abowe
Implementing Advanced Concepts for Biological Utilization of Waste

Interesting biodegradable waste feedstock potentials in fermentation point of view

Case study: Finland

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1. INTRODUCTION **3**
2. WWTP SLUDGE FROM PULP, PAPER AND BOARD PRODUCTION **3**
2.1 GEOGRAPHICAL DISTRIBUTION 5
2.2 QUALITY 7
3. SPOILT GRASS SILAGE **7**
4. HOUSEHOLD BIOWASTE **8**
5. BIOFUEL PRODUCTION IN SUSTAINABILITY POINT OF VIEW **10**
6. BIBLIOGRAPHY **12**

1. Introduction

Waste based feedstock can offer interesting possibilities for reducing GHG emissions, because waste management in current status is usually generating GHG emissions more than it can be avoided by using GHG friendly systems. However, it is important to know the origin and character of these waste feedstocks to see new utilization path ways in current operational environment where waste legislation denies landfilling of biodegradable waste. For example, total biodegradable feedstock energy potential in Finland was reported as 25 TWh per year which is about 6.6 % of total energy consumption [1]. Most of the energy potential lies in agricultural biomass, about 82 % of total potential. Municipal based waste had energy potential of 8 % of total while rest 10 % was agricultural manure potential. Because landfilling regulation (331/2013) denies landfilling of household biowaste and forest industry sludge their geographical distribution and character was estimated. In addition, agricultural side stream biomass like spoilt grass silage could offer additional potential for biological processes. Thus, selected feedstock materials in this assessment were household biowaste, forest industry sludge and spoilt grass silage.

Selected biodegradable waste fractions and their distribution in biological utilization point of view were assessed in this paper. Assessment is part of the work in Abowe project where dry digestion and novel biorefinery system feasibility are tested in project target areas. Within the project dry digestion system is demonstrated in West Lithuania, Estonia and Sweden while biorefinery system is tested in Finland, Poland and Sweden. University of Eastern Finland makes feedstock and sustainability assessment in those target areas in co-operation with local testing partners. In case of Finland, feedstock over view was carried out in sustainable biological utilization point of view.

2. WWTP Sludge from pulp, paper and board production

Forest industry based waste water treatment plant (WWTP) sludge amount in geographical origins and its quality were assessed in Finnish operational environment. It was estimated that in Finland landfilled fiber and filler sludge as well as waste water treatment plant (WWTP) sludge in 2012 were 41.2 kt/year of (Table 1 and Figure 1). These materials are under of landfilling legislation which means that after 2016 they cannot be landfilled and new methods for their end treatment should be found (331/2013). Actually, it was reported that WWTP sludge production in 2010 was 465 kt of dry sludge when more than half, 282 kt of dry sludge was combusted [2]. Thus, potential amount of sludge for biological end treatment processes could be in order of hundred thousands of dry tons per year.

Table 1. Amount of landfilled waste from pulp, paper and board production is based on Finnish forest industry statistics [3].

Landfilled waste in 2012	DM t/year
Ash	24 200
Soda dregs and lime sludge waste	64 200
Deinking sludge and waste	2 100
Fiber and filler sludge	1 700
WWTP sludge	39 500
Wood waste	1 200
Other waste	13 600
In Total	146 600

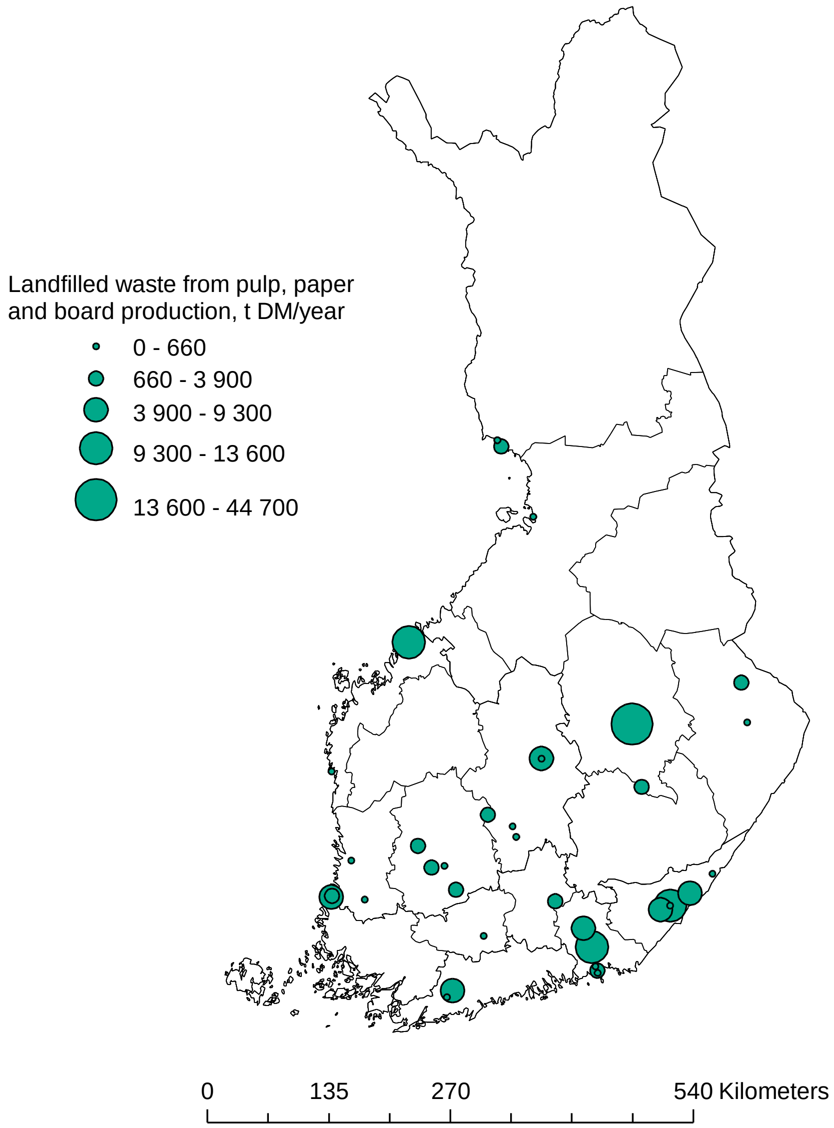

Figure 1. Amount of landfilled forest industry waste is based on forest industry statistics [4].

2.1 Geographical distribution

Geographical WWTP sludge production is represented according to forest industry statistics and estimations about specific sludge productions (Figure 2). WWTP sludge is formed when organic material as particle and dissolved form is removed from the main wastewater flow before main wastewater flow is discharged to the environment. Primary sludge contains mostly woody based materials that are removed from the main wastewater flow in the first clarifying step. Secondary sludge contains biological cells and it is removed from second clarifier after biological treatment process. In addition, tertiary treatment is also used if there is need to fulfill discharge limit conditions.

Even sludge production and its properties depend on mill; total sludge production in geographical perspective was estimated. Usually, primary sludge production is twice more than secondary and tertiary sludge production altogether. Thus, sludge production estimations are based on primary sludge productions. From paper and board production primary sludge production from can be from 5 to 10 kg DM per dry ton of the end product [5]. Thus, sludge production was estimated as 7 kg DM per ton of paper or board.

In addition, sludge is formed from mechanical and chemical pulping wastewaters. In mechanical pulping primary sludge production can be from 15 to 20 kg DM per dry ton of pulp [5]. In sulfate pulping primary sludge production can be from 20 to 25 kg DM per dry ton of pulp and in sulfite pulping from 50 to 60 kg DM per dry ton of pulp. Thus, sludge production was estimated as 33 kg DM per dry ton of pulp.

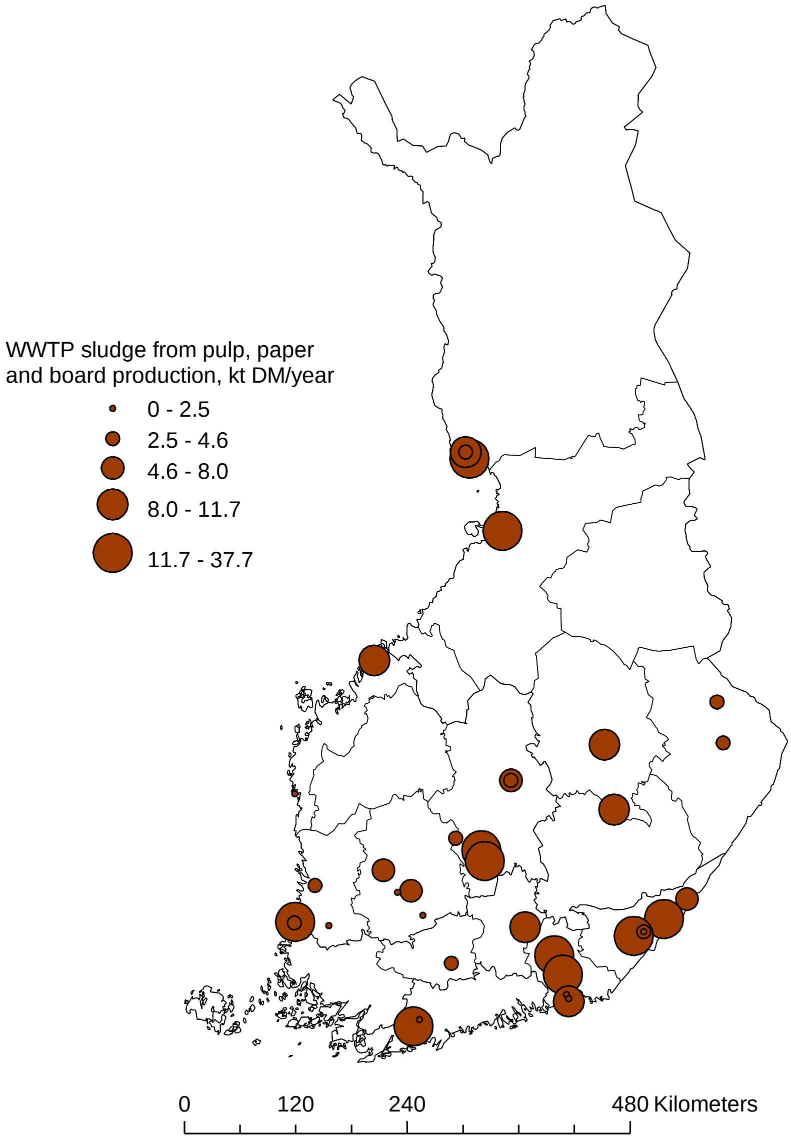

Figure 2. Sludge production was estimated according to pulp, paper and board production in 2012 [4].

2.2 Quality

Amount of organic material in sludge is under of interest, because it could be converted through fermentation into valuable bio chemicals. Organic material can be in dissolved or particle form in wastewater fractions. If raw wastewater influent from mill is considered most of the organic material can be in dissolved form [6]. Instead, if sludge after dewatering step at around 34 % dry matter concentration is considered only negligible part of organic material is dissolved form.

Sludge organic matter concentration after dewatering step depends mostly on where the raw wastewater to the WWTP arrives. Generally, fine paper mill sludge can contain organic materials from 40 % to 50 % of dry matter [5]. Quite low amount of organic material is mostly resulting from addition of fillers and their accumulation in the end of WWTP process. Instead, organic matter can be from 80 to 95 % of dry matter only from sulfate pulp wastewater sludge [5] which is the most favored chemical pulp in Finland [7]. From delinking sludge the organic matter concentration is lowest, no more than 30 % of total dry matter [5]. Thus, most desired sludges for biological utilization in organic matter point of view are WWTP sludge from pure sulfate pulping or paper and board production that are using low amounts of fillers.

Woody based sugars as dissolved form in wastewater fractions are attractive in biological utilization point of view. Chemical pulping obviously degrades woody macro components such as hemicelluloses that end up to wastewater [8]. Dissolved woody sugars from hemicelluloses such as *Xylans* could be utilized in fermentation processes. In addition, cellulose would need to be hydrolyzed into its sugars before it could be utilized in fermentation.

3. Spoilt grass silage

Geographical distribution of spoilt grass silage is based on Ministry of Agriculture and Forestry field block data base [9] and estimation about the amount of spoilt grass silage (Figure 3). Province wide grass silage yields from 2013 are available from ministry of Agriculture and Forestry [10]. Yield was 15 380 (kg FM)/ha when total cultivated field area and yield were 411 600 ha and 6 328.9 kt/year, respectively. When it is assumed that 3.26 % of total yield is spoiled [11] with average dry matter concentration of 33 % [10] the total spoilt grass silage potential in Finland is 70 kt/ DM/year.

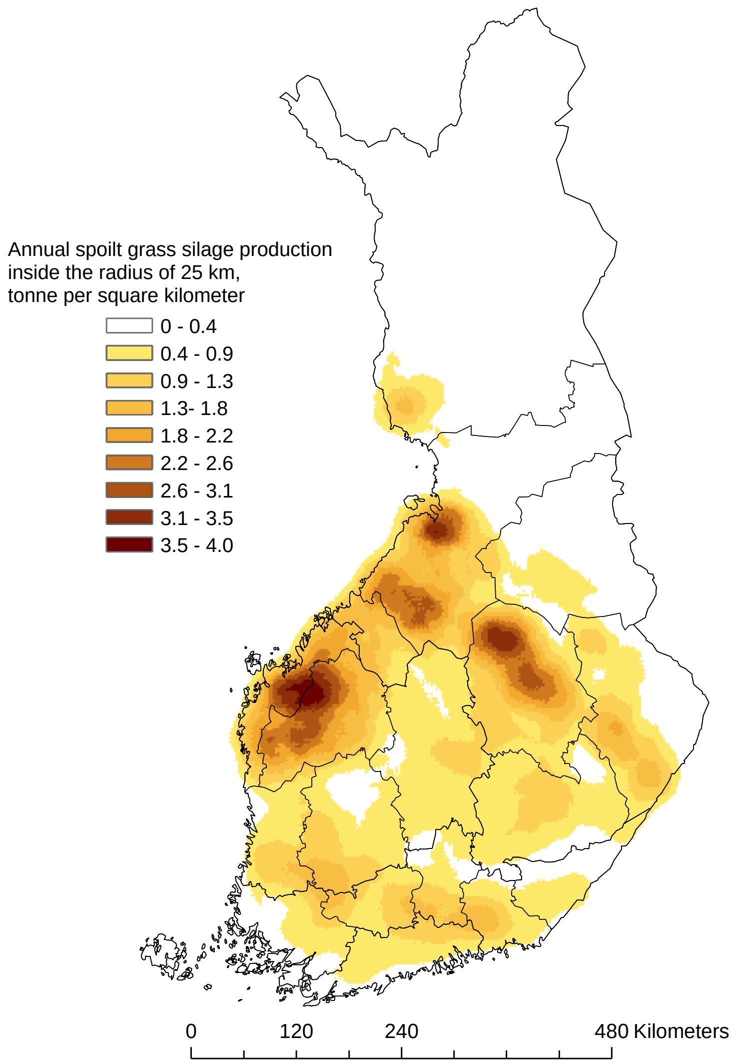

Figure 3. Spoilt grass silage production in terms of fresh mass units was estimated according to data from Ministry of Agriculture and Forestry.

4. Household biowaste

Distribution of household biowaste was modeled according to socio economic data [12] and estimated production rates (Figure4). Biowaste potential would be 151.8 kg/inh if all biodegradable waste could be collected and assuming that biowaste production is 30 % of total municipal solid waste (MSW) production of 506 kg/inh as it was in 2012 [13]. Total biowaste potential would be 270 kt DM/year when Finnish population is 5.3 Million and DM is 33 % of FM [14]. Still, only part of this is separately collected. For example, in North Savo province in 31 kg of biowaste per inhabitant was separately collected [15]. Thus, it is assumed that in Finland 30 kg of biowaste per inhabitant is separately collected. It would result annual yield of 52 kt DM/year. Because, huge part of total generated biowaste is mixed with MSW it would enter into waste incineration plants if alternative solution for waste management is not found. Total waste incineration capacity after 2016 is 1 355 kt of MSW per year [16] (Figure 5).

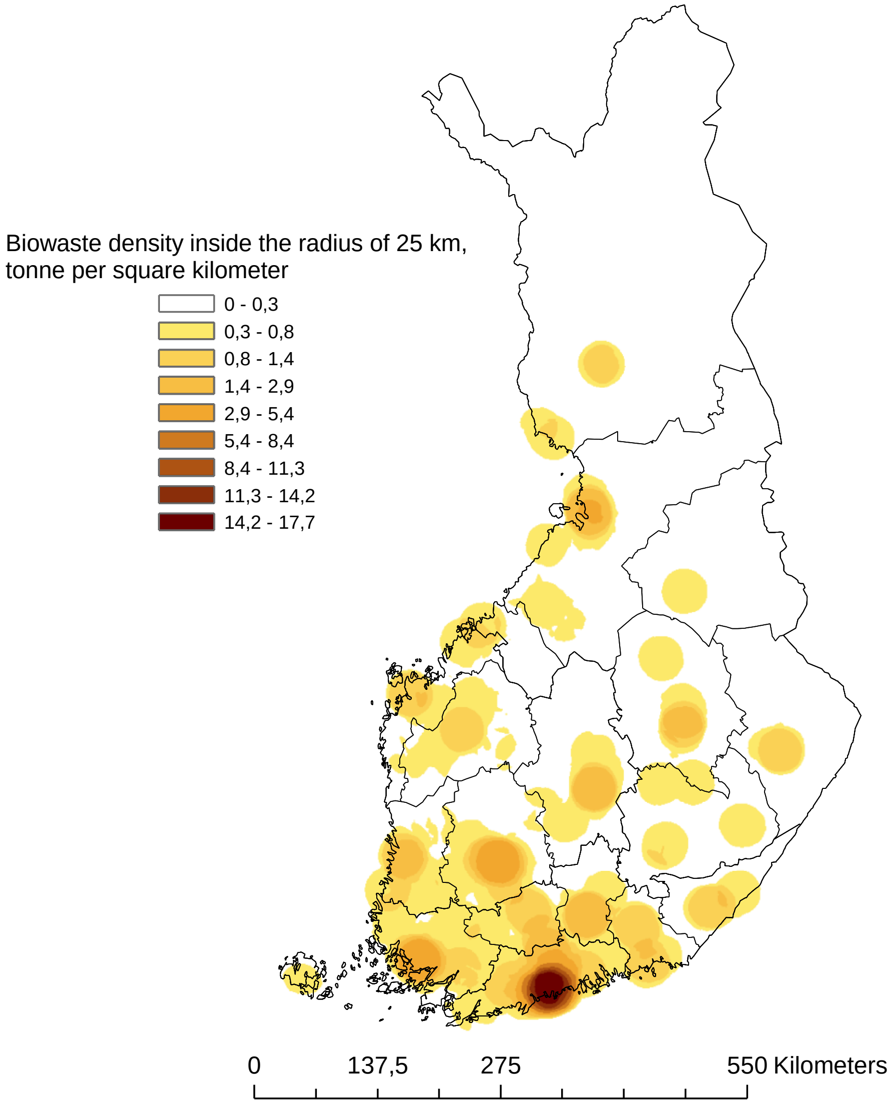

Figure4. Household biowaste distribution in terms of fresh mass units was calculated from grid data base.

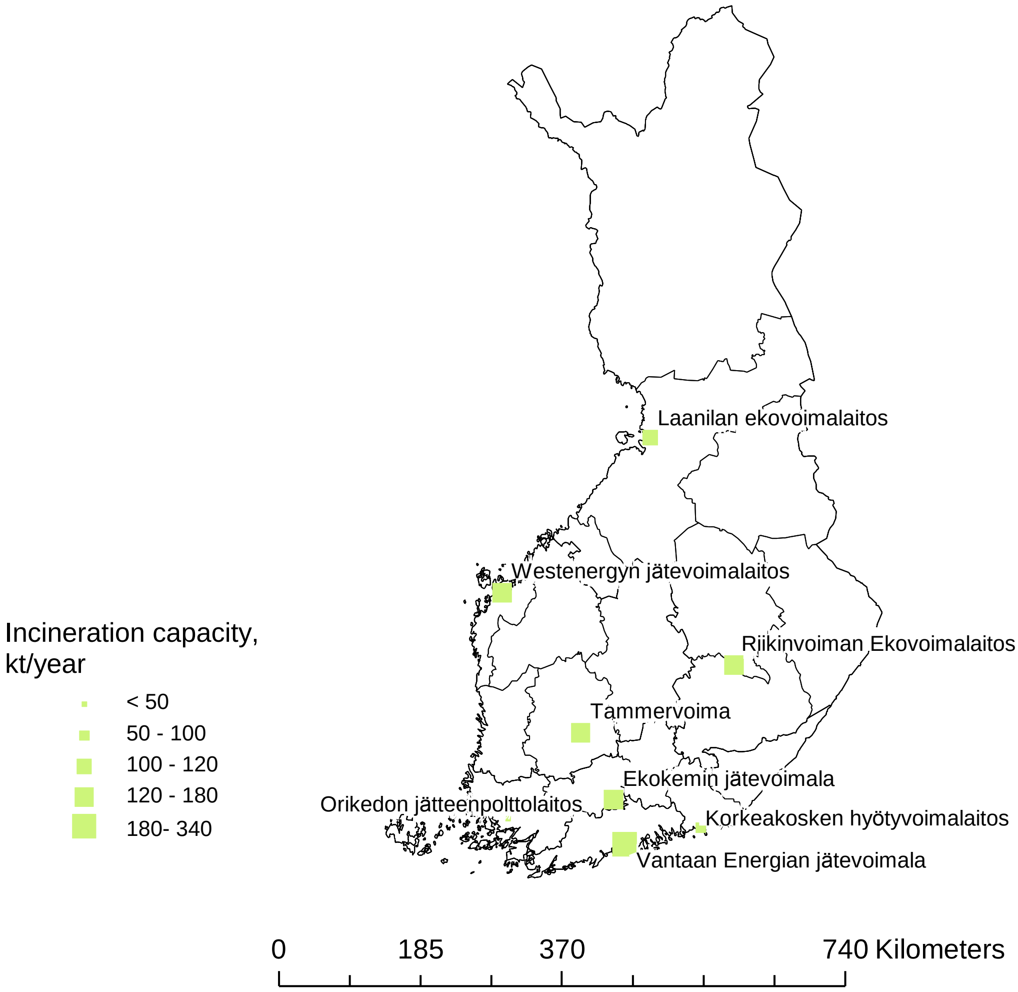

Figure 5. Waste incineration plants in operation after 2016[16].

5. Biofuel production in sustainability point of view

Biological production of fuels and chemicals can help to achieve required GHG emission targets. Renewable energy directive (RED) (2009/28/EC) gives rules how to calculate GHG emissions for biofuel production and how GHG reductions are calculated from fossil fuel and biofuel productions. GHG reductions increases if it can be shown that by replacing fossil fuels, chemicals or current practices with biofuel production it is possible to emit less GHG emissions. For example, fossil fuel reference has GHG emissions of 302 kg CO_2 equivalent per MWh of the fuel (Table 2). If biofuel could be produced with lower GHG emissions per MWh it would cause GHG reductions. After first of January in 2018 biofuel production systems should have GHG reductions more than 60 % compared to this fossil fuel reference value. Table 2 shows that especially Butanediol is one of the most potentials biofuels to be replaced and to achieve GHG reductions targets.

Table 2. GHG reductions from bio chemicals according to (2009/28/EC) directive and Gabi life cycle inventory data base [17].

Biofuel or chemical	kg CO_2 eqv./(kg fuel)	kg CO_2 eqv/MWh
Ethanol	2,24	301
Propanol	1,71	194
2.3 butanediol	5,07	716
Hydrogen	3,19	96
Acetone	1,59	212
Acetic acid	1,16	320
Fossil fuel reference (2009/28/EC)	3,60	302

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