Life Cycle thinking, the key for a Circular Economy: the Municipality of Halandri case

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Abstract The present work is an overview of a Horizon 2020 project called Waste4Think, which proposes source separation and separate collection of the **F**ermentable **H**ousehold **W**aste (FHW) in the Municipality of Halandri, aiming to evaluate this material as potential feedstock for the valorization of alternatives for the recovery of high-grade materials. Eco-innovative solutions which will be employed in the Municipality also include: Citizens involvement methodologies reinforced with the use of the Information and Communication Technologies (ICT tools such as Apps, educational materials and serious games), separate collection for nappies and biowaste from supermarkets, use of decision making tools for the optimization of the collection and operation of the plants and the implementation of the Zero Waste Nursery concept.

A **F**ood **R**esidue **B**iomass (**FORBI)** product is generated from the pre-sorted FHW, (the only non-recyclable fraction of MSW). FORBI is generated by drying/shredding household food waste, which is door-to-door collected by the Municipality. FORBI is a valuable raw material that may be used for: the production of biogas (Hydrogen, Methane and HYTHANE), compost, animal feed, bioethanol, electricity, pellets, activated carbon and an alternative fuel for the cement industry.

Preventing landfill disposal of the FHW follows a life Cycle Thinking (LCT), which is the key of a Circular Economy (CE). The present work is a part of the H2020 project “Waste4Think”. It is envisioned that the results will help transform the Municipality of Halandri from being a “Waste generator” to being a “Biomass producer”.

Keywords: Life Cycle Thinking, Circular Economy, Waste management, Eco-design, fermentable fraction of household waste.

1. Introduction

Due to rapid urbanization, industrialization and population increase, the amount of municipal solid waste (MSW) generated is expected to reach 9.5 billion by 2050 (FAO, 2009). In Europe, 88 million tons of food are wasted, with an overall cost estimated at 143 billion euros (FUSION, 2016). According to Directive 98/2008, biowaste is a biodegradable subset of waste and includes a wide variety of materials, e.g. biodegradable garden, park waste, household food waste and catering waste (EPPERAA, 2012).

Worldwide, the production of fermentable household waste is expected to increase by 44% from 2005 to 2025, especially in developing countries. In Europe, the amount of fermentable household waste is expected to increase from 89 million tons in 2006 to 126 million tons in 2020 (Capson Tojo G *et al.* 2016; Melikoglu M *et al.* 2013; Monier V *et al.* 2010). 40% of solid urban waste in Halandri consists of non-recyclable, compostable household waste (fruit residues, vegetables, cooked food residues, etc.).

The organic fermentable fraction of domestic waste is a heterogeneous substrate, based on the composition and source. The content of household waste can be very different and unpredictable in several countries (Cesaro A. and Belgiorno V. 2014). Typically, the main fraction of household waste consists of fermentable foods such as rice, meat, fruit, vegetables and cellulose paper, which are biodegradable organic materials rich in carbohydrates, proteins and lipids (Baiano A. 2014). The composition of the polymers of carbohydrates (starch, cellulose and hemicellulose), proteins, lipids, fibers and inorganic materials makes compostable household waste a promising raw material (biomass) (Pleissner D and Lin C.S.K. 2013).

2. The project Waste4Think

The main objective of Waste4Think is to move forward the current waste management practices into a circular economy concept, demonstrating the value of integrating and validating a set of 20 eco-innovative solutions that cover the whole waste value chain. The benefits of these solutions will be enhanced through a holistic waste data management methodology, and will be demonstrated in 4 complementary in nature urban areas in Europe (Zamudio (ES), Halandri (GR), Seveso (IT), and Cascais (PT)). The eco-innovative solutions include technical and non-technical tools such as: a) ICT tools to support the daily operation and long-term planning, b) Apps for citizens empowerment and engagement, c) Educational materials based on innovative teaching units and serious games, d) Tools for citizen science for the co-creation of novel solutions, e) Mechanisms to boost behavioral changes based on economic instruments and social actions, and f) Decentralized solutions for valorization and reuse of high value resources (Waste4Think, 2015).

3. Implementation of Alternatives for the Recovery of High-grade Materials

3.1. Halandri's waste management system

MSW collection schemes currently in place in the municipality of Halandri cover the majority of MSW generated within the area. The main streams are mixed waste (green bins) and a separate collection system of sorted recyclables (blue bins). Other specific waste streams separately collected are: used tyres, end-of-life vehicles (ELVs), used lubricants, batteries and accumulators, waste of electric and electronic equipment (WEEEs) etc.

3.2. Fermentable Household Waste (FHW) in the Municipality of Halandri

In order to increase the eco-sustainability of food waste management, it is necessary to exploit renewable by-products from food waste. Nevertheless, the use of by-products is still in its infancy due the necessity to invest in research and new recovery technologies, the costs of which are still higher than landfill taxes. Exploitation of the generated biomass product (FORBI) from food waste will be based on collaboration between research and industry for the adaptation and use of already existing technologies and plants for the recovery of by-products. By changing their fermentable household waste collection habits, citizens will help to: a) *Save money*: Reducing the amount of "landfill tax charges" spent on transporting food waste to landfills and b) *Improve the environment*: fermentable household waste is biodegradable, this means it is a natural, fermentable, useful product that can substitute nonrenewable sources. At the same time, food waste ending up in landfills produces biogas (at least 50% of which escapes to the atmosphere contributing to the greenhouse effect) and leachates that may well contaminate underground water resources.

The study is performed in a residential area in the Municipality of Halandri, Greece. In the case-study area, fermentable household waste of Halandri's municipality is collected from 702 residents, 240 households, twice a week. Participants have been provided with 30-liter portable household bins and biodegradable bags made of starch, while the filled bags are deposited in locked 120 liter bins, proximally located. Residents handle in this manner only kitchen food waste such as cooked food waste, fruit, vegetable, used tissue paper (cellulose), except of bones and fluids. The 120 liter bins are collected of every three days by a truck, which will in future be fueled by biogas produced from FORBI, in a cyclical economy approach (Fig.1).

The collected material is then transferred for drying and shredding in a specially designed area $24m^2$ (Fig.2). The material is heat-treated (92-98^{0}C) and shredded in a GAIA GC-300 dryer/shredder, in order to generate a valuable biomass product, FORBI (**F**ood **R**esidue **B**iomass product).

The treatment takes 9 hours at 92-98^{0}C and 2 hours of cooling with a maximum power usage of 23.8 kW. The exact processing times and energy use vary somewhat, depending mainly on the original waste moisture content. The drying system reduces the amount of fermentable waste percentage by a percentage reaching up to 75%. The moisture content in the household fermentable waste is high (60-80%). The drying benefits are the reduction of the final volume and weight, the removal of odors and a longer shelf life and product homogeneity (Fig.3).

Figure 1. *Collection, Drying and shredding fermentable Household Waste in Halandri.*

A **B** **C**

Figure 2. A. *Drying/Shredding pilot plant* ***B.*** *Dryer/Shredder,* ***C. P****roduced* ***F****ood* ***R****esidue* ***B****iomass product FORBI.*

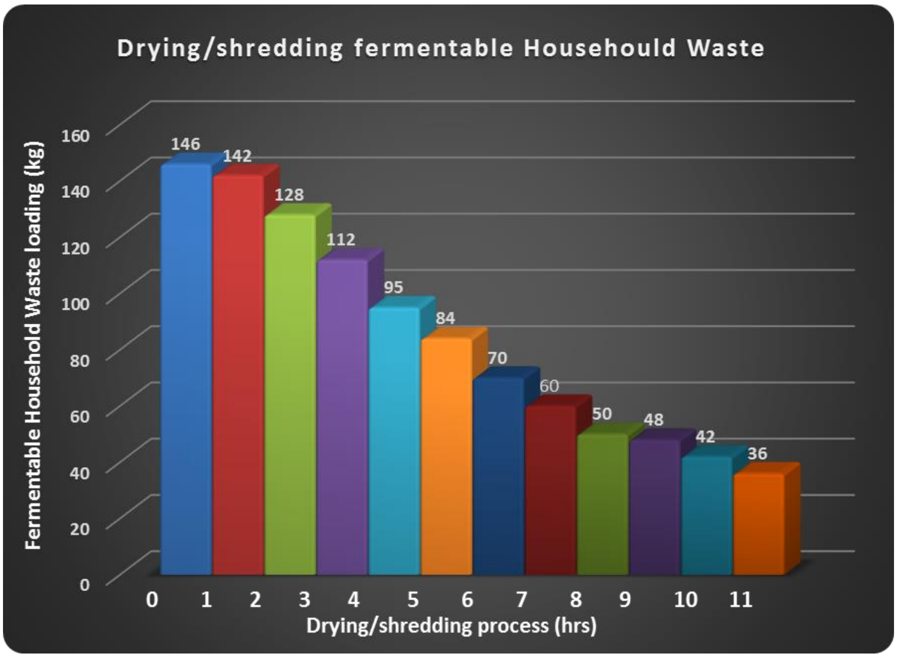

Figure 3. *Evolution of the weight for a typical Fermentable Household Waste loading (kg)* ***vs*** *Drying/shredding processing time (hrs).*

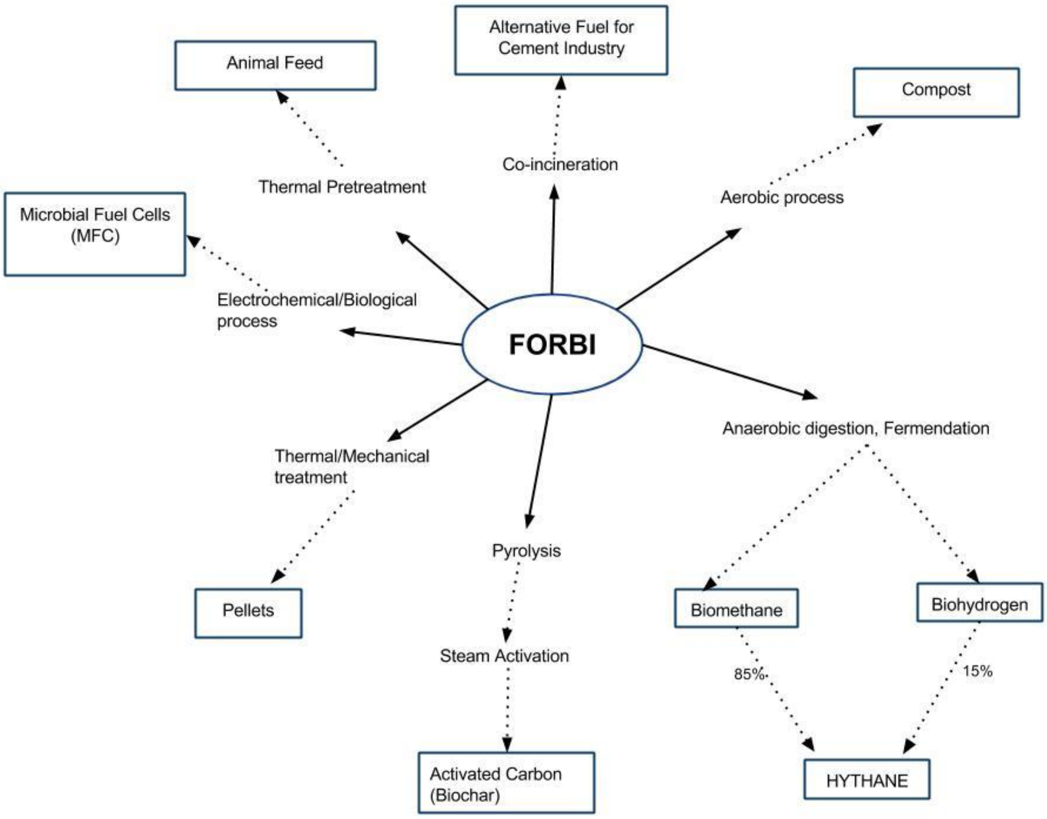

Figure 4. *Alternatives for the Recovery of High-grade Materials from FORBI*

A typical weight reduction up to 75% by the treatment in the dryer is achieved (Fig.3). FORBI has a very good mix of carbohydrates, lipids and proteins as well as the advantage that it can be stored for prolonged periods of time, without deteriorating. It is relatively homogeneous and with standard characteristics. As it can be generated in guaranteed quantities on a year-round basis, it may find several uses, including production of pellets, biogas, animal feed, activated carbon, compost, bioethanol, hythane and electricity, while it may also serve as an alternative fuel for the cement industry (Fig.4).

A questionnaire was distributed in March 2017 to participants in the Waste4Think project. 55 households responded stating a high satisfaction rate for the collection frequency of the fermentable household waste (34% declared satisfied and 66% very satisfied). In the meantime, a large number of citizens have indicated a desire to be included in the program.

4. Innovative Social Actions in Municipality of Halandri

In the municipality of Halandri innovative methodologies are also developed to promote behavioral changes in waste producers (citizens and other stakeholders). In particular:

- A social campaign to increase awareness, encouraging critical view and modifying habits to achieve a circular economy approach (10,000 leaflets were distributed to Halandri's citizens for participating in the Waste4Think project (September 2016)).
- Design of innovative learning methods for citizens and stakeholders
- Different serious games and STEM (Science-Technology Engineering Mathematics) lessons to be developed for the 6th secondary school of Halandri specifically in the following themes:
  - Monitoring of waste generation
  - Waste management: prevention reuse
  - Waste separation and recycling
  - Food Waste
  - Compost
  - Product life cycle and environmental impact

Also promoting basic and advanced concepts related to sorting, eco-design, waste management and circular economy will be developed through a set of Serious Games which main objectives and audience will be

- To teach how to correctly sort the waste in the Municipality

- To introduce qualified people to the principle of eco-design and circular economy concept with different examples like nappies.
- To show the citizen how the waste management system works from the bin to the end treatments adopting the role of a waste manager they will decide the configuration of the system to improve the sustainability of the process.
- Social engagement and participation as well as local trade promotion will be also fostered by the implementation of a set of mobile Apps (Waste4Think, 2015).

Conclusion

Currently, the municipality of Halandri is involved only in collecting, transporting and disposing waste, without exploiting its wastes. The proposed solution will allow this municipality (and any other municipality that will chose to follow Halandri's example) to become a FORBI producer. In this regard, we are currently at the cradle stage of a life-cycle. The importance of the success of this initiative is outstanding and it can revolutionize the current operating practices, while new businesses may be generated as a result. Since many municipalities may choose to follow this example, it is possible that the supply of the "biomass product" will grow rapidly, causing a lowering of the price and limiting profit margins. It is difficult at this stage to foresee the evolution of this market, since it will highly depend on (a) the number and size of the municipalities that will follow this in the course of time and (b) the new "biomass product" customers that will be founded as a result of this. The most relevant expected impacts are: a 20% increase in waste sorting, 10% saving of management costs, and 10% reduction of GHG emissions. The experience gained, and the synergies among the partners describe the best possible scenario to launch new governance and business models.

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WASTE 4think Moving towards Life Cycle Thinking

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