Policy Brief

Operations of large solid biomass fired power plants - a sneak public peek

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Operations of large solid biomass fired power plants - a sneak public peek - Policy brief

This brief is the second of four briefs prepated within the framework of project ***„Woody biomass: win-win or lose-lose? Energy, climate and air pollution effects of biomass to power projects in the context of selected Western Balkan countries."***

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INTRODUCTION

Would you like to run a dispatchable renewable power source that is theoretically capable to deliver the negative GHG emissions?

If so, you might wish to learn how those who already use biomass without carbon capture and storage reached that point, what customers they serve and if and how they have addressed sustainability issues.

If you would like to find out what more lies ahead on the road to possible negative GHG emissions power production, please read our work on the biomass policy in the EU.

In case that you are interested about the prospects in Serbia and Bosnia and Herzegovina please be patient a bit more as we will soon be publishing our briefs that may help you navigate in your future decision-making processes.

Now let as take a sneak peek into the available information about some of the largest biomass to power plants in Europe and frameworks in which they came to being.

Whatever your interest in reading this paper is, please be reminded that sustainable use of biomass for energy must be in line with cascading principles of use of wood, with the need to preserve biodiversity and ecosystems and with the need to maintain and increase carbon stocks.

BACKGROUND

Solid biomass remains the dominating type of biomass used for energy in all countries, but liquid biofuels, renewable waste and biogas/biomethane are also relevant.

- Countries with the highest use of solid biomass for energy tend to have a high domestic forest area per capita and important wood processing industries, while their forests are still expanding.
- A few countries with limited domestic forest biomass potential (the Netherlands, the UK, Belgium, and Denmark) rely on solid biomass imports for energy - these countries have imposed sustainability requirements to (large scale) biomass use to mitigate some of the risks related to biomass sourcing from outside the country (which they cannot control with domestic forest policies).

- The amount of MSW used for power and/or heat production is clearly linked to the stage of waste management development in a country, which is quite advanced in Scandinavia and West Europe where performant collection systems have been implemented and landfill is almost completely phased out.
- Germany is most advanced in biogas/biomethane use. Nevertheless, other countries are catching up; particularly Denmark has taken major steps in biogas/biomethane lately. Biogas used to be primarily used directly for CHP generation; the raw gas is now more and more upgraded and fed into the gas grid. While biogas/biomethane use peaks above 25% of natural gas use in Denmark, it tends to be equivalent to 1-5% of natural gas use in most countries, showing that major steps will still be needed to phase out fossil gas[1].

Electricity production from biofuels accounted for 2% of total electricity production in 2020.[2] Countries that are members of the IEA Bioenergy partnership[3] produced almost all that electricity.[4] Those countries, in particular Finland and Sweden, are global leaders in modern bioenergy production and consumption.

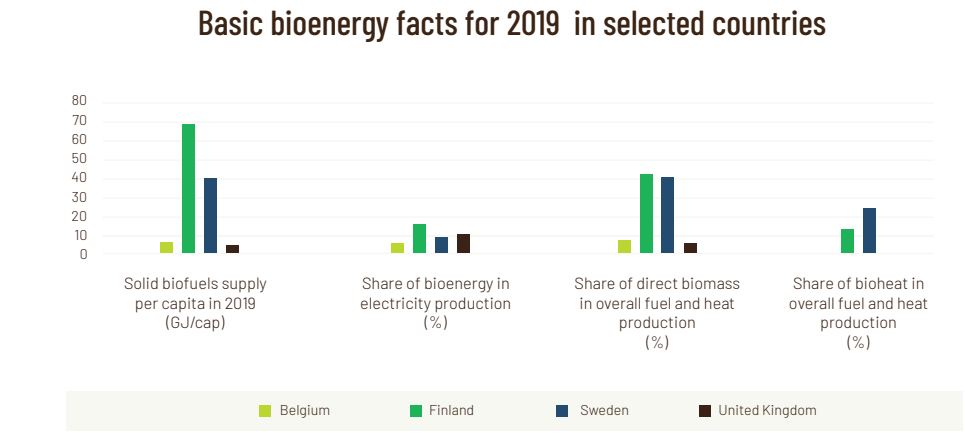

Figure 1 *Basic bioenergy facts for 2019 in selected countries. Source: IEA Bioenergy*[5]

1 IEA Bioenergy Countries' Report – update 2021, Implementation of bioenergy in the IEA Bioenergy member countries , IEA Bioenergy ExCo, November 2021

2 https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser?country=WORLD&energy=Electricity&year=2020

3 https://www.ieabioenergy.com/blog/publications/2021-country-reports/

4 https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser?country=WORLD&energy=Electricity&year=2020

5 https://www.ieabioenergy.com/blog/publications/2021-country-reports/

PLANTS - THE THREE STORIES

From coal to biomass

> *"We've decades of understanding of how to use coal, but we've only been operating with biomass since we started the full conversion trials in 2011," We've got few running hours under our belts with the new fuel versus the hundreds of man years of coal knowledge and operation all around the country."*
>
> **Adam Nicholson,**
> *Section Head for Process Performance at Drax Power*

Conversion form coal burning to biomass burning gave birth to some of the largest biomass fired power plants in the world. This conversion usually starts with co-firing before full conversion takes place and coal usage is completely abandoned. In numerous instances co-firing or even full conversion to biomass was used to achieve economically viable compliance with environmental norms (such as Large Combustion Plants Directive or carbon taxing) at the end of the lifetime of the plant. Legislative changes, economic incentives, risk mitigation strategies were among the drivers behind the decisions to convert.

A closer look at the example of UK reveals how has the power sector reacted to generations of policies. Since the Electricity Act of 1989 the United Kingdom (UK) has been developing policies to incentivize the acquisition of renewable energy. As a result of policy incentives all major coal-fired power plants in UK have adopted biomass co-firing. 2011 marked the peak of co-firing production in the UK when co-firing accounted for only 6.45% of renewable electricity generation. The following years co-firing rates diminished as co-firing Renewables Obligation Certificates (ROCs) became banded to lowered rates and co-firing at low ratios lost was discouraged. In response, coal-fired plants around UK began making the switch to dedicated biomass to receive greater ROC support and to 191 comply with Large Combustion Plant Directive (LCPD) and Industrial Emission Directive (IED) 192 emission levels[6]. These and the other factors facilitated largest coal to biomass conversion taking place at Drax power plant.

6 https://www.osti.gov/servlets/purl/1407416

Drax power plant[7]

Figure 2 *Drax power plant. Source*[8]

The station at the site near Selby in North Yorkshire, includes 4 x 645MW biomass fired units and produces around 14 terawatt-hours (TWh). Ful conversion of the first unit was completed in 2013, while conversion of the last, fourth generation unit was completed in 2018.

The total biomass conversion cost for the first three Units at Drax has been given as 700,000,000 GBP (around 416 EUR/kWe); the cost of conversion of Unit 4 was only 30,000,000 GBP (around 54 EUR/kWe) due to the use of spare parts from the conversion of the previous units as well as to the fact that no additional investments related to biomass fuel supply (e.g. port and rail infrastructure, storage, etc.) were implemented[9].

The Drax power plant is currently the world's largest biomass consumer, using in its four biomass converted units more than 7 million tons of wood pellets in 2018, mostly from the USA (62.2 %) and Canada (17.3 %), with smaller volumes sourced from EU, Brazil, and other European countries. World trade flows of sawdust and waste wood were dominated by Drax in the year 2020[10].

The BBC claimed that some of the wood used comes from primary forests in Canada[11].

According to Guardian, the thinktank Ember has estimated that, from 2012 until 2027, when the support runs out, Drax would have collected **more than £11bn in subsidies**[12].

7 https://www.drax.com/about-us/our-sites-and-businesses/drax-power-station/

8 https://www.drax.com/about-us/our-sites-and-businesses/drax-power-station/

9 https://www.biofit-h2020.eu/files/pdfs/BioFitHandbook_EN_2ndEdition_2022-03-15.pdf

10 https://resourcetrade.earth/?year=2020&category=1048&units=value&autozoom=1

11 https://www.bbc.com/news/science-environment-63089348

12 https://www.theguardian.com/business/2023/feb/23/drax-power-station-profits-nearly-double-call-for-subsidies-cut

UK National Audit Office is preparing a report that is supposed to bring more clarity and understanding around the issues that are of critical relevance for Drax operations:

- the government's current biomass strategy and how this contributes to the government's overall strategy of achieving Net Zero by 2050
- how support for biomass has been implemented, how its support has been funded including future spending allocations, how sustainability criteria are monitored and enforced
- how government has identified the main risks to successful implementation, the long-term environmental implications, and the future plans for biomass[13]

Rodenhuize 4

Rodenhuize 4 is one of the earliest examples of a 100 % retrofit to biomass. The conversion was implemented with a series of successive steps, starting from installation of transport, storage, handling, and milling infrastructure for wood pellets and the conversion of a single burner row in 2005. This has been followed by the switch of two coal burner rows to wood pellet firing and, finally, the with the complete switch from coal combustion to wood pellets, burner replacement, and other retrofitting options, including the installation of a Selective Catalytic Reduction (SCR) unit for control of the NOx emissions[14]. Plant capacity at the final stage was 205 MWe and it used pulverized fuel (PF) combustion technology of wood pellets. Majority of fuel used was imported from the third countries[15].

Figure 3 *Rodenhuize 4. Source*[17]

Flemish green power certificate support system for Rodenhuize expired in February 2023. The Max Green biomass plant has been closed and has been used as a cold back-up plant since March 2023[16].

13 https://www.nao.org.uk/work-in-progress/the-governments-support-for-biomass/

14 https://www.biofit-h2020.eu/files/pdfs/BioFitHandbook_EN_2ndEdition_2022-03-15.pdf

15 https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Wood%20Pellets%20Annual_The%20Hague_European%20Union_E42023-0034.pdf

16 https://corporate.engie.be/en/energy/biomass/max-green-rodenhuize

17 https://corporate.engie.be/en/energy/biomass/max-green-rodenhuize

Polaniec Green Unit

Retrofit of Polaniec Green unit in Poland, which is one of the 8 units at Polaniec power plant with the capacity of 195 Mwe has been finalized in 2013. The older pulverized fuel boiler was replaced with a state-of-the-art CFB boiler, and the steam turbine was retrofitted as well[18]. The unit uses 80% of wood chips and 20% of agrobiomass.

The cost of a complete fuel replacement was assessed at €1250/kWe in 2020. The unit was also modernized along with other coal units. Its annual utilization in the period from 2015 to 2018 stood at annual capacity factor of above 70%, among the highest in Poland for all plants[19].

Figure 4 *Polaniec Green unit. Source*[20]

18 https://www.biofit-h2020.eu/files/pdfs/BioFitHandbook_EN_2ndEdition_2022-03-15.pdf

19 Supporting Information for "Retrofit Decarbonization of Coal Power Plants – A Case Study for Poland https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjot7f_-J2DAxVZxQIHHXXzDZwQFnoECA8QAQ&url=https%3A%2F%2Fmdpi-res.com%2Fd_attachment%2Fenergies%2Fenergies-14-00120%2Farticle_deploy%2Fenergies-14-00120-s001.pdf%3Fversion%3D1610365976&usg=AOvVaw0mLt5nqGIZ7UwnZfFaM3aa&opi=89978449

20 https://www.shi-fw.com/insights/projects/polaniec-power-station/

Forest residues and wood waste for electricity and heat

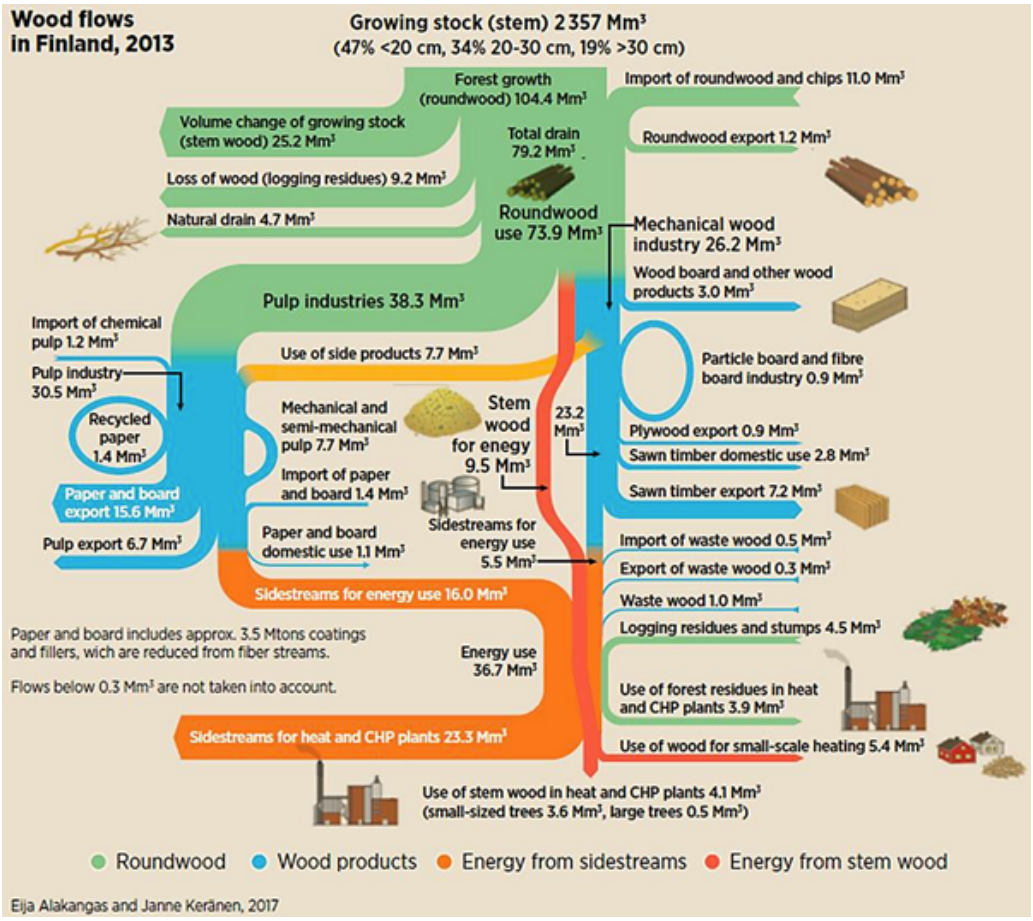

Figure 5 *Wood flows in Finland in 2013. Source*[21]

Supply of wood for energy in Finland comes from the three main streams: energy from stem wood, sidestream for energy use from pulp industries and sidestream for energy use from mechanical wood industry. Overall, some 36.7 Mm3 of the wood output from Finnish forests was used for energy in some way, of which 23.3 Mm3 was used in large-scale heat and CHP plants. Thus, just less than half of the 73.9 Mm3 of roundwood harvested in Finland was used for energy, while just more than half of wood went into various products such as timber, plywood, pulp, or paper[22].

21 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Mar/IRENA_Bioenergy_from_Finnish_forests_2018.pdf?rev=3f509dc7c57d433ca9e01d8a694422e0 (page 10)

22 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Mar/IRENA_Bioenergy_from_Finnish_forests_2018.pdf?rev=3f509dc7c57d433ca9e01d8a694422e0

The maximum sustainable allowable cut in Finland is calculated by Natural Resources Institute using a large-scale forest planning tool called MELA, with integrated stand level simulation and forest level optimisation. In the past no sustainability constraints were imposed in the metho concerning tree species, cutting methods, age classes or the growth/drain ratio, to efficiently utilise the dynamics of forest structure[23].

Sustainability challenge

Recent estimates by Natural Resources Institute Finland showed that forest carbon sinks are lower than previously estimated despite their moderate rise in 2022. The rise has anyhow been attributed to reduced logging as the price of pulp has collapsed while that of pulp wood has soared domestically due to the suspension of exports from Russia. Finnish carbon sinks have been shrinking for the past decade mostly as a consequence of rising logging volumes and the ageing and slowing growth of forests. Finland is presently set to fall well short of its targets related to emissions from the land-use sector for both 2025 and 2030.

https://www.helsinkitimes.fi/finland/finland-news/domestic/23672-finland-s-land-use-sector-was-narrowly-a-carbon-sink-in-2022-says-luke.html

23 ibid

Alholmens Kraft[24]

Figure 7 *Alholmens Kraft power plant. Source*[25]

Alholmens Kraft power plant is located at the factory premises of UPM-Kymmene Ab in Alholmen, Jakobstad, Finland. Its electricity capacity is 265 MWe and it also provides 60 MWth of district heat to the inhabitants of Jakobstad along with 100 MWh for process steam and heat for the UPM Kymmene plant in Jakobstad.

The boiler used by the plant is the largest CFB-boiler (Circulating Fluidised-Bed Boiler) in the world and was supplied by Kvaerner Pulping. Wood fuels account for 50-70% of the combustion. UPM's Pietarsaari Factories supply bark from pulpwood and sawlogs and is the largest single provider. Most of the rest of the wood-based fuel consists of logging residues from the region's forests. Rice, tops and branches are made into bales of springs in the forest and crushed by a slow-speed crusher at the power plant. Stumps are crushed either at the power plant or at an earlier stage in the supply chain. Wood that is not good for mass production is also included in the fuel mix. Plant also burns peat while pit coal as supplementary or reserve fuel[26].

Plant is owned by Pohjolan Voima one of Finland's biggest energy companies whose shareholders are also their customers: a wide range of Finnish industrial and energy companies, for whom Alholmens and other plants electricity and heat at cost price.[27] The electricity produced by the plant is also sold in open competition on the Nordic market[28].

The company claims to have a strong sustainability policy covering different aspects including biodiversity[29].

24 https://www.alholmenskraft.com/en/company/bio-fuelled_power_plan
25 https://www.alholmenskraft.com/en/production/fuel
26 https://www.alholmenskraft.com/en/production/fuel
27 https://www.pohjolanvoima.fi/en/
28 https://www.alholmenskraft.com/en/company
29 https://www.pohjolanvoima.fi/en/responsibility/biodiversity/

Keljonlahti

Figure 8 *Keljonlahti power plant. Source*[30]

The Keljonlahti power plant, commissioned in 2010, is a biofuel power plant in Central Finland producing electricity and district heat for the Jyväskylä area. The plant is operated by Alva-yhtiöt Oy which is 100% owned by the City of Jyväskylä. The plant has 210 MWe capacity in electricity only (condensing) mode while its output in combined heat and power mode is 163 MWe and 260 MWth. Wood and peat as backup fuel are burnt in Foster Wheeler boiler. The plant underwent major turbine reconstruction to rectify the operational issues it had.[31]

Company claims to calculate carbon footprint of its entire operations[32].

Kaukan Voima[33]

Figure 9 *Kaukaan Voima plant. Source*[34]

30 https://www.fortum.com/products-and-services/power-plant-services/enext/references/jyvaskylan-voima

31 https://www.fortum.com/products-and-services/power-plant-services/enext/references/jyvaskylan-voima

32 https://alva.impact.page/alva/Graph

33 https://www.pohjolanvoima.fi/en/electricity-and-heat-production/thermal-power/our-thermal-power-plants/
https://www.pohjolanvoima.fi/wp-content/uploads/2023/02/pohjolan-voima-production-capaciy-on-31.12.2022.pdf

34 https://www.pohjolanvoima.fi/en/electricity-and-heat-production/thermal-power/our-thermal-power-plants/

Kaukaan Voima a 125Mwe and 262 MWth plant is operated by Kaukaan Voima Oy owned by Pohjolan Voima (PVO) and Lappeenrannan Energia[35]. The associated sawmill delivers bark generated from its processes to Kaukaan Voima Oy's biopower plant for use as raw material in energy production, while the wood chips and sawdust become raw material for the pulp mill[36]. The biopower plant also receives raw materials from the debarking facilities at the pulp and paper mill. Biomass is being burnt in circulating fluidized-bed (CFB) boiler island delivered by Foster Wheeler. Kaukaan Voima produces process steam and electricity for UPM's Kaukas mill and electricity and district heat for Lappeenrannan Energia. The power plant accounts for approximately 85% of the annual district heat requirement of the city of Lappeenranta.

In 2002 a project where the plant's minimum output was reduced by almost 20% was completed. The reduction of the minimum output of the boiler and the turbine increased energy efficiency and provides more flexibility in electricity production. The boiler and turbine now operate in a more extensive performance range, which assist us in operating better in the changed electricity market[37].

Recent developments- recovery boilers in Finland

At pulp mills, black liquor is typically combusted in the recovery boiler to produce heat and power. Bark, as a side product from debarking, is also typically either combusted or gasified. In both cases, additional heat and power is produced. Some of the pulp mills sell part of the produced heat to a communal district heating system[38].

Finnish Metsä Group focuses on wood supply and forest services, wood products, sawn timber, pulp, paperboard, and tissue and greaseproof papers. The essence of Metsä lies in their unique company structure as their parent company, Metsäliitto, is a cooperative owned by more than 90,000 Finnish forest owners. The owner-members hold roughly half of Finland's private- forests (i.e. some 5.3 million ha). Company claims that 85% of the wood they use comes from Finland, that all wood procured is traceable while 89% comes from certified forests.

The Group in its reports states that their sustainability policies include carbon and biodiversity targets and developed monitoring and verification systems.

35 https://www.pohjolanvoima.fi/en/electricity-and-heat-production/thermal-power/our-thermal-power-plants/

36 https://www.upmpaper.com/knowledge-inspiration/blog-stories/articles/2020/06/Thriving_together/

37 https://www.pohjolanvoima.fi/wp-content/uploads/2023/03/pohjolan_voima_annual_report-2022.pdf

38 https://www.biofit-h2020.eu/files/pdfs/BioFitHandbook_EN_2ndEdition_2022-03-15.pdf

Group owns and operates large industrial facilities that include its own energy production. They produce 27.7 TWh renewable energy of which 25 TWh were used in own production while 2.7 TWh were sold[39].

Aanekoski[40] [41]

Figure 10 *Äänekoski bioproduct mill (photo courtesy Sami Karppinen / Metsä Group). Source[42]*

Metsä Group's bioproduct mill in Äänekoski, Finland was started up in August 2017 as a result of 1.2 billion EUR investment. Its energy production facility hosts Valmet boiler designed for a capacity of 7 200 tonnes dry solids a day (tds/d). The Äänekoski recovery boiler has multiple high-power features, including patented heat recovery from flue gas to combustion air, enabling the mill to produce 260 MW of electricity and sell 1.4 times more electricity to the grid than it needs for its own operation.

All the energy needed by the mill is produced from production side streams. The Äänekoski bioproduct mill has an annual electricity generation capacity of 1.8 TWh, which is equivalent to 2.5 per cent of the overall electricity production in Finland.

39 https://www.metsagroup.com/globalassets/metsa-group/documents/investors/financial-reporting/vuosikatsaus-en/metsa-group-annual-and-sustainability-report-2022-pages.pdf

40 https://bioenergyinternational.com/valmets-technology-plays-key-role-metsa-groups-aanekoski-bioproduct-mill/

41 https://www.metsagroup.com/globalassets/metsa-fibre/attachments/brochures/aanekoski-bioproduct-mill-e-brochure-en-2022-07.pdf

42 https://bioenergyinternational.com/valmets-technology-plays-key-role-metsa-groups-aanekoski-bioproduct-mill/

Kemi

Figure 10 *Kemi bioproduct mill. Source*[43]

On Wednesday, September 20, 2023, Metsä Fibre's Kemi bioproduct mill in Finland was successfully started up. Its Valmet recovery boiler and Dussan Škoda 270 MW power turbine[44] are paired to produce two terawatt hours (TWh) of renewable electricity per year. Kemi bioproduct mill is, according to Metsa group, the most efficient wood processing plant in northern hemisphere. The value of the investment in the mill amounted to EUR 2.02 billion and it is the largest investment ever made by the Finnish forest industry in Finland. The Kemi bioproduct mill is the world top regarding to material, environmental and energy efficiency. It will not use any fossil fuels at all[45].

43 43 https://www.metsagroup.com/metsafibre/about-metsafibre/pulp-production/kemi-bioproduct-mill/

44 https://www.pulpandpaperonline.com/doc/the-largest-wood-processing-plant-hemisphere-doosan-skoda-power-turbine-0001

45 https://www.metsagroup.com/metsafibre/about-metsafibre/pulp-production/kemi-bioproduct-mill/

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