

Separate Collection System of Recyclables and Biowaste Treatment and Utilization in Metropolitan Area Finland

Petri Kouvo, Aino Kainulainen, Kimmo Koivunen

Abstract—Separate collection system for recyclable wastes in the Helsinki region was ranked second best of European capitals. The collection system includes paper, cardboard, glass, metals and biowaste. Residual waste is collected and used in energy production. The collection system excluding paper is managed by the Helsinki Region Environmental Services HSY, a public organization owned by four municipalities (Helsinki, Espoo, Kauniainen and Vantaa). Paper collection is handled by the producer responsibility scheme. The efficiency of the collection system in the Helsinki region relies on a good coverage of door-to-door-collection. All properties with 10 or more dwelling units are required to source separate biowaste and cardboard. This covers about 75% of the population of the area. The obligation is extended to glass and metal in properties with 20 or more dwelling units. Other success factors include public awareness campaigns and a fee system that encourages recycling. As a result of waste management regulations for source separation of recyclables and biowaste, nearly 50 percent of recycling rate of household waste has been reached. For households and small and medium size enterprises, there is a sorting station fleet of five stations available. More than 50 percent of wastes received at sorting stations is utilized as material. The separate collection of plastic packaging in Finland will begin in 2016 within the producer responsibility scheme. HSY started supplementing the national bring point system with door-to-door-collection and pilot operations will begin in spring 2016. The result of plastic packages pilot project has been encouraging. Until the end of 2016, over 3500 apartment buildings have been joined the piloting, and more than 1800 tons of plastic packages have been collected separately. In the summer 2015 a novel partial flow digestion process combining digestion and tunnel composting was adopted for source separated household and commercial biowaste management. The product gas from digestion process is converted in to heat and electricity in piston engine and organic Rankine cycle process with very high overall efficiency. This paper describes the efficient collection system and discusses key success factors as well as main obstacles and lessons learned as well as the partial flow process for biowaste management.

Keywords—Biowaste, HSY, MSW, plastic packages, recycling, separate collection.

I. INTRODUCTION

HELSINKI Region Environmental Services Authority HSY is a municipal actor producing waste management and water treatment and distribution services for over one

Petri Kouvo is with Lappeenranta University of Technology, P.O. Box 20, FI 53851 Lappeenranta and with Helsinki Region Environmental Services Authority, P.O. Box 100 00066, Helsinki (phone 358-40-868 1048, e-mail: petri.kouvo@hsy.fi).

Aino Kainulainen and Kimmo Koivunen are with Helsinki Region Environmental Services Authority, P.O. Box 100 00066, Helsinki (e-mail: aino.kainulainen@hsy.fi, Kimmo.koivunen@hsy.fi).

million inhabitants in the Helsinki region, Finland. HSY also produces and provides information regarding land use, population statistics, and air quality, for residents and decision-makers. HSY organizes waste management for residential properties and the public administration, and supplies high-quality drinking water for inhabitants. Air quality is monitored at current 12 monitoring sites while the monitoring network continues to be expanded and developed further. In addition to Helsinki, HSY has three additional member cities located in the close proximity: Cities of Espoo, Vantaa, and Kauniainen. Currently there are some 700 employees at HSY while turnover is around 350 M€. 120 M€ annual investments make HSY a significant regional supplier.

HSY was established in 2010 through a merger of waterworks of the member cities, waste management services, and regional and environmental information services provided by the Helsinki Metropolitan Area Council.

The population of the Helsinki Metropolitan Capital Region is about 1.1 million [1]. The total amount of 4 million tonnes of waste was generated in the region in 2014 [2] of which 65% was due to civil engineering: significant amount of soil is generated at several construction projects underway: few examples include extension of the Helsinki subway, new residential areas, and a brand-new wastewater treatment plant of HSY. The plant, when introduced in 2020, will undoubtedly display the best purification performance in the Baltic Sea region, while its energy efficiency will be one of the highest in the entire Europe.

According to a recently published study by European Commission [3], Helsinki is one of the best performers among European capitals in separate waste collection. In its strategic policy, Strategy 2020, HSY pursues an active role in the improvement of the state of environment as well as in regional material and energy efficiency. One of the HSY's objectives is to be an innovative forerunner, and an active and reliable cooperation partner in its fields. HSY recognizes its responsibility as the most prominent public environmental body in Finland, and has set strategy-based environmental indicators which are regularly monitored. HSY also actively contributes to environmental objectives in various forums and collective strategies such as implementation of the Helsinki Metropolitan Area Climate Strategy 2030, and the Helsinki Metropolitan Area Climate Change Adaptation Strategy.

II. WASTE TO RESOURCES

HSY is responsible for organizing waste management for

residential properties and the public administration [4]. Duties of HSY as an operator include, e.g., transport and treatment services for waste generated by households, public services, private educational institutes, and health care organizations, whereas waste management of commercial actors is mainly organized by private companies.

HSY also acts as an authority of the municipal waste management. In this role, HSY formulates the waste management regulations, according to which source separation and collection of biowaste, metal, glass, paper and cardboard is implemented at the properties. Biowaste as well as cardboard packages are source separated at properties with least 10 apartments, while bigger properties (20 or more apartments) include also metal and glass packages collection. The waste management regulations are based on the national waste law, which, in turn, rests on the waste directive.

In addition to the waste regulation based source separation at properties, recycling is promoted through a network of waste sorting stations and regional collection points. Furthermore, in Finland, there is a very efficient deposit-refund-system for bottles and aluminium cans.

Annually, HSY collects about 200 000 tons of mixed solid waste (MSW) from households and public organizations. MSW is transported to a new Waste to Energy plant operated and owned by Vantaa Energy Ltd. The plant was introduced in September 2014. Through the plant, all MSW, from which recyclable wastes have been separated as described above, from households and the services is utilized in energy production. Less than 10% of MSW is currently landfilled. The landfill is located in Ämmässuo Waste Treatment Centre at the borderline of Cities of Espoo and Kauniainen.

The main operations of the Waste Treatment Centre include treatment of source separated biowaste, treatment of ash and bottom ash from the waste-to-energy plant, collection and utilization of landfill gases, treatment of contaminated soil as well as landfill treatment and final disposal. One waste sorting station is also located in the area. Ämmässuo Waste Treatment Centre is going through a transition into a resource-efficient eco-industrial centre. The Ekomo project was launched in 2015. Ekomo will be a center of operations based on material recycling where companies can work in close cooperation with HSY and other businesses operating in the area. The objective is to make Ekomo an internationally acknowledged showcase of industrial symbiosis based on the infrastructure, platforms, and material flows provided by public sector. First cooperation projects have already been launched. Green asphalt project target to reuse of used asphalt from demolition and construction sites. The aim is to utilize mineral fractions of bottom ash in new green asphalt production as well as excess heat from landfill gas power plant.

Other Ekomo project includes the purification of sand used for sanding the roads and pavements. Purified sand can be reused, and the fine fraction separated from sand is utilized in top soil production from compost.



Fig. 1 Ämmässuo Waste Treatment Centre

III. BIOWASTE TO BIOGAS AND SOIL PRODUCTS

In addition to MSW, HSY collects about 50 000 tons of source separated biowaste. Biowaste is transported to the Waste Treatment Centre as well, for treatment in a brand new process combining traditional composting and anaerobic decaying technologies. Treatment of HSY's biowaste is based on the partial flow digestion process. The most suitable parts of the biowaste are selected and directed to each treatment process. Thanks to the biogas production, the part-stream dry digestion technique is ecologically a more sustainable treatment than composting alone [5], [6]. Through the biowaste treatment, also energy from biowaste is efficiently recovered.

After two decades of tunnel composting, HSY has recently implemented a new process utilizing anaerobic digestion (AD). The partial flow digestion process begins with pre-treating the biowaste by sieving. The fine fraction of the incoming biowaste is fed into a dry anaerobic digester, while the coarse fraction is fed directly into the composting process with the digestate and bulking materials in order to provide organic carbon for the composting process (Fig. 2).

By choosing a dry digestion reactor and with the novel partial flow process that facilitates excess moisture evaporation during composting, the difficult wastewaters usually associated with the anaerobic treatment of biowaste can be avoided [7]. The digestion facility consists of two continuous horizontal plug-flow reactors that are fed with a screw below the surface of the reactor bed. The feeding screw was chosen instead of a conventional pump to avoid blockage that can occur with heterogeneous materials. The feed, characterized in a development project optimizing the process, has a total solids (TS) content of 30 percent and is rich in nitrogen with a Total Kjeldahl Nitrogen content of 27 g kgTS^{-1} . After a retention time of at least 21 days, the digestate has a TS content of about 18 percent and is removed from the reactor using a vacuum. At this point, the digestate and the coarse biowaste separated in the pre-treatment are mixed together along with bulking materials, such as woodchips, and composted in a tunnel composting facility for 10 days before maturing outside in windrows. The tunnel composting facility has 15 batch reactors and the process includes a two-day hygienization period where the temperature of the reactor is kept above $70 \text{ }^{\circ}\text{C}$.

Composting nitrogen-rich materials produces large amounts of gaseous ammonia and other odorous substances. These are removed from the exhaust air with a biowasher and biofilter.

Ammonia in the exhaust air is dissolved in water and turned into elemental nitrogen before being released into the atmosphere.

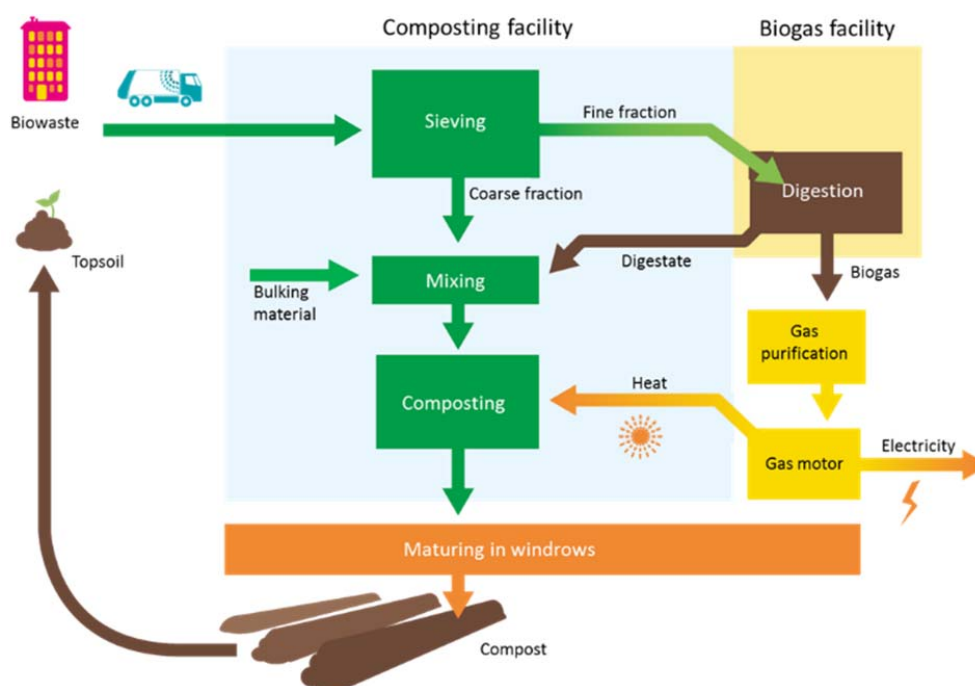


Fig. 2 The schematic of the partial flow digestion process in Helsinki metropolitan area

IV. WASTE COLLECTION AND TRANSPORT IN CO-OPERATION WITH PRIVATE COMPANIES

Waste transports are selected through competitive tendering for each collection area at intervals of five years. Waste is collected in practice by contractors. Emptying of waste containers at the properties can be supervised in real-time which together with an incentive system created for the contractors has enabled very high reliability of the waste transport service.

V. SORTING STATIONS

HSY has created a network of waste sorting stations, where inhabitants and small enterprises are allowed to bring waste not suitable for conventional MSW collection at the properties. Such waste can include, e.g., furniture and big metal waste as well as garden waste, hazardous waste, and, for example, Electrical and Electronic Equipment Waste (WEEE). About half of the material received at the stations ends up in recycling. There are five waste sorting stations today, and new stations will appear in the future. The newest one was opened in September 2015 in Vantaa.

VI. COLLECTION POINTS

Besides, there are regional collection points distributed throughout the region, which, so far have been operated by HSY [7]. In the future, however, HSY will work in close cooperation with Finnish Packaging Recycling RINKI Ltd, which represents the producers of glass, metal, carton, and

plastic packages as along with the new decree on packaging and packaging waste, the responsibility concerning the collection and recycling of domestic packaging waste is transferred to the producers [8]. The collection of plastic has been started at the collection points this year. Plastic collection has also been piloted at selected residential buildings from spring 2016 on.



Fig. 3 Collection points

VII. RENEWABLE ENERGY PRODUCER

Considering its fields of operation, it is not a surprise that HSY is a significant regional energy consumer. HSY's energy consumption is currently approximately 200 GWh, of which over half is due to electricity, consumed by water and wastewater treatment, and waste treatment processes. Vehicles, in contrast, are responsible for less than one percent of the total energy consumption. Besides consumption, HSY also produces significant amount renewable energy, mostly

based on biogas. One of the HSY's objectives has been to be completely energy self-sufficient by 2017. The target has already been achieved. HSY also contributes to energy efficiency and has joined municipalities' energy-efficiency agreement.

At the Waste Treatment Centre, landfill gas is recovered at a gas power plant. The plant, introduced in 2010, is able to utilize all gas collected from the landfill areas which are no longer used for landfilling MSW. Currently, the amount of collected methane is about 2000 m³/h and it will decrease during the next decades as the decomposition of waste progresses. Methane formation at more recently used landfill area is plotted in Fig. 3. The plant is one of the largest utilization plants of landfill gas in Europe, generating 15 MW of electric power. This corresponds the electricity need of ca. 8 000 detached houses. In addition to this, the Waste Treatment Center produces heat mostly for its own purposes. Due to the gas power plant, the area is self-sufficient in its energy production, and a great deal of produced electric power is sold to the national grid. The landfill gas collection system and the power plant also significantly reduce the carbon

dioxide emissions.

The plant has a recovery system of exhaust gases, i.e. the ORC process (Organic Rankine Cycle). The process is able to utilize exhaust gases of the power plant for additional electricity production. In 2012, thanks to the high technological level of the plant, reduction of landfill emissions and beneficial economical effects, HSY conquered the Energy Globe Award national category and ranked high also in the international comparison.

In addition to landfill gas production, biogas plant produces roughly 6.5 million cubic meters of biogas each year with a methane content of about 60 percent. The produced biogas is utilized at a CHP plant that includes also an Organic Rankine Cycle unit, which generates additional electricity and heat from the heat in exhaust gases. This innovative approach enables an increase of 6% in the efficiency of the electricity production process. The ORC process utilizes an organic fluid that has a lower boiling point compared to water. This allows lower temperature heat sources to be used in electricity generation with turbines.

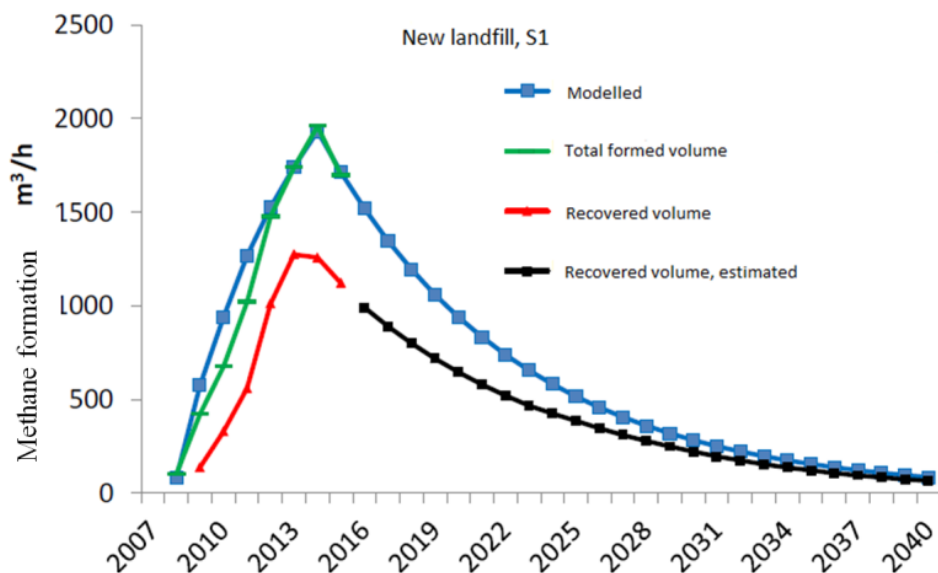


Fig. 4 Estimated methane formation in 2007-2040 and measured values 2008-2015 at the S1 landfill area

VIII. SIGNIFICANT INVESTMENTS

HSY is a prominent actor also when it comes to investments made in the public sector with its 120 M€ investments in 2014. HSY is to implement its investments increasingly through innovative public procurement procedures. During the recent years, HSY has networked strongly both with domestic and European cooperation partners. HSY is a member in ICLEI (The International Council for Local Environmental Initiatives) and Procura+, and cooperates through its pilot in Water PiPP (Water Public Innovation Procurement Policies) project. In Finland, HSY cooperates with several partners such as Tekes, the Finnish Funding Agency for Innovation, from which HSY gets funding for its strategic project Resource-wise Helsinki Region. One of the basic ideas of the project is

to support the development of Ekomo by networking with companies and launching pilots with them. For SMEs especially, HSY is considered as an important reference which would boost their entrance to domestic and international markets. As a public actor, HSY can provide companies innovation and development platforms, located in real operational environments (such as Ekomo). Companies can then pilot their technologies on the platforms and successful pilot cooperation can result later in actual purchases.

IX. RESEARCH AND DEVELOPMENT (R&D)

HSY implements actively various R&D projects in all of its fields and is a partner in several domestic and European cooperation projects. HSY implements innovative forms of

cooperation including hackathons and assignments to university student teams. Currently, there are several projects underway covering, e.g. biomass, ashes and slag, energy efficiency, and nutrient recovery.

Some of the projects are repeated at regular intervals, such as studies regarding composition of MSW. MSW composition studies give information about utilization potential of MSW, and can be used for instance to promote waste prevention or when new treatment processes are designed. The previous MSW composition study was carried out in September 2015.

In 2015, HSY created an LCA model regarding the biowaste treatment process at the Waste Treatment Centre. Using the model, it is possible to examine environmental effects of the process parameters. The information can be utilized in process optimization.

HSY has monitored the decomposition processes in the landfill structures since 2006. In these studies, temperature, formation of methane (Fig. 4) and its recovery rate, leachate properties such as nitrogen, chloride and sulfate contents, BOD₇/COD, water balance, etc. are monitored. The results give information about the activity of decomposition as well as proper functioning and safety of the landfill structure.

As an example of completed cooperation projects, Julia 2030 project, partially funded the European Union LIFE+ programme, established a basis for Helsinki Region joint climate work in 2009–2011. Another project, From Waste to Traffic Fuel (W-Fuel), examined the possibilities of promoting biogas production and use as transport fuel. W-Fuel project was funded by the Central Baltic INTERREG IV A Programme.

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