaffolds, are more useful to frame a dynamic in which upgrading and adaptation to regulation are the common drivers of new investment (Massarutto, 2015), whereas innovation is mostly incremental.

As a matter of fact, some contributions inspired to the Complexity approach are very explanatory of dynamics of MW industry: the importance to watch at standard operations with a pair of fresh eyes, since innovation often takes the form of the assignment of new functions to existing artifacts, or the relevance of narratives such as Zero Waste or Zero Landfill to address the medium-long run objectives of agents.

Another contribution of Complexity theory is the emphasis on interaction as a pre-condition for innovation. This is quite relevant for MW industry, where a landfill oriented system market, characterized by relationships at the minimum level and confined to commercial and technical issues, is destined to be abandoned in next years. But if the designed successor has to be what we have labelled as "waste-to-energy" market system, the risk of low interactions and insufficient innovative force internal to the MW industry will endure.

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