Food Waste to Biofuels

Nordic Energy Research

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Summary

Reducing waste and better utilization of waste and losses in the value chain is among the means for international climate policy and for transformation to renewable energy.

Food waste and spill can play a role as a solution for low carbon transport, assuming that the principles of waste hierarchy are followed. This means that energy use of food waste is the least preferable option after prevention, re-use and recycling. It is, however, more desirable solution than disposal without recovery. Also waste-to-energy can be diversified and improved for better utilization.

The purpose of this report is threefold:

1. Data on the amounts and current utilization of Nordic food waste
2. Detect waste sources and technology routes for food waste-to-transport fuels
3. Detect contributors and barriers for increasing the use of food waste for transport fuels and policy input on how to deal with the situation.

The Nordic countries (Sweden, Denmark, Norway, Finland and Iceland) **generate around 10 million tons** of food waste every year, excluding cereal straw. Most of the food waste is generated in households, with some 5 million tons of annual generation. In addition, some 25 million tons of cereal straw is generated in the Nordic countries, of which less than 10 million tons is estimated to be available for utilization. In this context, food waste refers to waste and residue streams along the food value chain from primary production, processing, distribution to end use.

Almost **90%** of food waste generated in the Nordic countries, excluding cereal straw, is **currently collected and utilized**, mainly for energy. Incineration, biogas and food/feed are the most significant end uses of food waste, followed by composting. Utilization of food waste for transport fuels, excluding biogas, is still relatively small i.e. less than 1% of the total volume of food waste generated.

Increased production of transport fuels from food waste in scale requires redirection of waste volumes from incineration to biofuels. Theoretically, this would offer a food waste potential of less than 3 million tons annually in the Nordic countries. Utilization of this resource requires, however, improved collection of biomass fraction of municipal solid waste. In addition, redirecting waste streams from incineration to biofuels should not cause additional emissions through substitution of incinerated waste with fossil fuels. Considering uncollected and underutilized waste streams, used cooking oil and increased rendering rate represent a potential of less than 0.1 million tons annuallyIt should, however, be noted that 1 t of used cooking oil or animal fats has generally a higher biofuel yield compared to 1 t of household waste, depending on the waste composition and biofuel production technology applied. There are various **technology routes** available enabling more intensive utilization of food waste streams for transport fuels. Most feedstocks can be utilized in biogas production offering options for nutrient recycling as well. Increased utilization of biogas for transport fuels requires development of biogas vehicle and distribution infrastructure. However, other technologies are available as well for production of low blend or drop-in biofuels from food waste. Also these technologies allow recycling of by-products to fertilizers or animal feed.

To increase the amount of food waste utilized as biofuels, the following topics are to be considered:

- upgrading biogas to transport fuel and diversion of food waste from incineration
- mobilizing smaller fractions of rendering
- aquaculture waste or determining ways to address the offshore fish waste
- bringing cereal straws into consideration for ethanol production
- consider improved distribution capacity across national borders, and to harmonize the economic incentives across industrial sectors.

Opportunities and needs for Nordic collaboration should be considered for each of the topics as well as the practical feasibility of the identified measures.

In order to leverage the best practices around the Nordic countries, coordination of the biofuels policy priorities between the Nordic countries would be beneficial.

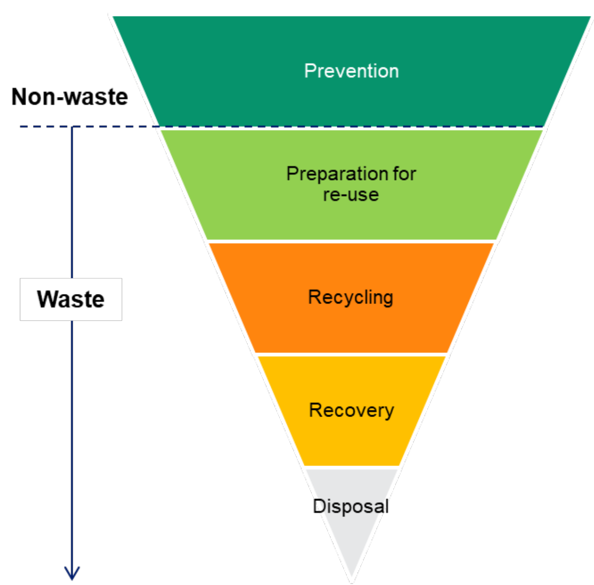
Contents

1. Background

Food waste is gaining increased attention among consumers and policy makers globally. For example, the European Commission states that wasting food is not only an ethical and economic issue, but it also depletes the environment of limited natural resources. Preventing food losses and waste is widely recognized as a key priority for addressing issues related to food waste.

Energy use of food waste can be regarded as a least preferable option before disposal, when following the principles of waste hierarchy (Figure 1). However, climate change and the need to phase out fossil fuels create a need to find alternative ways to reduce emissions in the energy sector. In the Nordic countries, transport sector is a major source of emissions, and new solutions to address transport sector emissions are being developed. According to the prevailing EU climate policy principles, sustainable biomass assortments, including non-edible fractions of food waste, are regarded as a solution for low carbon transport. Therefore, food waste can play a role as a solution for low carbon transport, assuming that the principles of waste hierarchy are followed.

Figure 1 Waste hierarchy and food waste



2. Objectives

The objective of the work was to assess the possibilities to increase utilization food waste to energy in the Nordics, with a focus on transport fuels. This involves the following key questions to be addressed:

1. How much food waste is currently generated in the Nordic countries and how it is currently utilized
2. What are the possible waste sources and technology routes to increase utilization of food waste for transport fuels
3. What are the main contributors and barriers for increasing the use of food waste for transport fuels

The purpose of the assignments was to review available information sources in order to create a high level understanding on the availability and utilization of food waste in the Nordic countries, as a starting point for further initiatives. The availability of public information on the topic is very limited and thus, the assessment is largely built on Pöyry expert estimates based on the publicly available information*.

3. Definition of food waste

In this context, food waste refers to waste and residue streams along the food value chain from primary production, processing, distribution to end use. Primary production includes cereal straw and other waste and residue streams generated in agriculture and farming. Processing covers waste streams from food industry, rendering being an example of processes generating waste streams suitable for energy use. Distribution involves waste streams retail and wholesale, whereas end use refers to food service and households generating various food waste streams. Some of the food waste assortments, such as used cooking oil, are generated in various parts of the food value chain and thus, these waste assortments are discussed as one waste stream without distribution between sources of origin.

The amount of cereal straw generated is considerably larger compared to the other waste streams and thus, in this context, the amount of cereal straw is discussed separately from the other waste streams in the food value chain. In addition, it is important to note that the analyzed waste streams include both edible and inedible fractions of food waste, and that there is limited support for energy use of edible fractions of food waste.
In this context, biofuels refer to any bio-based transport fuels such as ethanol, biodiesel, renewable diesel and biogas.

4. Availability of food waste

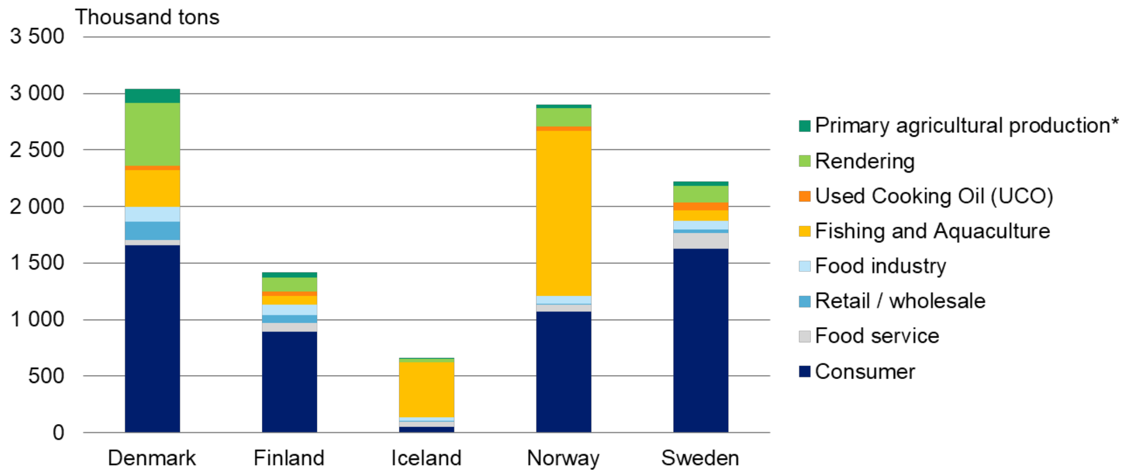
4.1 Generation of food waste

The Nordic countries i.e. Sweden, Denmark, Norway, Finland and Iceland generate around 10 million tons of food waste every year, excluding cereal straw. The amount of food waste is the highest in Denmark and Norway, both countries generating some 3 million tons of food waste annually, followed by Sweden with an annual generation volume of some 2 million tons. Most of the food waste originates form households, with some 5 million tons of food waste generated every year in the Nordic countries.

There are variations between sources of origin of food waste among the Nordic countries. For example in Norway and Iceland, fishing and aquaculture generates the major share of food waste, whereas in other countries, most of food waste originates from households. In Denmark, a significant share of food waste is generated in the rendering industry (Figure 2).

*FAOSTAT, Eurostat, Swedish Board of Agriculture, FUSIONS EU, LUKE, EPA Denmark, EPA Sweden, Katajajuuri et al. 2014, Silvennoinen et al. 2015, Ostfoldforskning, Statistics Sweden, Statistics Finland, Statistics Denmark, Statistics Iceland

Figure 2 Estimated Generation of Food Waste in the Nordic countries



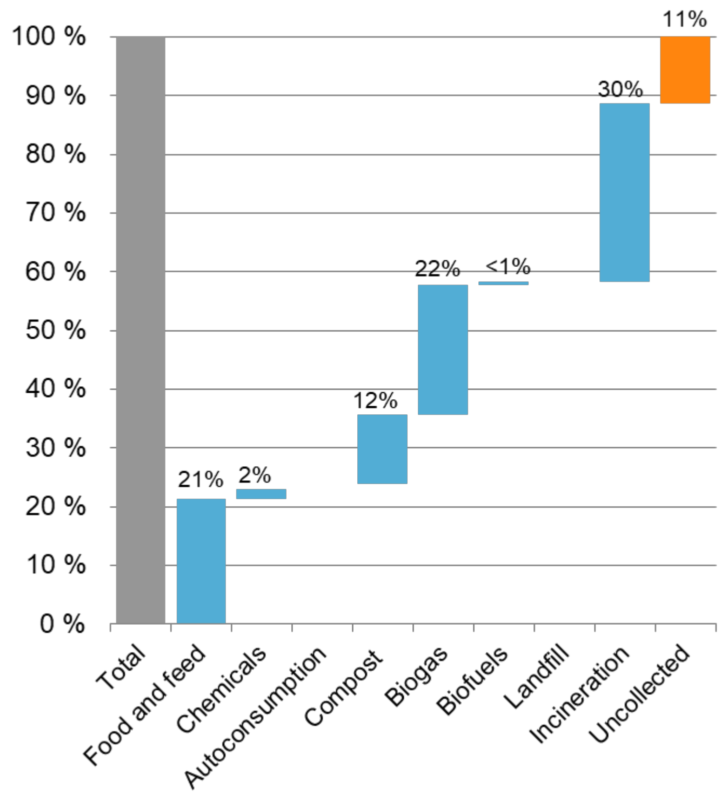
*Excluding cereal straw

In addition to the 10 million tons of food waste generated, some 25 million tons of cereal straw is generated in the Nordic countries, of which less than 10 million tons is estimated to be available for utilization. In a Nordic context, most of the straw is generated in Denmark, followed by Sweden and Finland.

4.2 Collection and utilization of food waste

In general, food waste is currently being utilized to a relatively high degree (Figure 3). Of about 10 million tons of food waste generated in the Nordics, excluding cereal straw, almost 90% is currently collected and utilized, mainly for energy. Incineration, biogas and food/feed are the most significant end uses of food waste, followed by composting. Utilization of food waste for transport fuels, excluding biogas (used also for e.g. heating), is still relatively small i.e. less than 1% of the total volume of food waste generated.

Figure 3 Estimated utilization of food waste in the Nordic countries



The orange bar in above figure represents the 11% of uncollected or unused waste generated annually. Of about 1 million tons of this waste, a great majority, 83%, comes from fishing and aquaculture. This waste is handled at sea and not brought ashore at all, and thus is not expected to become available for utilization. Another 10% is the uncollected portion of used cooking oil. Around 5% consists of waste from meat rendering, as around one third of the livestock slaughter is done by small farm operations. Potential consolidation of this industry sector is expected to make additional by-product volumes available for utilization. Finally 1% comes from primary production in agriculture, excluding cereal straws.

5. Use of food waste in transport fuels

5.1 Technology routes for food waste to biofuels

There are various technology routes available for enabling more intensive utilization of food waste streams for transport fuels. The technology routes enable production of ethanol, biodiesel, renewable diesel and biogas based on alternative technologies such as anaerobic digestion, esterification, hydrolysis and fermentation, hydrogenation and thermal gasification. Some technology routes are suitable for selected food waste assortments, but for example the biogas route through anaerobic digestion allows relatively large flexibility in terms of feedstock assortments used. In addition, there are differences in terms of the rate of commercialization of the alternative technologies, anaerobic digestion, esterification and hydrogenation being examples of the technologies currently used in a commercial scale. The suitability analysis is presented in figure 4.

Figure 4 Technology routes to transport fuel production from food waste

Feedstock	Technology	Product
Agricultural residues	Thermal gasification / Hydrolysis and fermentation	Ethanol / Renewable diesel
Meat rendering	Hydrogenation / Chemical esterification / Anaerobic digestion	Renewable diesel / Biodiesel / Biogas
Fish and Aquaculture	Hydrogenation / Chemical esterification / Anaerobic digestion	Renewable diesel / Biodiesel / Biogas
Food industry	Anaerobic digestion / Hydrolysis and fermentation	Biogas / Ethanol
Retail & wholesale	Hydrogenation / Chemical esterification	Renewable diesel / Biodiesel
Food service waste	Hydrogenation / Chemical esterification	Renewable diesel / Biodiesel
Household food waste	Anaerobic digestion / Hydrolysis and fermentation	Biogas / Ethanol
Biowaste & Organic fraction of MSW	Thermal gasification / Mechanical separation and anaerobic digestion	Ethanol / Renewable diesel / Biogas

5.2 Nordic case examples for food waste to biofuels

Daka ecoMotion, Denmark, biodiesel

Daka ecoMotion has a biodiesel production plant in Løsning, Denmark, with annual production of 55 million liters of biodiesel. The main feedstock is refined animal fats originating from slaughtherhouse and primary agriculture by-products. In addition to animal fats, Daka ecoMotion can also utilize used cooking oil and other oils not suitable for food production.

Biodiesel is produced by two step trans-esterification and produced biodiesel can be used in automotive fuels. By-products from the process are glycerin and potassium sulphate. Glycerin can be used for energy production purposes in biogasification and co-incineration plants while potassium sulphate can be used as fertilizer.

LABIO and Gasum, Finland, biogas

Biogas production and refining plant in Kujala, Finland, is a joint venture of LABIO Oy and Gasum Oy. LABIO is responsible for the raw biogas production while the gas refining and distribution of the upgraded biogas belongs to Gasum. LABIO also operates the composting plant which is integrated to the same site.

Production plant has two main feedstock sources: biowaste from household, industrial and commercial origins and sewage sludge. As an example of the feedstock supply, LABIO has a co-operation with Finnish brewing company, Bryggeri Helsinki. LABIO uses the brewing by-product, mash, to produce biogas which is then used in Bryggeri's own operation.

Organic waste is digested under anaerobic conditions to produce raw biogas which is then upgraded. Biogas production potential is 50 GWh and in 2017, biogas production was 45 GWh. Quality of the upgraded biogas is comparable to natural gas and it is mainly used in the transportation sector. The by-product of the process, digestate, is sent to the composting plant to produce fertilizers and mould raw material.

Gasum, Sweden, biogas

Gasum Oy has 12 biogas production plants of which seven are located in Finland and five in Sweden. In Lidköping, Sweden, Gasum produces biogas in co-operation with FordonsGas. The biogas production plant uses mainly local food industry residues such as vegetable waste products from grain trade and food production. The production plant annually digests approximately 60 000 tons of substrate and biogas production potential is 60 GWh per year. Gasum is responsible for producing the upgraded biogas which is then either liquefied or compressed and distributed by FordonsGas.

St1, Finland and Sweden, bioethanol

St1 has developed fuel ethanol technologies by utilizing various residues and wastes. St1 Biofuels is responsible for the development and sales of three types of ethanol technology: Etanolix® based on food industry waste (e.g. bakery waste), Bionolix® based on municipal and industrial bio-waste and Cellulonix® based on cellulosic waste (e.g. sawdust) as feedstock.
In this context, the Etanolix® and Bionolix® technologies are discussed as the Cellulonix® technology focuses on feedstock assortments beyond food waste value chain.
In addition to fuel ethanol production, Etanolix® and Bionolix® processes result in by-products. By-products from Etanolix® process are biogas and liquid animal feed. Due to the technology and animal feed end uses, the use of meat based feedstock in the Etanolix® process is restricted, for example by the EU food safety regulations. However, meat based feedstock can be used in Bionolix® processes. By-product, stillage, from Bionolix® process can be used for biogas production. The side products of biogas production can be utilized as fertilizer.
St1 operates five Etanolix® plants (total 10 ktoe) and one Bionolix® plant (<1 ktoe). Four of the Etanolix® plants are located in Finland (Jokioinen, Lahti, Vantaa and Hamina) and one in Sweden (Gothenburg). The one Bionolix® plant is located in Finland (Hämeenlinna).

One example of the Etanolix® technology is the production plant in Gothenburg which started operation in 2015. The production capacity of that plant is 5 million liters of ethanol per year. The plant utilizes biowaste and process residues from local bakeries and bread shops as a feedstock. The bioethanol plant is integrated to the St1 oil refinery.

Neste, Finland, the Netherlands and Singapore, renewable diesel

Neste produces renewable diesel in Porvoo (Finland), Rotterdam (the Netherlands) and Singapore with a total annual production of 2.6 Mt. Neste uses NEXBTL hydrogenation technology for renewable diesel production. The produced renewable diesel can be used to replace fossil diesel in the transportation sector. The chemical consistency of the renewable diesel is comparable to the fossil diesel which allows it to be mixed with fossil diesel without restrictions.

In 2017 Neste used 3.2 million tons of renewable feedstocks. More than 75% of the used feedstock was wastes and residues, while the remaining less than 25% was vegetable oils. Examples of the used wastes and residues are animal fat from the food industry, fish oil from the fish processing industry, vegetable oil production residues (e.g. Palm Fatty Acid Distillate (PFAD)) and used cooking oil.

6. Contributors and barriers

The context of using food waste for biofuels is generally very complex and involves various aspects such as circular economy and sustainable societies, climate change mitigation, health and safety as well as technology and infrastructure development.

Circular economy is considered one of the key paths for sustainable future societies, involving responsible use of raw materials, prevention of waste, efficient collection of waste streams as well as re-use and recycling of materials. Production of transport fuels from food waste is not necessarily in contradiction with the principles of circular economy. For example, the by-products of food waste based biofuel production can be utilized as animal feed with certain limitations. In addition, biofuel production routes allow utilization of by-products for fertilizers. In some cases, food waste could be recycled into materials and chemicals instead of energy use. These activities are, however, heavily impacted by the economic viability of the business case in question.

Direct energy use, such as incineration, does not allow further recycling of food waste and thus, directing the incinerated food waste volumes to biofuel production would not change the food waste recycling rate from the current situation. Redirecting waste streams from incineration can be regarded as the most significant potential for using food waste for biofuels with annual waste potential of less than 3 million tons. Utilization of this potential would, however, require sustainable substitutes for energy production as part of the waste stream is directed away from waste incineration. In addition, improved collection of the organic fraction of municipal solid waste from households is required.

Anaerobic digestion is an example of a technology not sensitive to the feedstock quality and thus suitable for transport fuel production from food waste from households. More intensive adoption of biogas in transport sector requires, however, significant efforts in infrastructure and technology development, from biogas supply infrastructure to vehicles. This, in turn, requires political support for gas fueled transport infrastructure to ensure stable investment environment along the biogas to transport value chain. Other technology routes than biogas allow production of low blend or drop-in biofuels without significant investment requirement in infrastructure. However, these technologies might be more sensitive to the quality of the feedstock used.

Considering uncollected and underutilized waste streams, used cooking oil and increased rendering rate present the largest potential for biofuels production in the Nordics. However, the absolute volume of this potential is considered relatively small. By increasing the collection of used cooking oil, especially from households, there is a potential to collect up to 50 000 tons of used cooking oil per year. By increasing the rendering rate of slaughterhouse by-products processed in industrial rendering facilities there is a potential feedstock increase of 20 000 tons per year. While the underutilized portion of fishing and aquaculture is significant, this waste is handled and disposed of at sea due to fish handling and hygiene regulations.

The recent EU Renewable Energy Directive towards 2030 sets guidelines for desirable biofuel feedstocks to be used for decarbonizing the transport sector. The directive limits the utilization of food and feed based biofuels but promotes the use of more desirable non-edible feedstocks. Used cooking oil and animal fats non-suitable for human and animal consumption are treated separately in the directive meaning that utilization of these feedstocks is permitted only to a certain extent. The most desirable feedstock, with a minimum target and no limitations, covers a broad range of food waste based feedstocks, such as

- biomass fraction of mixed municipal waste (with certain limitations),
- biowaste from private households subject to separate collection (with certain limitations),

- biomass fraction of industrial waste not fit for use in the food or feed chain, including material from retail and wholesale and the agro-food and fish and aquaculture industry (excluding used cooking oil and non-edible animal fats), grape marcs and wine lees, but also straw and bagasse.

This means that utilization of many food waste streams are supported by the recent EU Renewable Energy Directive for 2030.

7. Policy input

Due to the limited availability of food waste, the key policy element to be considered in the Nordic context is the role of waste incineration and related substitutes, in case food waste fractions are directed away from energy generation. Another important element is the technologies and infrastructure for utilization of biogas in transport and related policy areas. Beyond biogas, support mechanisms for market introduction of food waste based biofuels produced with technologies other than biogas remains as a key measure to promote the adoption of sustainable food based biofuels under the guidelines of the EU renewable energy directive. Coordination of the biofuel policy priorities between the Nordic countries would contribute to Nordic collaboration and adoption of the best available technologies and solutions for market introduction of sustainable transport fuels.

A brainstorming session was organized in a Nordic conference in June 2018 in Stavanger, Norway in order to identify potential measures for addressing the use of food waste for biofuels. The topics to consider were

- upgrading biogas to transport fuel and diversion of food waste from incineration,
- mobilizing smaller fractions of rendering
- aquaculture waste or determining ways to address the offshore fish waste
- bringing cereal straws into consideration for ethanol production.
- and to consider improved distribution capacity across national boarders, and to harmonize the economic incentives across industrial sectors.

The criteria to consider for each of the topics were opportunities and needs for Nordic collaboration as well as the practical feasibility of the identified measures.

Many of the brainstorming groups emphasized the importance of Nordic collaboration, especially in harmonization of practices and regulations related to food waste and biofuels. For example, the participants emphasized the need for harmonized view on the role of biofuels in the transport sector decarbonization in connection to alternative solutions such as electricity and hydrogen. At the same time, it was stated that biofuels are especially needed to complement the electrification of transport . In general, a zero emission approach was emphasized as a guiding principle for any potential future collaboration in the biofuels sector. In addition, the importance of Nordic collaboration was raised in promoting improved sorting of municipal solid waste. Examples of this include introduction of mandatory food waste separation but also sharing good experiences in food waste sorting by individual municipalities. Research and development was mentioned also as an opportunity for Nordic collaboration, as it was stated that in the Nordic countries there are many isolated research centers, which hampers cross-sectoral collaboration. Also test labs were mentioned as a tool to share recent findings and innovations.

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Related Publications

- Nordic Energy Technology Perspectives 2016
- Potential for Bioenergy in the Nordics
- Renewable Energy Supply and Storage
- Sustainable Future Energy Systems 2050