PÖYRY

POTENTIAL FOR BIOENERGY IN THE NORDICS

Nordic Energy Research

Final Report

31st January 2019

COVER LETTER

In 2016 Nordic Energy Research (NER) published a study of the current energy landscape in the Nordic region, examining how the Nordic countries could meet their climate and energy targets in the most cost-effective manner. The study, “Nordic Energy Technology Perspectives 2016”, concluded that in order to achieve a Nordic “carbon neutral scenario” by 2050, the use of biomass as fuel would need to increase by about 50% in the intervening years, both in stationary plants and in transport.

In light of this finding NER has commissioned Pöyry Management Consulting Oy to examine the potential biomass resources in the Nordics, namely forest, agro and waste biomass. By interviewing experts in the fields of fields of forestry, agriculture and waste, this report – titled “Potential for bioenergy in the Nordics” – takes stock of the theoretical biomass potential in the Nordic region. It provides a straight-forward, but detailed breakdown of the current and future theoretical biomass resources in each Nordic country.

In addition to examining the potential of biomass energy sources in the Nordics, this report also points out possible obstacles to mobilising biomass as energy, and knowledge gaps that need to be filled. The hope is that this report will provide a knowledge basis for policy decisions on biomass in the Nordic countries, as well as a basis for further research.

Hans Jørgen Koch

CEO, Nordic Energy Research

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EXECUTIVE SUMMARY

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According to Nordic Energy Technology Perspectives 2016, a strong growth of biomass use (~50 per cent up to 2050) is needed in the Nordics to attain the "Carbon Neutral Scenario". Biomass use has to increase both in stationary plants (heat and power plants, industry) and in transportation. Nordic Energy Research appointed Pöyry in spring 2018 to collect information on the Nordic biomass potentials, mobilisation obstacles and related knowledge gaps. The *purpose* of the work was to create a basis for policy recommendations to the Nordic Governments to promote mobilisation of bioenergy to meet the growing use of bioenergy by 2050. For that purpose, the *objective* of the work is to present estimates of the size of the bioenergy resources available on the Nordic countries and to identify major obstacles for a significantly increased supply of bioenergy until 2050. The geographical *scope* of the assignment covers Norway, Sweden, Denmark, Finland and Iceland. The biomass assortments in focus are forest, agro and waste.

Pöyry collected information regarding the potential bioenergy resources available in the Nordic countries by interviewing two to three experts per country in the fields of forestry, agriculture and waste. The information includes estimates of current and future theoretical biomass potential, issues restricting the mobilisation of supply potential, and knowledge gaps regarding the biomass potential and mobilisation. In addition, a Nordic seminar was held in November 2018 in Vantaa, Finland to further discuss the findings with the Nordic experts, and to gather solutions to the main identified Nordic level biomass mobilisation obstacles and knowledge gaps. Based on the biomass potential data gathering, Pöyry concludes that the estimates on biomass potentials were in some cases restricted by timeframe, definition of the potential and in some cases no data on potential was available for certain biomass types (please see Annex 1).

Based on the interviews and the analysis, forest biomass accounts for 70%, agro biomass 20% and waste biomass 10% of the current Nordic theoretical biomass supply potential. Of the current potential Sweden accounts for 43% and Finland for 36%, explained especially by large forest biomass potential. Norway accounts for 12% and Denmark for 9%. Iceland with small population and very limited forest and agricultural sector accounts for less than 1% of the total Nordic potential. The total supply potential is increasing, but demand (Nordic Energy Technology Perspectives 2016, Scenario 2DS) even more implying tightening supply-demand balance and a need for better biomass mobilisation.

EXECUTIVE SUMMARY – FOREST BIOMASS

The theoretical potential for forest biomass is expected to increase in the Nordics. This mostly in Sweden and Finland where the potential is already notably higher than in other Nordic countries – Sweden represents 47% and Finland 39% of the total current forest biomass potential in the Nordics. This is due to substantial harvesting levels and a chemical pulp industry producing black liquor. Norway´s share of the total potential is some 11%. Denmark and Iceland have only very small forest resources and no chemical pulp industry, and together account for 3% of the total potential. Of the total Nordic forest biomass potential forest chips account for 35%. Not all the potential is utilized as especially the mobilisation of harvesting residues and stumps has been somewhat challenging. Due to the large Nordic chemical pulp industry, black liquor represents 35% of total potential. It is fully utilized already and mainly for energy. Solid industry by-products account for 30% of the total Nordic forest biomass potential, and are mostly fully utilized either for energy or material.

Forest and soil protection need, economic obstacles, terrain restrictions, quality problems, forest owners´ lack of harvest willingness and public opinion were seen to hinder the mobilisation of forest biomass in the Nordics according to the country specific interviews. When it comes to the knowledge gaps, more basic knowledge is needed in less forest industry intensive countries whereas in forest industry intensive countries the supply chain efficiency and technology could be further developed.

Based on the workshop, at the Nordic level one of the largest mobilisation obstacles is increasing transport distances due to competition for biomass, which leads to higher biomass costs. The main solutions for the obstacle could be building better roads, creating better online data for road conditions (seasonality changes), optimising the transport system through digitalization and increasing the transport loads. Increasing cost of harvesting due to difficult terrain, fragmented ownership of forest areas, climate change impacts etc. was also seen as a major Nordic biomass mobilisation obstacle. The main solutions for mitigating harvesting cost increase were to improve the collaboration between small forest owners through digitalisation, having more educated forest owners, as well as development of more adapted harvesters and digitalization to better optimize to different harvesting conditions. Conflict between production and other values (such as biodiversity) was seen as a major knowledge gap in the workshop. This could be solved by researching optimised strategies and spreading knowledge to the public. The other main Nordic level knowledge gap is how climate change will affect the harvesting and transport, which could be solved by creating modelling scenarios.

EXECUTIVE SUMMARY – AGRO BIOMASS

Current and future theoretical potential for agro biomass is highest in Sweden and Denmark, Sweden accounting for 31% and Denmark for 29% of the total current Nordic potential. Finland accounts for 24%, Norway 16% and Iceland only 1% of the total agro biomass potential. In the future the agro biomass potential is expected to increase in Finland and Denmark whereas the potential is expected to stay the same in Norway and Iceland but decline somewhat is Sweden due to straw & husk potential decreasing. Of the current theoretical potential straw & husk accounts for 49%, manure for 35%, energy crops 10% and grasses for the remaining 6%. Agricultural biomass is at present mainly utilized only in Denmark whereas in the other Nordic countries the potential is quite significantly underutilized.

According to the country level interviews and analysis especially the economical and regulatory obstacles as well as missing synergy hinder the agro biomass mobilisation. There is lack of knowledge regarding what kind of biomass should be cultivated to reach high yields and serve different end uses. More knowledge on the technology options in the entire supply chain would also be needed.

Based on the workshop, straw is an abundant resource, but the utilisation rate is low (except in Denmark) due to the low price. This could be solved by creating demand for straw e.g. by producing biochar out of straw, using of straw for higher value products, biofuel and/or biogas, and combusting of straw and capturing the resulting CO_2. Energy crops could contribute significantly to biomass potential in the Nordics, but the largest mobilisation obstacles are limitations set by the EU regulation. This could be solved by adding environmental and climate benefits into the EU Common Agricultural policy (CAP) and start calling “energy crops” rather e.g. “biomass crops”. The Nordic level knowledge gap is how to internalise environmental effects of agriculture in the economy. This could be solved, for example, by including agriculture in the CO_2 –quota system and including the environmental effects to the EU Common Agricultural Policy. The Nordic experts also wanted to better understand how to best utilize biomass to balance the whole renewable energy system. Better understanding could be gained through a Nordic project that includes agronomists, energy technologists and energy system modellers. If biomass was used to serve a bigger energy system balancing purpose this could also increase public acceptance of bioenergy and bring energy security benefits.

EXECUTIVE SUMMARY – WASTE BIOMASS

Current and future theoretical potential for waste biomass is highest in Sweden and Finland, Sweden accounting for 38% and Finland for 27% of the total current Nordic potential. Denmark accounts for 19%, Norway 14% and Iceland only 2% of the total current waste biomass potential. Future development of the potential is stable to growing due to population and economy growth. There is, however, policy pressure to reduce and separate biowaste in most of the Nordic countries due to the EU policy pressure. Around 30% of the total Nordic waste biomass potential consists of the bio fraction of municipal solid waste (MSW). Most of this is already incinerated as mixed waste for energy. Only in Iceland landfill ban for organic waste has not yet been implemented, and incineration is not common. Some 28% of the waste biomass potential consists of post consumer paper waste. This is, however, already almost fully utilized as raw material for recycled paper products. Some 26% of the waste biomass potential originates from the post consumer wood waste. The Nordic collection rates for waste wood differ, and the waste wood that is collected is currently mainly used for energy. Some 8% of the total waste biomass potential is waste water sludge. Generally waste water is treated in the Nordics but the sludge utilization depends on a country. In Iceland a large portion of waste water is still untreated. Together 8% of the waste biomass potential consists of other waste streams (slaughter and fishery waste, and used cooking oils and fats). These streams are quite well collected but novel utilization is still missing.

According to the country level interviews and analysis utilization rate of mixed MSW for energy is already high but separation of bio-fraction could be increased. Lacking regulation for waste water sludge use also hinders mobilisation. In Finland and Iceland bio-MSW and waste water sludge utilization could still be increased if better knowledge and data would exist. In Norway fishery waste could be better utilized with more knowledge. In Sweden the bio-MSW sorting and feedstock optimization still need attention and more knowledge.

The largest Nordic level mobilisation obstacle is how different sectors, such as waste, agro, energy etc. could collaborate better. The solution to this would be for example a large Nordic level project to understand the markets and possible products where these resources could be used. Generally more systems thinking and synergy finding could be used to improve the collaboration between the sectors. The reputation of waste sector could also be improved by calling it for example the “resource sector”. Based on the workshop, the largest Nordic level knowledge gap is the source separation of biomass. It could be improved through legislation (EU Circular Economy Package), source separation incentives, credible systems and educating people to enhance source separation.

BACKGROUND & METHOD

PROJECT BACKGROUND & OBJECTIVE

- **Background and objective**
  - According to Nordic Energy Technology Perspectives 2016, a strong growth of biomass use (~50 per cent up to 2050) is needed in the Nordics to attain the “Carbon Neutral Scenario”.
  - Biomass use has to increase both in stationary plants (heat and power plants, industry) and in transportation.
  - Nordic Energy Research appointed Pöyry in spring 2018 to facilitate a process for collecting information on the Nordic biomass potentials, and related mobilisation obstacles and knowledge gaps.
  - This report combines the key findings from both the country level and Nordic analysis carried out during the process. The findings can be a basis for policy recommendations to the Nordic Governments to promote mobilisation of bioenergy to meet the growing use of bioenergy by 2050.

METHOD

Information presented in this report is mainly based on external expert interviews and publicly available reports.

Country level analysis

- Estimates of current and future (2050 if available) theoretical biomass potentials, issues restricting the biomass mobilisation, and related knowledge gaps were gathered by interviewing 2-3 Nordic experts per country in the fields of forestry, agriculture and waste.
- Publicly available reports were utilized to complement the analysis.
- In some cases where data on biomass potentials was missing Pöyry made own estimates.

Nordic level analysis

- Key findings from the country level analysis were presented in the Nordic seminar in November 2018.
- During the seminar the main Nordic level biomass mobilisation obstacles and knowledge gaps were gathered and solutions to these drafted involving expert participants from all the Nordic countries.

Combined report

- This report combines the key findings from both the country level and Nordic analysis.
- The findings can be a basis for policy recommendations to the Nordic Governments to promote mobilisation of bioenergy to meet the growing use of bioenergy by 2050.

BIOMASS ASSORTMENTS - DEFINITIONS

The work covers forest, agricultural and waste biomass assortments for which the theoretical potentials were collected from interviews, public available reports and in some cases based on Pöyry analysis.

Forest

Black liquor

Chips
Bark
Sawdust
— Solid industry by-products

Harvesting residues
Stumps
Small diameter wood
— Forest chips

Agro

Energy crops

Straw & husk

Grasses

Manure

Waste

MSW, bio fraction

Waste water sludge

Post consumer wood

Post consumer paper waste

Used cooking oils & fats

Slaughtering waste
Fishery waste
— Fishery & Slaughter Waste

Theoretical potential (*overall maximum amount of biomass which can be considered theoretically available for bioenergy production within fundamental bio- physical limits*) in each Nordic country at present and in the future for the years available.

BIOMASS USE - DEFINITIONS

Biomass assortments analysed can be used for biofuels or biogas production or combusted direct to electricity and heat. Some assortments can be used for materials.

Forest

Agro

Waste

Biofuels production

Biogas production

Combustion to energy

Direct combustion to electricity and/or heat

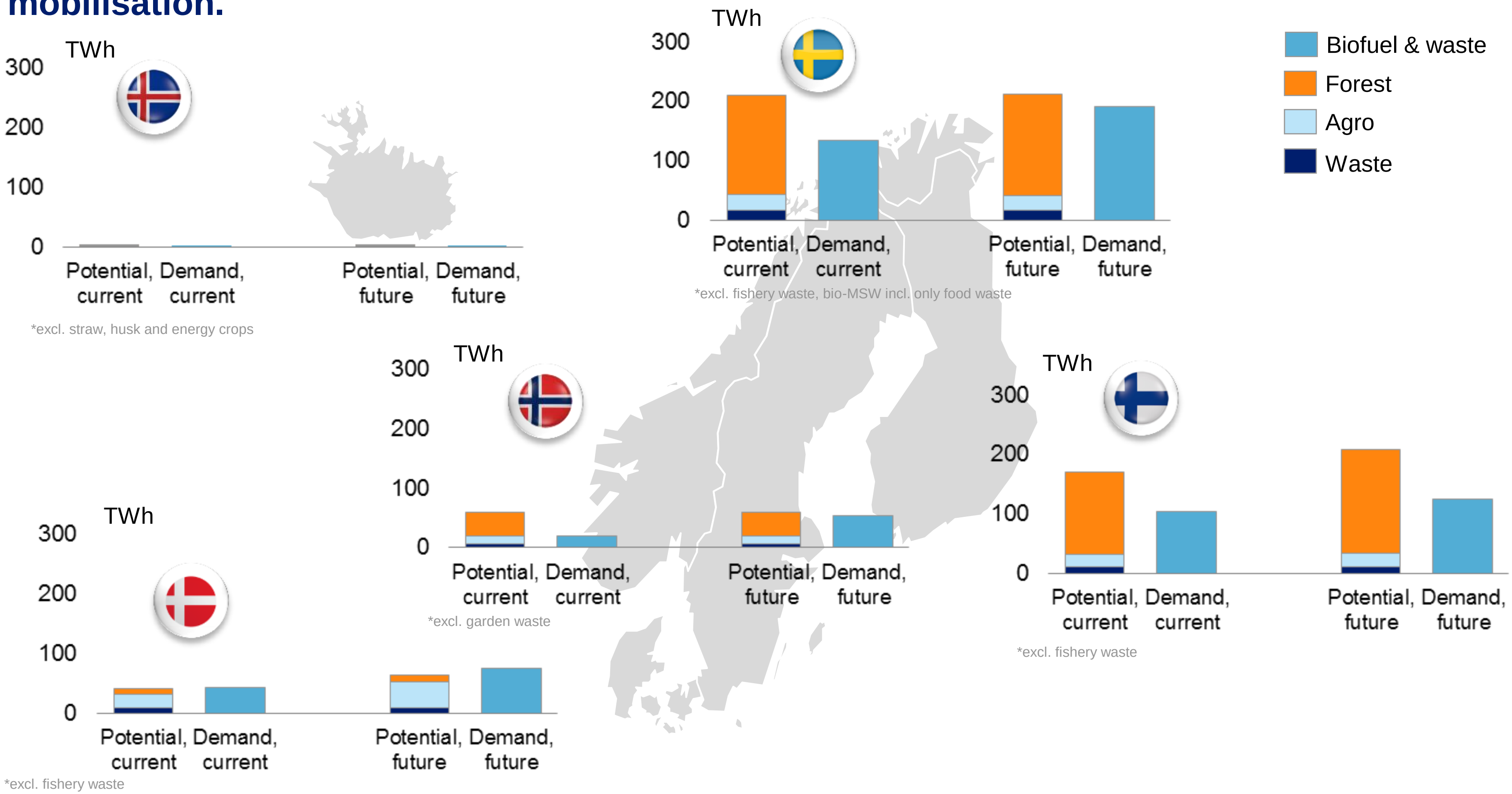
Material use*

**especially forest industry chips and post-consumer paper waste*

KEY FINDINGS OF THE NORDIC LEVEL ANALYSIS

THEORETICAL BIOMASS SUPPLY POTENTIAL VS DEMAND

Based on the data collected, forest biomass accounts for 70%, agro biomass 20% and waste biomass 10% of the Nordic theoretical biomass potential. Potential is increasing, but demand even more implying tightening supply-demand balance & need for better mobilisation.



Source: Biomass potentials: Please see Annex 1. Demand: Nordic Energy Technology Perspectives 2016 (NETP 2016), Scenario 2DS, years 2013 and 2050

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NORDIC LEVEL BIOMASS MOBILISATION OBSTACLES AND KNOWLEDGE GAPS

Based on the Nordic expert workshop the following most relevant mobilisation obstacles and knowledge gaps for different biomass categories were identified at the Nordic level.

	Mobilisation obstacles	Knowledge gaps
Forest	**Competition for biomass increases transport distances leading to higher biomass costs.**	**Conflict between production and other values (e.g. forest biodiversity protection).**
	Increasing cost of harvesting due to e.g. difficult terrain, small areas (e.g. due to ownership structure), climate change etc.	**How climate change will affect harvesting and transport?**
Agro	**Energy crops (grass, short rotation crops) could contribute significantly but is limited by EU regulation.**	**How can we internalize environmental effects (soil carbon, nutrient losses, GHG etc.) in the economy?**
	Straw is an abundant resource but use rate is generally low (except high in Denmark) due to low price.	**How can we best utilize biomass to balance the whole renewable energy system (wind, solar etc.)?**
Waste	**Source separation of biomass could be improved.**	**How to collaborate across sectors (waste, agro, fisheries, energy etc.)?**

Suggested solutions to these mobilisation obstacles and knowledge gaps are listed on pages 17 – 19
The full workshop material can be found in Annex 2

Source: Nordic workshop, see Annex 2

Forest biomass

Mobilisation Obstacles & Solutions

Competition for biomass increases transport distances leading to higher biomass costs.

√ Better roads

√ Better online data on road conditions (due to seasonality some roads may be unavailable and there should be more data on that)

√ Digitalisation – optimizing the transport system (road, rail, waterway)

√ Higher transport loads (bigger vehicles so that one time transport loads were bigger) and better compacted loads

Increasing cost of harvesting due to e.g. difficult terrain, small areas (e.g. due to ownership structure), climate change etc.

√ Collaboration between small forest owners (digitalisation)

√ More adapted harvesters and digitalization to optimize to the conditions

√ More educated forest owners

Knowledge Gaps & Solutions

Conflict between production and other values (e.g. forest biodiversity protection).

√ Research for optimized strategies (combined production and protection can be done), and spread knowledge to the public to allow more knowledgeable decisions

How climate change will affect harvesting and transport?

√ Modelling scenarios

Source: Nordic workshop, see Annex 2

Agricultural biomass

Mobilisation Obstacles & Solutions

Energy crops (grass, short rotation crops) could contribute significantly but is limited by EU regulation.

√ Environmental and climate benefits into the EU Common Agricultural Policy (CAP) and calling ”energy crops” rather e.g. ”biomass crops”

Straw is an abundant resource but use rate is generally low (except high in Denmark) due to low price.

√ Potentially making biochar

√ Use straw for higher value products and biofuel

√ Use straw for biogas

√ Combustion and capture CO_2

Knowledge Gaps & Solutions

How can we internalize environmental effects (soil carbon, nutrient losses, GHG etc.) in the economy?

√ Include agriculture in the CO_2 -quota system

√ Include environmental effects in the EU Common Agricultural Policy (CAP)

How can we best utilize biomass to balance the whole renewable energy system (wind, solar etc.)?

√ A Nordic project including agronomists, energy technologists and energy system modellers

√ Would increase public acceptance of bioenergy

√ Energy security benefits

Source: Nordic workshop, see Annex 2

Waste biomass

Mobilisation Obstacles & Solutions

How to collaborate across sectors (waste, agro, fisheries, energy etc.)?

- √ Systems thinking
- √ Finding synergies
- √ Big Nordic project understanding markets and possible products→ Where to use the resources
- √ Improve reputation of waste sector, call it ”resource sector”

Knowledge Gaps & Solutions

Source separation of biomass could be improved.

- √ Legislation (EU Circular Economy Package is coming)
- √ Source separation incentives (e.g. waste fee lower if you separate)
- √ Credible systems (people separate only if they know that the separated biomass is utilized effectively)
- √ Education/information for people to enhance source separation

Source: Nordic workshop, see Annex 2

KEY FINDINGS OF THE COUNTRY LEVEL ANALYSIS

METHOD – COUNTRY ANALYSIS

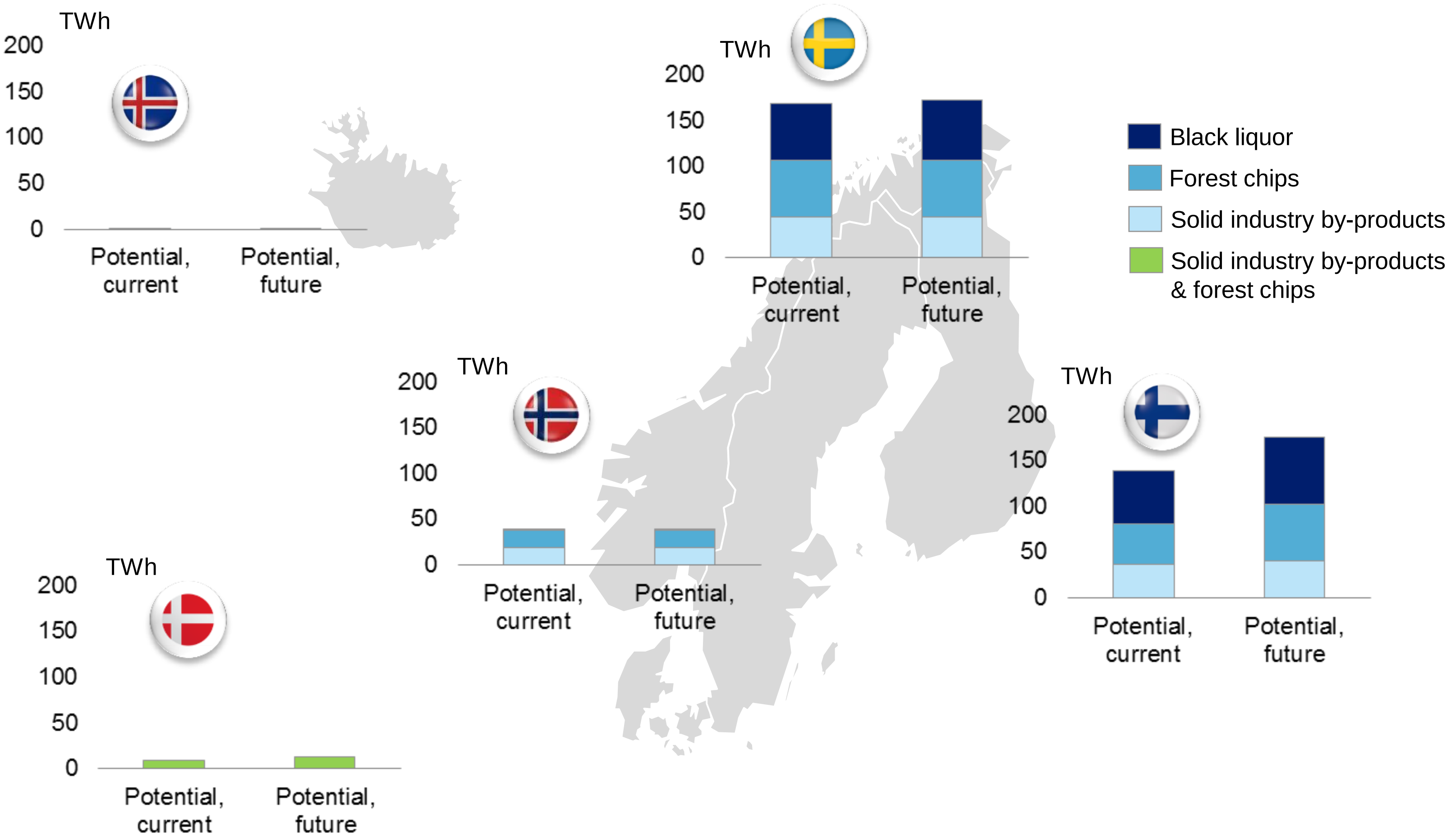
Theoretical biomass potentials, mobilisation obstacles and knowledge gaps were collected by interviewing 2-3 experts per country including forest, agriculture and waste experts.

List of experts interviewed:

Country	Organisation	Biomass
	LUKE	Forest
	Environmental Ministry	Waste
	LUKE	Agro
	Icelandic Forest Service	Forest
	Environment Agency of Iceland	Agro/Waste
	Vistorka	Agro/Waste
	Lunds Universitet	Forest/Agro
	Jordbruksverket	Agro
	Norwegian University of Life Science	Forest
	Sintef	Marine
	Østfoldforskning	Agro/Waste
	Aarhus University	Agro
	Syddansk Universitet	Agro
	University of Copenhagen	Agro/Forest

FOREST BIOMASS – POTENTIALS

Theoretical potential is expected to increase in the Nordics - most in Sweden and Finland where the potential is notably higher than in other Nordic countries.



Source: Please see Annex 1

FOREST BIOMASS – MOBILISATION OBSTACLE SUMMARY

Based on the interviews forest and soil protection need, economic obstacles, terrain restrictions, quality problems, forest owners´ lack of harvest willingness and public opinion hinder mobilisation.

	Economic	Geographic	Ecological	Quality at end use	Forest owners	Public opinion
	✓		✓			✓
	✓	✓	✓			
			✓			
			✓			
	✓			✓	✓	

Source: Interviews with Nordic biomass experts

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FOREST BIOMASS – MOBILISATION OBSTACLES

Based on the interviews increasing forest and soil protection need, economic obstacles, terrain restrictions, quality problems and forest owners´ lack of harvest willingness restrict mobilisation.

- Currently cheaper to import chips than buy domestic.
- Biomass potential could increase with plantations but this could increase fire, insect and pathogen risk. Public opinion could also be negative, and farmers would plant forest only if supported by government.
- Land is expensive for new plantations, and tree nursery potential is lacking.
- Most have access to geothermal. Wood biomass demand only to replace fossil fuels but this only in small scale.

- Biomass can mostly be mobilised if forest owners/resource owners are paid for properly
- Impurities in stumps have somewhat restricted use, and stump-harvesting has decreased.
- Forest owners willingness to carry out operations timely.

- Terrain restrictions.
- Increasing level of forest conservation.
- Economic competitiveness against other energy sources.

- Increasing amount of protected forests will limit the use of potential forest biomass for energy.

- Increasing amount of areas to protect biodiversity.
- Acidification might create restrictions regarding the use of harvesting residues.

Source: Interviews with Nordic biomass experts

FOREST BIOMASS – KNOWLEDGE GAPS

Based on the interviews more basic knowledge needed in less forest industry intensive countries whereas in forest industry intensive countries the supply chain efficiency and technology could be further developed.

- Optimal forest management in monoculture plantations?
- Risk management knowledge, e.g. on fire and disease risk.

- How to utilize industry by-products more efficiently?

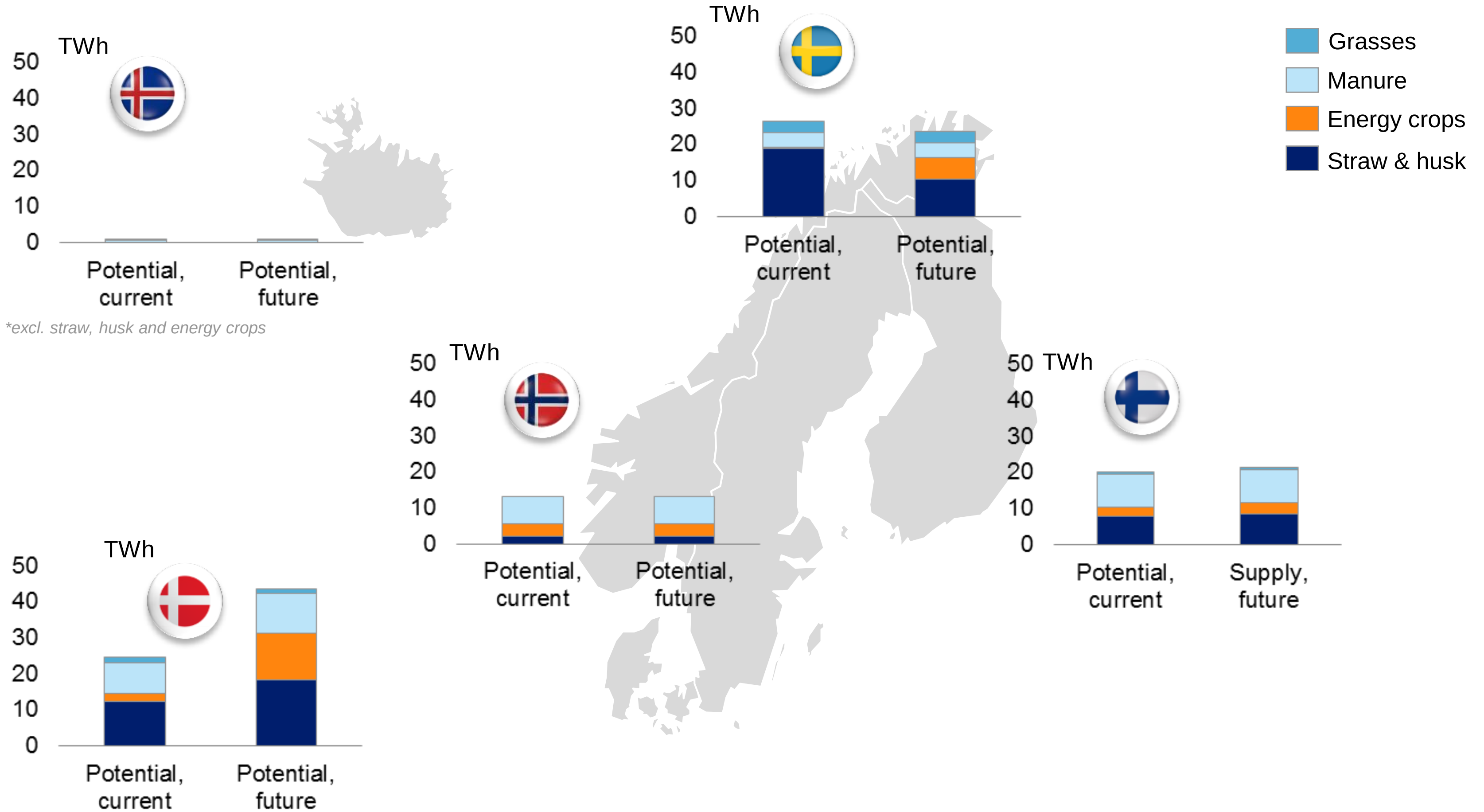
- Biomass growth levels in forests?
- Competition between energy sources?
- Behaviour of forest owners regarding harvesting?

- Potential of multifunctional forest machines to reduce negative seasonality impacts on harvesting entrepreneurs?
- Potential to increase return transportation of biomass?
- Potential to integrate biomass value chains with other value chains?
- How to reduce dry matter loss in supply chain?
- Technology and machinery for efficient and sustainable procurement of biomass in peatland forests?
- Digitalisation, big data and sensor technology to decrease procurement costs & better optimize procurement spatially and seasonally?

Source: Interviews with Nordic biomass experts

AGRO BIOMASS – POTENTIALS

Current and future theoretical potential is highest in Sweden and Denmark. Increase in the potential is expected especially in Denmark whereas the potential is expected to decrease or stay the same in the other Nordic countries.



Source: Please see Annex 1

AGRO BIOMASS – MOBILISATION OBSTACLE SUMMARY

Based on the interviews especially economical, regulatory obstacles and missing synergy hinder the mobilisation.

	Economic	Geographic	Ecological	Regulatory	Missing synergy	Public opinion
				✓	✓	
	✓	✓		✓		
			✓	✓		✓
	✓			✓		
	✓			✓	✓	

Source: Interviews with Nordic biomass experts

AGRO BIOMASS – MOBILISATION OBSTACLES

Based on the interviews lack of demand, subsidies and communication as well as ecological barriers and scattered supply sources hinder mobilisation.

- Communication between resource owner and end user lacking.
- Regulation is not consistent and does not have long term perspective, which hinders use of biomass.

- National biogas strategy has enhanced biogas production and use. Support in place e.g. for farmers that supply manure for biogas plants and for biogas production.
- Demand is lacking for both the domestic biomass in transport (as imported, “not always sustainable” liquid biofuels dominate the market) and heat & electricity (as energy is already cheap and hydro power based).
- Hard to collect large enough amounts of manure from single farms to profitably produce biogas as farms are generally small, transport distances long and geographic barriers exist.
- Small scale is similarly a problem for other biomass assortments and their economic mobilisation.
- Farms typically own forest and use fuelwood – making investments to biogas production has not been seen reasonable economically.

- Level of carbon has decreased too low in some agricultural land, which is why biomass collection is prohibited on this land for next 10-20 years, also farmers are able to reduce climate impact by putting straw into soil to increase soil carbon levels.
- There has been discussion about adding a tax for some biomass resources that are used for energy. This would lead to lower utilization of the biomass potential as other sustainable energy sources would be favoured.
- Subsidies are needed to mobilise biomass, e.g. to mobilise manure a government subsidy is needed and collection should be localized.
- Location of biogas plants, “not in my backyard”.
- Organic farming is increasing, which would reduce biomass potential for energy, as organic farming is less intensive and has lower yields than regular farming.
- Although straw is already used for energy, a lot of straw is still unutilized as the prices are too low and there is no market for the excess straw.

- Government subsidies would be needed to mobilise biomass as fossil fuel prices are low.
- Biorefineries need to be developed to utilize current and future by-product streams efficiently.
- More synergies between biorefineries and farmers would create a win-win situation, i.e. biomass from farmers to biorefineries and heat & electricity from biorefineries to farmers with better price.

- LULUCF policy could prevent using food-based biomass for energy.
- Cost competitiveness (price of oil, diesel and electricity is very low).

Source: Interviews with Nordic biomass experts

AGRO BIOMASS – KNOWLEDGE GAPS

Based on the interviews there is lack of knowledge regarding what kind of biomass should be cultivated to reach high yields and serve different end uses. More knowledge on the technology options in the entire supply chain would also be needed.

- How could co-operation within the agricultural sector and also with the forestry sector work more efficiently?
- Pre-treatment options of straw for biogas.
- How can organic farming be intensified in order to increase biomass yields (i.e. straw)?
- What kind of biomass should be cultivated to reach higher yields?
- What biomass should be cultivated for biorefineries and how?
- Could robots be used in harvesting?

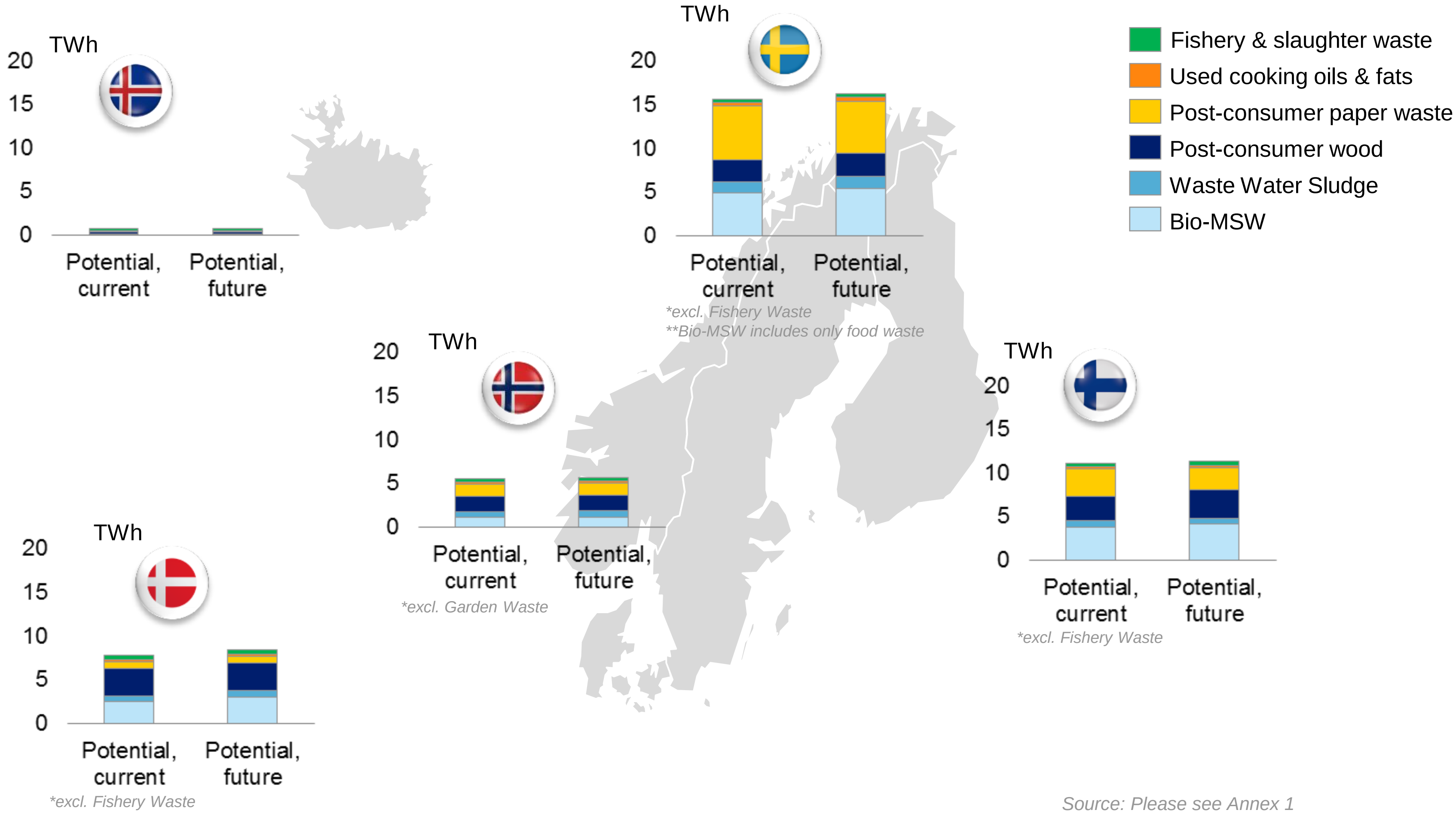
- Knowledge on technology of biorefineries to create efficient utilization of by-product streams.
- What kind of biomass should be cultivated in agricultural land to best serve the biorefineries?
- Could nitrogen capturing plants be more utilized so that the biomass potential and soil conditions could increase?
- There are no proper statistics on manure amounts.

- Some biomass fractions should not be used for energy as it would decrease food production, but this needs more research.
- More practical (not theoretical) research needed regarding agro feedstock use for biofuels.
- How to make agro-based bioenergy production more efficient technically?
- Knowledge on use of energy crops from commercial point of view, i.e. efficient harvesting, most suitable feedstock, logistics, storing.

Source: Interviews with Nordic biomass experts

WASTE BIOMASS – POTENTIALS

Development of potential is stable to growing due to population and economy growth. There is, however, policy pressure to reduce and separate biowaste in most of the countries.



Source: Please see Annex 1

WASTE BIOMASS – MOBILISATION OBSTACLE SUMMARY

Based on the interviews utilization rate of mixed MSW for energy is already high but separation of bio-fraction could be increased. Lacking regulation for WWS use hinders mobilisation.

	Lacking regulation for WWS utilization	Most MSW incinerated without separation
	✓	
	✓	✓
		✓
		✓
	✓	✓

Source: Interviews with Nordic biomass experts

WASTE BIOMASS – MOBILISATION OBSTACLES

Based on the interviews there is existing policy pressure to reduce and better utilize biowaste in most of the countries.

- Waste water untreated and nearly no sludge mobilised. Treatment likely to begin in future, with sludge for biogas (and fertilizer) use. Regulation recently changed allowing sludge fertilizer use.
- No landfill ban on bio-MSW implemented yet. Without a ban, there should be a fee set for landfilling to incentivize collection.

- Lack of certificate system for use of waste water sludge as fertilizer hinders biogas production.
- Most of MSW biogenic fraction is already used for direct combustion.
- EU trends specified separately below.

- High collection rate of paper waste and not much room to enhance it.
- Food waste from households & industries: large potential, but sorting rate is low especially in households & in small and medium sized companies.
- In larger cities waste water sludge is treated and used for biogas production for transport sector. However, biogas has lost incentive position for liquid biofuels.
- In smaller cities and remote areas waste water is treated but waste water sludge is generally not used for biogas. There is an on-going discussion if use of waste water sludge for biogas production would be made obligatory in these areas.

- All waste that can´t be recycled is already incinerated for energy.
- EU trends specified separately on the right.

- All waste is already collected and used.
- EU trends specified separately on the right.

- EU policy pressure to reduce amount of MSW biogenic fraction could lead to reduced availability for energy in longer term.
- EU policy pressure to better collect/separate (MSW) biogenic fractions is likely to increase supply of separated material to some extent, but emphasis should be given to material use instead of energy, if possible. After being used as material, the waste will eventually end up for energy use.

Source: Interviews with Nordic biomass experts

WASTE BIOMASS – KNOWLEDGE GAPS

Based on the interviews the knowledge gaps regarding waste biomass vary between countries.

- Waste water treatment, biogas production and sludge utilization as fertilizer should be developed.
- How to reduce landfilled MSW amounts – a ban or fee on waste landfilling?

- How to utilize different feedstocks most efficiently from climate perspective?

- Statistics on MSW amounts should be renewed to have knowledge on exact waste potentials.
- How to best enhance waste water sludge biogas use (certification system for the sludge fertilizer use)?

- How to make the best use of large potential of fishery waste?
- Should the free dumping of fishery sewage be banned as has been done for human sewage?

- How to better optimize MSW sorting and collection for material and energy use?

Source: Interviews with Nordic biomass experts

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Pöyry Management Consulting

ANNEX 1 – BIOMASS POTENTIALS

BIOMASS POTENTIALS – DATA GAPS

Estimates on biomass potentials were in some cases restricted by timeframe, definition on potential and in some cases no data was available for certain biomass types.

Current and future (2050 if available) theoretical biomass potentials were gathered by interviewing 2-3 Nordic experts per country in the fields of forestry, agriculture and waste. Publicly available reports and in some cases Pöyry analysis were utilized to complement the analysis.

Obstacle	Description and solution
Time frame	• In many publicly available studies the potentials were only estimated until 2020 or 2030 (some cases only current potentials were estimated). Also, the current potentials were sometimes not available at all or they were referring to rather old historical data. • To overcome the obstacle, Pöyry used the best available data years when reporting. The reference years are presented in the following pages for the data transparency. In some cases Pöyry made own projections.
Definition of potential	• Different studies sometimes define the biomass potentials in different manner (theoretical, technical, techno-ecological, economical). To find data that would be showing theoretical potential (or close equivalent) was not simple and in some cases not available. • To overcome the obstacle, Pöyry focused on studies where the biomass potentials were presented for theoretical potential. In some cases Pöyry made own calculations on potentials.
No data on certain biomass types	• In most of the countries the publicly available data gathered by the help of the country experts did not contain all the biomass assortments of a certain category. • To overcome the obstacle, the missing potentials are reported and also specified in the following pages.

Source: Pöyry analysis

BIOMASS POTENTIALS – FOREST

Feedstock	Potential current (GWh)	Potential future (GWh)	Timeframes	Source	Original unit	Conversion factor to original unit	Conversion factor source
Black liquor	58 029	73 554	2018, 2030	[1]	GWh	-	
Chips	19 097	21 367	2017, 2030	[2]	1000m³	2,24	[6]
Bark	10 020	10 990	2017, 2030	[2]	1000m³	1,32	[6]
Sawdust	6 732	7 533	2017, 2030	[2]	1000m³	2,04	[6]
Harvesting residues	16 094	25 822	2017, 2030	[3]	1000m³	2,40	[6]
Stumps	14 647	22 320	2017, 2030	[3]	1000m³	2,04	[6]
Small diameter wood	13 727	13 727	2017, 2030	[3]	1000m³	2,12	[6]
Black liquor	62 741	66 163	2018, 2030	[1]	GWh	-	
Chips	24 304	24 304	2020, 2030	[4]	Mill. m³ sub	2240	[6]
Bark	11 310	11 310	2020, 2030	[4]	Mill. m³ sub	1320	[6]
Sawdust	8 568	8 568	2020, 2030	[4]	Mill. m³ sub	2040	[6]
Harvesting residues	30 000	30 000	2020, 2030	[4]	GWh	-	-
Stumps	28 000	28 000	2020, 2030	[4]	GWh	-	-
Small diameter wood	3 000	3 000	2020, 2030	[4]	GWh	-	-
Black liquor	0	0	2020, 2030	[1]	GWh	-	-
Chips	8889	11 667	2015, 2050	[5]	PJ	277,778	-
Bark							
Sawdust							
Harvesting residues							
Stumps							
Small diameter wood							

BIOMASS POTENTIALS – FOREST

	Feedstock	Potential current (GWh)	Potential future (GWh)	Timeframes	Source	Original unit	Conversion factor to original unit	Conversion factor source
	Black liquor	1 431	1 431	2018,2030	[1]	GWh	-	-
	Chips	14 000	14 000	2020, 2020	[7]	GWh	-	-
	Bark	4 500	4 500	2020, 2020	[7]	GWh	-	-
	Sawdust							
	Harvesting residues	9 900	9 900	2020, 2020	[8]	GWh	-	-
	Stumps	1 120	1 120	2020, 2020	[8]	GWh	-	-
	Small diameter wood	7 970	7 970	2020, 2020	[8]	GWh	-	-
	Black liquor	0	0	2018, 2030	[9]	GWh	-	-
	Chips	0	0	2018, 2030	[9]	GWh	-	-
	Bark	0	0	2018, 2030	[9]	GWh	-	-
	Sawdust	0	0	2018, 2030	[9]	GWh	-	-
	Harvesting residues	0	0	2018, 2030	[9]	GWh	-	-
	Stumps	0	0	2018, 2030	[9]	GWh	-	-
	Small diameter wood	42	339	2018, 2050	[9]	Dry tons	0,00424	[6] [9]

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BIOMASS POTENTIALS – AGRO

Feedstock	Potential current (GWh)	Potential future (GWh)	Timeframes	Source	Original unit	Conversion factor to original unit	Conversion factor source
Energy crops	2 387	3 405	2012, 2030	[1]	Kton dm	5,5	[7]
Straw & husk	7 815	8 288	2012, 2030	[1]	Kton dm	4,875	[8]
Grasses	676	706	2012, 2030	[1]	1000t	0.0049	[9]
Manure	9 100	9 100	2007, 2007	[2]	Tons	0,0005	[7]
Energy crops	330	6 111	2012, 2030	[1]	Kton dm	5,5	[7]
Straw & husk	18 764	10 277	2012, 2030	[1]	Kton dm	4,875	[8]
Grasses	3 161	3 161	2012, 2030	[1]	Kton dm	4,9	[8]
Manure	4 174	4 174	2030, 2030	[3]	GWh	-	-
Energy crops	2 222	12 778	2015, 2050	[4]	PJ	277,777778	-
Straw & husk	12 222	18 333	2015, 2050	[4]	PJ	277,777778	-
Grasses	1 389	1 389	2015, 2050	[4]	PJ	277,777778	-
Manure	8 611	11 111	2015, 2050	[4]	PJ	277,777778	-
Energy crops	3 450	3 450	2020, 2020	[5]	GWh	-	-
Straw & husk	2 230	2 230	2020, 2020	[5]	GWh	-	-
Grasses	N/A	N/A	-	-	-	-	-
Manure	7 500	7 500	2030, 2030	[5]	GWh	-	-
Energy crops	N/A	N/A	-	-	-	-	-
Straw & husk	N/A	N/A	-	-	-	-	-
Grasses	118	118	2008, 2008	[6]	Ton dw	0,0049	[8]
Manure	396	396	2008, 2008	[6]	Wet tons	0,0005	[7]

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BIOMASS POTENTIALS – WASTE

Feedstock	Potential current (GWh)	Potential future (GWh)	Timeframes	Source	Original unit	Conversion factor to original unit	Conversion factor source
MSW, biogenic fraction	3 787	4 080	2015, 2030	[1]	Tons	4,25	[7]
Waste water sludge	662	692	2018, 2030	[2]	Tons dm	0,0048	[8]
Post consumer wood	2 844	3 268	2012, 2030	[3]	1000 t	5,1	[8]
Post consumer paper waste	3 098	2 550	2015, 2030	[1]	Tons	0,0035	[8]
Used cooking oils and fats	256	267	2010, 2030	[4]	GWh	-	-
Slaughtering waste	430	454	2010, 2030	[4]	GWh	-	-
Fishery waste	N/A	N/A	-	-	-	-	-
MSW, biogenic fraction	4 917	5 412	2016, 2030	[5]	GWh	-	-
Waste water sludge	1 218	1 341	2018, 2030	[2]	Tons dm	0,0048	[8]
Post consumer wood	2 481	2 690	2012, 2030	[3]	1000 t	5,1	[8]
Post consumer paper waste	6 187	5 966	2010, 2030	[4]	GWh	-	-
Used cooking oils and fats	430	454	2010, 2030	[4]	GWh	-	-
Slaughtering waste	407	442	2010, 2030	[4]	GWh	-	-
Fishery waste	N/A	N/A	-	-	-	-	-
MSW, biogenic fraction	2 441	3 006	2018, 2050	[6]	PJ	277,777778	-
Waste water sludge	694	733	2018, 2030	[2]	Tons dm	0,0048	[8]
Post consumer wood	3 115	3 105	2012, 2030	[3]	1000 t	5,1	[8]
Post consumer paper waste	814	779	2010, 2030	[4]	GWh	-	-
Used cooking oils and fats	256	279	2010, 2030	[4]	GWh	-	-
Slaughtering waste	465	500	2010, 2030	[4]	GWh	-	-
Fishery waste	N/A	N/A	-	-	-	-	-

BIOMASS POTENTIALS – WASTE

Feedstock	Potential current (GWh)	Potential future (GWh)	Timeframes	Source	Original unit	Conversion factor to original unit	Conversion factor source
MSW, biogenic fraction	1 100	1 100	2030, 2030	[9]	GWh	-	-
Waste water sludge	639	710	2018, 2030	[2]	Tons dm	0,0048	[8]
Post consumer wood	1 790	1 790	2009, 2009	[10]	Tons	0,0051	[8]
Post consumer paper waste	1 365	1 365	2009, 2009	[10]	Tons	0,0046	[8]
Used cooking oils and fats	236	262	2012, 2012	[2]	GWh	-	-
Slaughtering waste	322	322	2008, 2008	[11]	GWh	-	-
Fishery waste	100	100	2020, 2020	[12]	GWh	-	-
MSW, biogenic fraction	51	59	2017, 2030	[13]	Tons	0,0013	[7]
Waste water sludge	41	48	2018, 2030	[2]	Tons dm	0,0048	[8]
Post consumer wood	205	220	2018, 2018	[13]	Tons	0,0051	[8]
Post consumer paper waste	136	200	2010, 2030	[13]	Tons	0,0043	[8]
Used cooking oils and fats	10	10	2018, 2018	[14]	Tons	0,0103	[8]
Slaughtering waste	86	101	2009, 2009	[13]	Tons	0,005	[8]
Fishery waste	142	142	2008, 2008	[13]	Tons	0,0118	[7]

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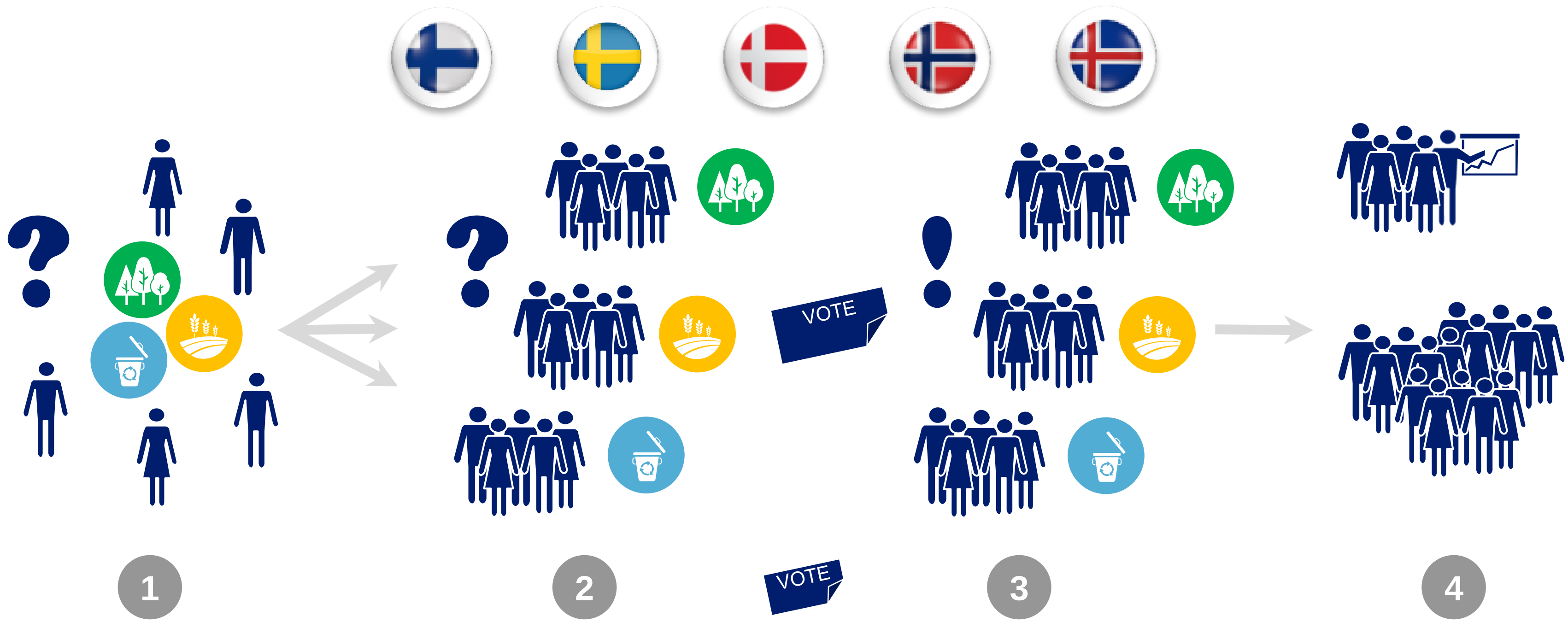
ANNEX 2 – WORKSHOP MATERIAL

METHOD – NORDIC WORKSHOP

The main Nordic level biomass mobilisation obstacles and knowledge gaps were gathered and solutions to these drafted during a workshop involving expert participants from all the Nordic countries.



Individually identifying Nordic biomass
- mobilisation obstacles
- knowledge gaps

Division into groups based on knowledge and expertise. Discussion on the identified
- mobilisation obstacles
- knowledge gaps.

Based on votes, finding a Nordic solution to 1-3
- mobilisation obstacles
- knowledge gaps

Presenting the group findings for the whole workshop on Nordic solutions to
- mobilisation obstacles
- knowledge gaps

WORKSHOP PARTICIPANT LIST

Forest, agriculture and waste experts from different organisations participated the workshop. All Nordic countries were represented in the workshop.

List of workshop participants*

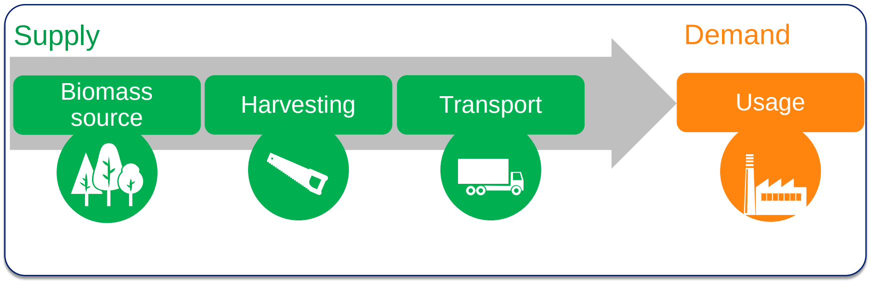
Country	Organisation
	LUKE
	Orkustofnun (Iceland's Energy Authority)
	Lunds Universitet
	Swedish Energy Agency
	Energiforsk
	Swedish Bioenergy Association (Svebio)
	Norges forskningsråd
	Østfoldforskning
	Aarhus University
	Danish Technical University (DTU)

**Some of these organisations were represented by more than one expert*

FOREST – MOBILISATION OBSTACLES

Results from the workshop phases 1 & 2 (incl. the votes).

MOBILISATION OBSTACLES



Forest biomass incl. logging residues and stumps	FSC certification and increased ”restrictions”	●●
Harvesting	Ownership structure Many small forest owners/not optimized harvesting	●●●
Climate change	Storms/fires etc.	
Forest industry by-products	Limited co-operation between the forest industry sector and other industry sectors (oil, chemical, energy etc.)	●●●
Lack of incentives	Carbon pricing	
Harvesting	Increasing cost of harvesting	☆

MOBILISATION OBSTACLES

Transport	With increasing competition, distances will increase → high cost of long-distance transportation	●●●● ☆
Black liquor	Big risk	●
Harvesting	Lack of technologies to access difficult conditions	●●●
Bark	Other ways to utilize	
Transport	Lack of online information on road condition	
Industrial by-products	Limited knowledge about ”energy” potentials (new energy carriers) within the ”traditional” forest industry sector	●
Biofuels	Competition from palm oil based biofuels (import)	●●
Lack of demand	Increased demand for better profitability for forest owners	

Source: Nordic workshop

FOREST – KNOWLEDGE GAPS

Results from the workshop phases 1 & 2 (incl. the votes).

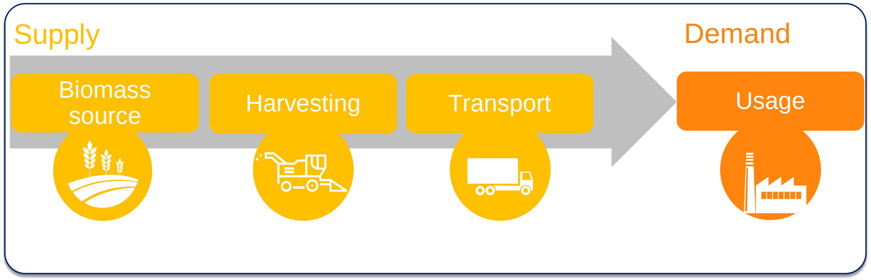
KNOWLEDGE GAPS	
”Effective” biodiversity measures – reduce conflicts between production/biodiversity	●●●●● ☆
Lack of data on environmental impact on different transport fuel options (land use?)	●●
Higher electricity efficiency in bio-power production	
How to deal with sudden extra supply (due to ”forest damages”)?	●●
Technologies for use of lignin and hemicellulose for biofuels	●●
Modern charcoal production technology	
Competition between industry and energy sectors	●●
Co-production of high-value products and energy carriers from forest by-products	●●●
How climate change will affect harvesting and transport?	●●●● ☆

Source: Nordic workshop

AGRO – MOBILISATION OBSTACLES

Results from the workshop phases 1 & 2 (incl. the votes).

MOBILISATION OBSTACLES



Energy crops	EU regulation limiting use of agricultural crops for biofuels	●●●● ☆
AD of manure, grass etc.	Possibility to use heat energy and low price for sold electricity	
All sources	Coordination of agri-, environmental and energy policy	●●
Grass fibre (after oxidation of protein)	Lack of knowledge of fermentation potential	●●
Sugar in grass, raw juice	Optimised use	●

MOBILISATION OBSTACLES

Straw	Economy too bad (not profitable) high transportation costs vs MJ	●
Straw	No demand – no price	●●●● ☆
(Excess) grass	High costs in comparison to competing energy/protein sources	
Manure	Use of digestate after AD	●
Manure	Transport costs and distances, small farms = small quantity	●
Manure	Small scale biogas plants: cheap and renewable energy already available on farms	●●●

Source: Nordic workshop

AGRO – KNOWLEDGE GAPS

Results from the workshop phases 1 & 2 (incl. the votes).

KNOWLEDGE GAPS	
Development of new oil crops beside rapeseed	●
Development of improved methods for biorefineries	●●
How much C is captured into the soil in different types of grass production systems?	
Best use of marginal lands. As we have large areas of abandoned farmland in Nordic countries today.	●●
How to internalize environmental effect in the economy?	●●●● ☆
How to breed and grow straw rich grain crops?	
Renewable fertilizer production	
Lack of experience for small scale biogas plants	
How to process digestate efficiently to fertilizer products?	

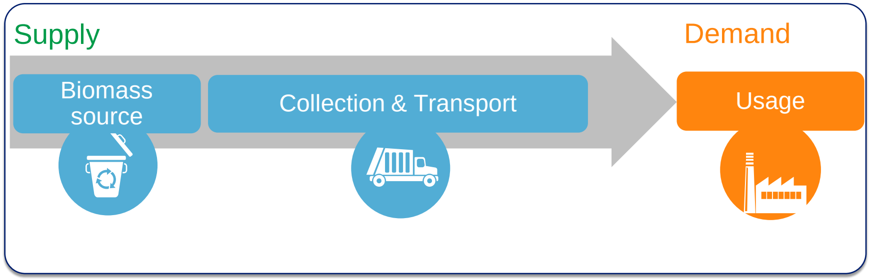
KNOWLEDGE GAPS	
How to integrate straw and grass use in biogas?	●●
Does biogas use of biomass reduce soil C?	●●●
Collaboration between sectors agriculture/waste/energy/transport	●
Utilization of all the biomass resources needs coordination – across forestry, agriculture and waste + energy, transport	●
How to best use biomass to balance the whole renewable energy system?	●●●● ☆

Source: Nordic workshop

WASTE – MOBILISATION OBSTACLES

Results from the workshop phases 1 & 2 (incl. the votes).

MOBILISATION OBSTACLES



Import/export of substrates	Difference in regulatory systems in the Nordic countries	●●
Bio waste sludge for anaerobic digestion	Utilization of digestate pollution	●●
Marine/ fishery waste	No regulation/incentives	
Bio waste	Source separation	●●●● ★
Bio waste	Pre-treatment technology costly	●
Bio waste/ sludge	Fertilizer ordinance/legislation	●

MOBILISATION OBSTACLES

Bio waste	Fertilizer image → unsellable products	●●●
Digestate	Not accepted for e.g. malting barley cultivation (beer image)	
MSW	Position – minimizing transport	●●●

Source: Nordic workshop

WASTE – KNOWLEDGE GAPS

Results from the workshop phases 1 & 2 (incl. the votes).

KNOWLEDGE GAPS	
Where to use the waste resources and for what? - Important to optimize economically, environmentally and resource	●●●●
What role should waste play in the future energy system?	
How to increase share of bio waste separated household, industry?	
How to collaborate across sectors marine/waste/energy/transport/agriculture?	●●●●● ☆
Knowledge about higher value products from waste (e.g. proteins)	●●●
Micro plastics/pollution in digestate (anaerobic digestion)	
Lack of recent data regarding quality/waste characteristics	●
Lack of information on quality connected to different separation and sorting systems	●●●
How to document source/safety of reuse (as fertilizer)?	

Source: Nordic workshop

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