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# Waste-to-wealth: The economic reasons for replacing waste-to-energy with the circular economy of municipal solid waste.

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**Abstract.**
Sharing the same raw material, recycling and composting are in direct conflict with incineration of municipal solid waste in combined health and power plants. Indeed, waste-to-energy plants in regions with high recycling rates import urban waste from other countries to use otherwise unused capacity and raise revenues. Using the case of Italy's economically most developed region, I discuss the economic viability of municipal solid waste incineration to produce electricity and heat in the context of the increasing role of electricity production from renewable energy sources as well as of the emerging circular bioeconomy. Four lessons and three guidelines aimed at local authorities and policy makers emerge from the present study.

**Key words.** Recycling, Composting, Waste-to-energy, Incineration, Municipal Solid Waste, Circular Economy, Green Jobs

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## 1. Waste-to-energy

Chiefly as a consequence of ingestion as the dominant exposure pathway for the public, the impact of urban waste incineration on human health is significant and of broad scope, including diverse adverse health effects, from infant deaths and miscarriage.[1] Furthermore, each municipal solid waste (MSW) waste-to-energy plant generates an highly toxic residue (fly ash) rich in heavy metals and hazardous organochlorines formed upon the partly removal of toxic compounds in the incinerator gas effluents.[2]

Originally introduced in Great Britain in the 1870s, when wood and biomass residues were abundant in urban waste, incineration has been, along with disposal in sanitary landfills, the main method of MSW disposal used across nations. The first plants in Britain were already able to burn waste at temperatures high enough to allow self-sustained combustion (*i.e.*, requiring no coal or wood) with minimal odors.[3]

Walsh has nicely recounted how refuse incineration in New York City where the first municipal incinerator was built in 1908, ended in the early 1990s with the voluntary closure of the three remaining municipal waste-to-energy plants due to absence of air pollution control equipment which made incinerators "vulnerable to stricter government emissions limits, ultimately resulting in their premature closure and the decline of incineration as a waste management practice in the city".[3]

Today, incineration of urban waste in combined heat and power (CHP) plants often using the hot water with district heating systems[4] is widely employed across the world. Generally, relying on generous public feed-in-tariff incentives paid to the electricity generated burning MSW, numerous waste-to-energy plants have been built and put in operation in the last two decades, chiefly in western Europe[5] and in China.[6]

Mostly due to waste-to-energy plants in Germany, France, the Netherlands, Austria, Sweden and Italy, the amount of municipal waste incinerated in former 28 (currently, 27) countries of the European Union has gone (Figure 1) from 32 million t in 1995 to 70 million t in 2018 (+117%). However, the amount of MSW recycled has gone from 25 million t in 1995 to 75 million t in 2018 (+201%), whereas the amount of MSW composted went from 14 million t of 1995 to 43 million t of 2018 (+202%).[4]

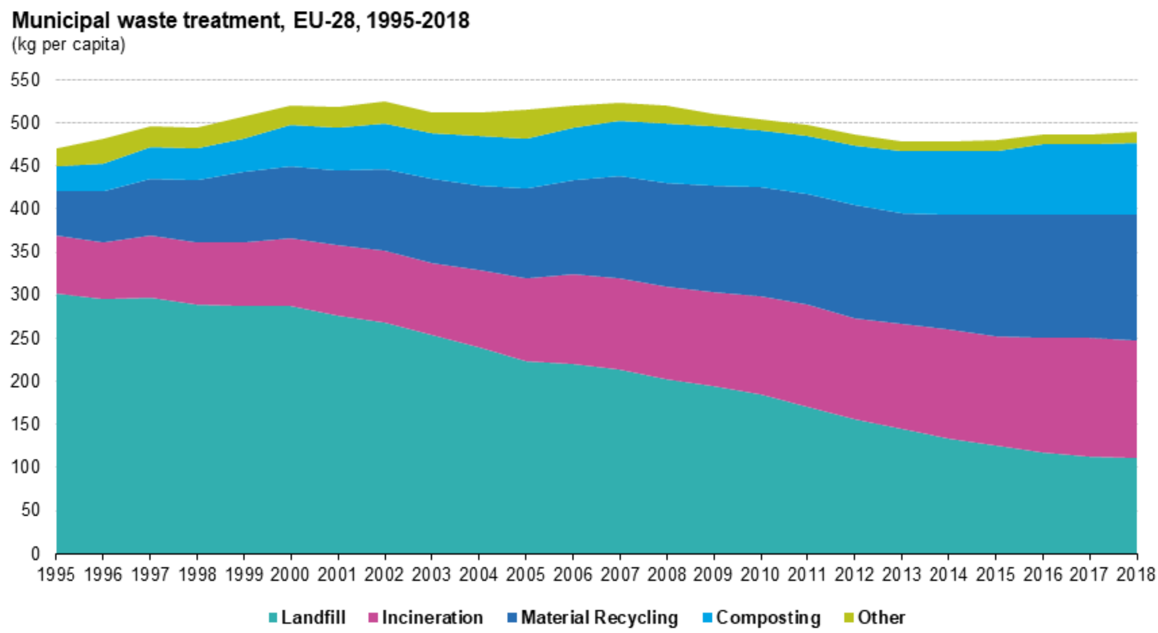


**Figure 1**. Municipal waste treatment in the former 28 country members of European Union, 1995-2018 (kg per capita) [Image courtesy of Eurostat, Reproduced from Ref.5, with kind permission].

In the course of the last three decades (1990-2019), in other words, urban waste recycling and composting have become so widespread and successful that several world's cities and regions reached and even surpassed 70% recycling rates, making urban waste increasingly unavailable for incineration.

This further worsens the poor economic sustainability of burning MSW in waste-to-energy plants which traditionally has required generous public incentives in the form of prolonged (20 or even 30 year) power purchase agreements for electricity fed into the grid paid with generous tariffs (feed-in-tariff) with waste-to-energy electricity formally classified as "renewable".[7]

In this study, rather than using abstract models, I use real data mostly from Italy but also from other countries to show the economic reasons for replacing waste-to-energy with the circular economy of municipal solid waste.

## 2. The case study of Lombardy, Italy

In Italy, I further focus on Lombardy, Italy's most economically developed and densely populated region, hosting 13 of Italy's 39 incinerators. Lombardy is used as a case study of an highly developed economic region which first opted for widespread uptake of MSW incineration and then had to face (and is facing) the quick rise of MSW recycling and composting rates up to percentages that require importing MSW to continue to operate the waste-to-energy plants. As such, the example will be useful for other regions of the world where policy makers are currently facing the dilemma whether to invest in incineration or in the circular economy of urban waste.

From the research methodology viewpoint, the study makes use of official data provided by Italy's public bodies as to the amount of recycling and composting rates, as well as of non-official data from reputed trade associations, newspapers and magazines as to the amount of MSW incinerated in Lombardy or the number of waste-to-energy plants promoted through feed-in-tariffs. The latter option was chosen so as to provide an updated picture.

In 2018, Lombardy collected for recycling and composting 61.7% of municipal urban waste, whereas 25.4% of urban waste was incinerated.[8] However, 400,000 tonnes MSW burned in the same year were imported from other Italy's regions.[9]

From the energy viewpoint, Morris has shown in 1996 that while recycling conserves energy that would otherwise be expended extracting virgin raw materials from the natural environment, burning refuse in a waste-to-energy plant equates to waste energy for 24 out of 25 typical municipal solid waste materials.[7]

Lombardy in 2018 hosted 64 composting plants, 6 aerobic and anaerobic integrated treatment, and 8 anaerobic digestion plants.[10]

Together, these plants treated, respectively, 1,004,723 t + 762,522 t + 233,683 t namely an overall amount of 2,000,928 tonnes. In the same year, the region's cities sent 1,944,000 tonnes of residual MSW to the region's waste-to-energy plants.[10]

The cost borne by Lombardy's cities and other Italy's regions delivering their non recycled waste to Lombardy's incinerators in 2018 varied between €100/t and €150/t.[11] This led for example a 40,000 inhabitant Lombardy's city (Desio) to launch the separate collection for recycling of even diapers (which, alone, amount to over 15% of the previously non-recyclable waste).[11] Thanks to this and to other improvements and innovations in the collection of recyclable materials, in year 2018 the recycling rate in Desio reached 78.31%, from 61.81% in 2017.[12]

In this way, having reduced the amount of waste sent to waste-to-energy plants, the average waste tax rate paid by the average family in Desio diminished by €6,[12] and this regardless of the lower prices paid for collected paper and glass.[13]

In general, the more cities in Lombardy progress towards achieving high recycling rates transforming waste into wealth, the less urban waste becomes available for burning.

## 3. The conflict for municipal solid waste

Urban waste is far from being a "renewable" energy source. In Italy its combustion to produce power cannot be any longer subsidized as it happened for decades likewise to virtually all countries hosting waste-to-energy plants. In the United States of America, for example, tip fees at incinerators were found to be two to three times higher than comparable recycling or composting fees, and yet as of late 2018, 23 States legally classified incineration as "renewable" in their energy legislation.[14]

As of 2017, in Italy only 6 out of 39 waste-to-energy plants still benefited from the feed-in-tariff incentives.[15]

The fact that waste-to-energy plants need large amounts of municipal waste to be economically viable, including plants using state-of-the-art combustion technology, is further demonstrated by the €540 million plant waste-to-energy plant *Amager Bakke*, near Copenhagen, which started operation on March 2017.[16]

Owned by five municipalities, in less than a year the value of the company managing the new plant "plummeted from plus 2.3 billion DKK to a negative 200 million DKK, corresponding to an overall loss of 2.5 billion DKK, or roughly 330 million euro" due to the fact, wrote a city councilman in his recent Master thesis dedicated to the plant, "that there was not enough garbage in the city to power the over-sized plant".[17]

Similarly, to use otherwise unused capacity, increase revenues and the low calorific content of MSW devoid of paper and plastics separately collected for recycling, since 2011 several countries with high recycling rates including Germany, the Netherlands, and Sweden started to import waste from Eastern and Southern Europe.[18]

Indeed, the analysis of municipal waste delivered to incinerators shows that a significant fraction (40%-60%) is recyclable or compostable.[19] For instance, recent analysis of municipal solid waste in the city of Johannesburg revealed that plastics and organic wastes constitute the highest waste content (28% plastics and 28% organic waste in the round collected refuse) almost independently of the season.[20]

Regions where recycling and composting rates are high produce a "fuel" whose calorific power is too low. Hence, waste-to-energy plants hosted in these regions need to import MSW from regions where recycling and composting rates are low in order to improve the calorific power of a "fuel" otherwise unsuitable for combustion.

However, driven by large societal and environmental megatrends, after two decades of false starts a large bioplastics industry is finally emerging across the world.[21] This will inevitably further lower the amount of post-consumer plastic waste available for burning at waste-to-energy plants.

**4. The impact of renewable electricity and circular economy on waste-to-energy plants**

The increasing share of renewable energy generation in all countries (including Italy)[22] with a significant penetration of power generation from renewable energy sources lowers the wholesale price of electricity. The latter merit-order effect[22] directly impacts the revenues of non-subsidized waste-to-energy plants generating their revenues from the tip fees as well from selling power on the wholesale electricity market.

This is exactly the situation currently faced by Lombardy's waste-to-energy plants, where already in 2018 a significant fraction (18.2%) of the waste burned in its plants had to be imported from other regions and countries. In the subsequent year, the rate of recycling and composting has further increased and will inevitably continue to do so as shown by Lombardy's province of Mantova, where it already reached 87.1% in 2018.[23]

With the almost immediate ban of China on importing plastics and other recycled materials in 2018,[24] most of Italy's (and Europe's) recycling plants faced a dramatic fall in the prices (tariffs) awarded for collected paper, glass and plastics. For instance, in Lombardy the price paid for collected glass to certain public waste collecting plants went from €30/t to €5/t, whereas that of paper went from €120/t to €20/t.[13] Yet, the same company insisted on the need to further increase the rate of separate waste collection for recycling because, at the time, the tip fee for disposing for example solid municipal waste in Lombardy's plants doubled from €80/t to €160/t.[13]

In brief, recycling remains convenient even at low prices of the recycled raw material since the tip fees for disposal of municipal solid waste in landfills or in waste-to-energy plants "hungry" for municipal solid waste continue to increase. This is because of the need to cover the operational costs and the diminishing revenues stemming from the low and decreasing input of MSW from surrounding cities and regions where rates of recycling and composting increase year after year to eventually exceed 80% rate.

It is also relevant to notice that one of the main problems that led to the deployment of so many waste-to-energy plants was the poor sanitary and environmental performance of first-generation composting plants processing the organic and biodegradable fraction of MSW (often more than half by weight) as well as from farming activities.[25] Today's composting plants do not emit bad odours and do not emit leachate in the soil. Only in Italy, in the 25 years between 1992 and 2017, more than 65 million t of organic waste were diverted from disposal in landfills or in waste-to-energy plants producing 23.5 million t of compost in a rapidly increasing number of plants (from about 30 facilities in year 1997 to more than 300 facilities in 2017, with a total treatment capacity higher than 8.5 million t).[26]

This is equivalent to substituting about 300,000 t of N, 190,000 t of K and 170,000 t of P in the chemical fertilizer market,[26] for an overall value of 650 million €, while storing on Italy's soils 7 million t of organic matter, thereby fighting soil erosion and loss of productivity of Italian farms.[26]

## 5. Lessons and guidelines

Four lessons and three guidelines for local authorities and policy makers emerge as main outcomes of the present study.

First, policy makers should be aware that recycling and composting are not complementary, but rather in direct conflict with incineration, as all these technologies compete for the same raw material: municipal solid waste.

Second, policy makers should be aware that the low and decreasing wholesale price of electricity due to increasing penetration of power generation from renewable energy sources,[22] makes electricity generation by burning municipal solid waste increasingly less convenient, worsening the already poor economic viability of waste-to-energy plants.

Third, policy makers should learn that the rapid emergence of bioplastics started with the introduction of biodegradable plastic bags and now expanding to high value-added plastic resins,[21] will rapidly lower the availability of plastics in MSW, further impoverishing its already low calorific value.[7]

Fourth, policy makers need to be aware that waste-to-energy plants using capital intensive equipment able to handle large tonnages with few employees create a limited number of jobs (0.1 jobs per 1,000 tonnes).[27] On the other hand, the circular economy of municipal waste, starting with recyclable material collection from locations such as households, drop-off points, offices and firms, is a powerful way to create jobs, especially in manufacturing and in reuse and remanufacturing activity (Table 1).[27]

Three guidelines are suggested to guide effective policy action in transitioning from waste-to-energy to waste-to-wealth based on today's circular economy technologies and methods applied to municipal solid waste management.

First, inspired by the key principle of the circular economy to reduce, reuse, recycle and recover waste (the 4R concepts),[28] local authorities and policy makers should refrain from signing long-term contracts to supply municipal waste to waste-to-energy plants, and rather focus efforts to maximize recycling rates for their MSW turned from a cost item (waste) into an earning item (wealth).

Second, consistent with the high recycling and composting rates achieved in a few years in many world's regions currently exceeding 70% and even 80%, policy makers should actively promote the development of a technologically advanced, second generation plastics recycling industry whose best companies, thanks to increased investment in waste collection, sorting, and recycling technologies are already able to recycle plastics to near virgin purity.[29]

**Table 1**. Jobs created by management activity in the circular economy of selected materials in municipal solid waste [Adapted from Ref.27, with kind permission of the Tellus Institute].

| Material | Collection (in 2008) | Processing | Manufacturing | Reuse/ Remanufacture |
|---|---|---|---|---|
| | *Jobs per 1000 t* | *Jobs per 1000 t* | *Jobs per 1000 t* | *Jobs per 1000 t* |
| Paper and cardboard | 1.67 | 2.00 | 4.16 | N/A |
| Glass | 1.67 | 2.00 | 7.85 | 7.35 |
| Ferrous | 1.67 | 2.00 | 4.12 | 20.00 |
| Aluminum | 1.67 | 2.00 | 17.63 | 20.00 |
| Non-ferrous | 1.67 | 2.00 | 17.63 | 20.00 |
| Plastics | 1.67 | 2.00 | 10.30 | 20.00 |
| Rubber and leather | 1.67 | 2.00 | 9.24 | 7.35 |
| Textiles | 1.67 | 2.00 | 2.50 | 7.35 |
| Wood | 1.67 | 2.00 | 2.80 | 2.80 |

Finally, aware that management education plays a key role in the transition from a linear to the circular economy,[30] policy makers and local authorities should deploy new educational activities to convert urban waste management companies from companies collecting waste for incineration or sanitary landfill, into circular economy organizations operating, not only in the materials value chain steps of collecting and sorting, but also in the key steps of manufacturing, reuse and remanufacturing.[31]


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