# Bioenergy in a changing climate: Linking mitigation and adaptation in the Nordic region

## Introduction

Bioenergy markets have expanded rapidly in the last decade, both in volume and in geographic scope. In the European Union, bioenergy is already the most important renewable energy source, and by 2020, its share of the energy mix is expected to more than double from 2005 levels, to 12%. The bioenergy trade is booming, with global commodity markets emerging for wood pellets and bioethanol in particular.

This trend has important climate implications, as bioenergy can replace fossil fuels in both transport (ethanol and biodiesel) and heat and power (wood pellets, wood chips). Upfront capital costs are relatively low, making it possible to transition to bioenergy quickly and at large scales.

Less understood is how bioenergy market development may affect different market actors' ability to adapt to a changing climate – and how climate change itself may affect bioenergy markets. This policy brief, loosely based on NORD-STAR Working Paper No. 2014-01, *Bioenergy Trade in a Changing Climate – A Review of Mitigation-Adaptation Inter-relationships from a Nordic Perspective*, examines that question.[1]

The Nordic region – including Denmark, Finland, Iceland, Norway and Sweden – has been a leader in integrating renewables into energy systems. Denmark, Finland and Sweden stand out in the use of bioenergy, which accounts for 20–30% of total energy consumption in each country. All three have high ambitions for further expansion of bioenergy, to reduce their dependence on fossil fuels.

The Nordic region is also prominent when it comes to bioenergy trade. The densely forested region has emerged as a hotspot for forest-based bioenergy trade; Sweden and Denmark in particular are large importers of wood chips and wood pellets from Estonia, Latvia and Russia. The Nordic countries have also been pioneers in large-scale imports of bioenergy from other continents. Wood pellets were carried from western Canada to combined heat and power (CHP) plants in southern Sweden as early as 1996, and both Finland and Sweden first imported ethanol from Brazil in the early 2000s.

### Key findings

- Bioenergy is a key component of climate change mitigation policies in the Nordic region, particularly in Denmark, Finland and Sweden, where there are high ambitions to further expand bioenergy to reduce dependence on fossil fuels.
- Bioenergy use in all three countries relies on extensive trade, primarily within Northern Europe and the Baltic Sea Region, but also with other European countries, the U.S., Canada and Brazil. Given that bioenergy crop production and forestry are expected to be affected by climate change, it is crucial to be aware of potential risks and prepare for them.
- Climate change is expected to increase agricultural and forest productivity in Northern Europe, due to higher average temperatures, more precipitation and a longer growing season. However, there are large and potentially underestimated risks due to storms, forest fires and insect infestations. Similarly, winter-related shipping disruptions are likely to decline, but drought-related issues may increase.
- Policy-makers can help increase the resilience and sustainability of bioenergy use by diversifying their supply to reduce their exposure to climate risks in any one region – which would also ease pressures on suppliers when scarce resources are needed locally. As warmer winters reduce energy demand in the Nordic region, the biomass freed up could be exported or used in industry.

## Climate change impacts across bioenergy supply chains

Forestry and agriculture are among the economic sectors expected to be most affected by climate change, as they depend on biological systems exposed to changes in mean temperatures, precipitation patterns and extreme weather events. Several studies have shown how the combination of climate change and increased demand for irrigated biofuel crops can exacerbate water stress in exposed regions. However, few have considered the implications of the globalization of bioenergy markets.



The Køge combined heat and power plant in Flemming Junckers Business Park in Køge harbour, Sjælland, Danmark.

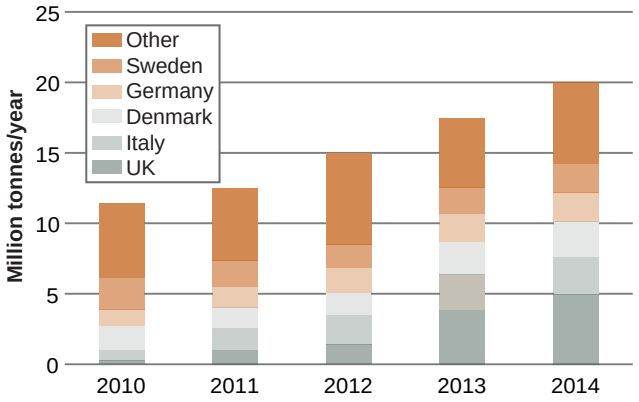


Figure 1: EU wood pellet consumption 2010-2014; 2013 & 2014 are estimates.[3]

Our analysis focuses on globalization and how it combines with the intricacies of bioenergy supply chains, using the Nordic region's bioenergy markets as a starting point. We analyse Nordic trade in four key fuels: bioethanol, biodiesel, wood pellets and wood chips. Based on a literature review, we examine how these supply chains are affected by climate change, from cultivation via distribution to final consumption.

## Nordic bioenergy policy and trade

The ongoing expansion of bioenergy in the Nordic region is driven primarily by the EU's Renewable Energy Directive, which aims to meet 20% of EU energy demand with renewables by 2020. Only three of the Nordic countries – Denmark, Finland and Sweden – are EU members, but Iceland and Norway are covered by the RED through their membership in the European Economic Area.

Both Iceland and Norway have abundant renewable energy sources beside bioenergy, however. Iceland has extensive geothermal energy and hydropower. Norway now produces 98% of its electricity production with hydropower, and uses it to cover most of the country's space heating needs as well. Since both Norway and Iceland are likely to reach their RED targets without much bioenergy, this brief focuses on Denmark, Finland and Sweden, for which bioenergy is likely to play a larger role.

All three countries use substantial amounts of *bioethanol*, and all rely on imports to a significant extent – although 25% of Swedish consumption is based on domestically produced wheat ethanol. Half of bioethanol imports come from other European countries; the majority of non-European imports in 2011–2013 came from the U.S. (ethanol from maize) and from Brazil (sugarcane ethanol). The share of ethanol from the U.S. has been fairly stable, around 3–5% of total Swedish bioethanol consumption, whereas the Brazilian share has fluctuated in the 2.5–10% range. The latter swings reflect, to a large extent, fluctuations in global biofuel trade patterns.

Denmark and Sweden rely heavily on rapeseed-based *biodiesel*, and Denmark also exports substantial amounts to Sweden. Sweden produces a large share of its biodiesel, but imports the raw material. A growing biodiesel market segment in both Sweden and Finland involves hydrogenated vegetable oils, using forestry residues, meat production residues and palm oil (the latter two mostly in Finland). This technology enables the production of a biodiesel that is chemically identical to fossil diesel.[2]

*Wood chip* markets tend to be geographically limited by the low energy density of wood chips. Transportation costs per energy unit become excessive over longer distances, and thus the wood chips used in Nordic countries come mostly from Northern Europe. There have been attempts to establish imports of wood chips to Norway from eastern Canada and to Denmark from Ghana, but neither of these has been very successful.

*Wood pellet* markets, on the other hand, have become quite internationalized, with large and rapidly expanding trade flows from western Canada and the southeastern U.S. to Western Europe, especially the United Kingdom. Both Sweden and Denmark have previously imported wood pellets from North America, but now mostly rely on the Baltic Sea region suppliers (Russia, Latvia and Estonia). Denmark, which imports 90% of its large and growing wood pellet consumption, gets much of its supply from Portugal, and also some from Sweden and Finland. However, Scandinavian pellet markets in general are decreasing in relative importance as a result of rapidly expanding consumption elsewhere. In the UK, conversion of power stations from coal to wood pellets is leading to a situation where some individual power stations will consume an amount of wood pellets equal to or above that of the entire country of Sweden.

## Climate impacts on bioenergy crops

The majority of bioenergy used in the Nordic region is currently of Nordic or Northern European origin. In general, climate change is expected to have a positive impact on biomass production potential in Northern Europe, including boreal Russia. Higher average temperatures, more precipitation and a longer growing season are all factors that will contribute to productivity improvements in both agriculture and forestry.

At the same time, there are large and potentially underestimated risks related to storms, forest fires and insect infestations, which could have significant effects on biomass supplies. However, the extent of these risks is difficult to assess. Furthermore, events that are devastating for agriculture and forestry overall might not harm the bioenergy subsector.[4]

The impacts on bioenergy supplies from outside the Nordic region are likely to vary dramatically depending on where they are grown. U.S. *bioethanol* from maize, for example, appears to be more vulnerable to climate change than Brazilian sugarcane ethanol. In Brazil, warming may enable the southward expansion of sugarcane plantations.[5] In the U.S., both flood and drought risks, as well as soil erosion, are growing concerns; moreover, the overall sustainability of maize ethanol is now widely questioned.

Biodiesel consumption in the Nordic region is dominated by raw material of European origin. As with Nordic forestry and agriculture, the general trend is of both increased productivity and increased exposure to pest infestations and extreme weather events. As for non-European raw materials, Argentinean soybean cultivation is likely to be negatively affected by climate change,[6] and the same goes for oil palm cultivation in Indonesia and Malaysia.[7]

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Demand for wood pellets for fuel has grown rapidly in recent years.

The two dominant non-European *wood pellet* supply regions are western Canada and the southeastern U.S. Climate change will have drastically different impacts on these two regions. In the southeastern U.S., increased water stress and drought are the main threats from increased average temperatures. Western Canada is expected to see a general increase in forest productivity, but more unpredictable indirect impacts could offset this. For example, huge swaths of forest in British Columbia are being devastated by a mountain pine beetle infestation associated with warmer winters. However, since one of the few possible uses of the damaged wood is production of wood pellets, the devastation could actually increase the potential wood pellet supply.

## Climate impacts on bioenergy logistics and distribution

Recent research has highlighted the vulnerability of globalized supply chains to climate change in general and extreme weather events in particular. For bioenergy markets, the nature and extent of impacts vary depending on length and complexity of supply chains as well as the geographic areas involved.

As the energy density of solid and liquid biofuels is lower than for fossil alternatives, larger transportation volumes are needed to ship a given amount of energy, thereby increasing the dependence of energy supply on continuous flows. This will likely entail a general increased vulnerability to outside disturbances, something which is important to be aware of given the large and growing reliance on bioenergy for heat supply in Danish, Finnish and Swedish cities.

Moreover, although bioenergy can often replace fossil fuels, they are not the same. Wood chips and wood pellets in particular are vulnerable to a rather wide array of negative effects if treated incorrectly, especially in transit and storage. Exposure to moisture and/or logistics shortcuts can lead to substance losses, foul smell and spontaneous combustion.

Currently, intra-Baltic Sea trade in wood chips and wood pellets can be disrupted by ice blocking transport routes. This threat is expected to become less severe with warmer winter temperatures, and the same goes for problems related to vegetable oils solidifying or being otherwise affected by sub-zero temperatures.

However, there are also threats that are expected to become more severe with a warmer climate. In the U.S., inland transportation of coal and oil products in the Mississippi River system have been brought to a halt by drought. The same routes are used to transport both wood pellets and bioethanol.

## Impact of climate change on bioenergy consumption

Space heating is a key driver of demand for wood chips and wood pellets in the Nordic region. As the climate warms, reduced demand for heating will result in reduced demand for wood fuels. This development is further exacerbated by continuous energy efficiency improvements in buildings.

Energy demand is expected to rise considerably during the warmer months, however, due to increased cooling needs. Given the growing appeal of biomass as a substitute for fossil fuels, it is reasonable to expect that at least some of the added demand for electricity would be met with bioenergy. In that sense, other countries' adaptation to warming temperatures could be a boon to the Nordic countries, which could export any biomass they no longer need to use at home.

Biomass demand could still increase for other reasons. First of all, the fact that like fossil fuels, bioenergy offers continuous energy, unlike intermittent renewables such as wind and solar power, makes it an attractive option to meet baseload demand and/or seasonal spikes in demand in a more diversified energy system.

## Building climate-resilient bioenergy supply chains

Climate change is expected to bring both new risks and opportunities for Nordic bioenergy supply chains. From an adaptation perspective, this raises two sets of questions: how to minimize risks and make the most of opportunities to benefit the Nordic countries, and how to ensure that bioenergy trade involving the Nordic countries does not exacerbate vulnerability elsewhere.

One approach that can reduce risks on both fronts is diversification. By sourcing fuels from different regions of the world, Nordic countries can reduce their exposure to climate risks in any one region, and also ease pressures on that region at times when scarce resources are needed locally. Another viable op-

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Rapeseed oil is widely used for biodiesel across Europe.

## Policy considerations

- Bioenergy-based mitigation strategies have great potential, but to be viable in the long term, they need to explicitly address adaptation needs as well. This includes hard-to-predict risks from extreme weather events and pest infestations, as well as indirect risks associated with bioenergy trade.

- Climate-resilient energy systems need to be flexible and diversified. Diversification is important at all stages of the supply chain – from supply, to means of transportation, to fuel-flexible energy conversion equipment, to the ability to switch easily between different energy sources: wind, solar, hydropower and bioenergy.

- Nordic policy-makers should develop strategies to maximize the opportunities arising in the region from increased biomass production potential and reduced regional bioenergy demand. At the same time, to the extent that they import bioenergy, they should work to ensure that bioenergy trade does not exacerbate vulnerability elsewhere, particularly in poorer countries.

tion is fuel flexibility in the consumption stage of the supply chain, such as CHP boilers that can use different fuels – from wood chips to household waste.

The expected reduction in demand for bioenergy from warmer winters in the Nordic region should in general be seen as a positive development, as reduced energy consumption and increased energy efficiency is a low-risk adaptation strategy. At the same time, as noted above, this could free up biomass resources for exports – or for new industrial endeavours.

In the Nordic region, the vast majority of remaining fossil fuel consumption takes place in the transport sector. Using the region's forest resources to produce transport fuels could be an option as demand for bioenergy levels off and demand for wood for pulp and paper declines due to the digitalization of information. There are still technological challenges to be tackled, but more than anything, clear political signals would be needed to drive investment.

Another important consideration is cost. Reducing costs is crucial for making bioenergy a viable alternative to fossil fuels, but excess emphasis on short-term cost minimization could be dangerous if it means relying too heavily on just-in-time logistics for fuel supply.

## Endnotes


1. The paper is available at http://www.nord-star.info/index.php/research/working-papers, and includes references for most of the material in this policy brief. Additional references are provided here for material that was not included in the paper.

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**The Nordic Centre of Excellence for Strategic Adaptation Research (NORD-STAR)** aspires to a Nordic region that can adapt sustainably to the impacts of climate change and the consequences of climate policy. Pursuing innovative science, sound economic analysis and effective communication, NORD-STAR aims to enable Nordic stakeholders to design and implement successful adaptation policy and practice. NORD-STAR fosters a strategic approach to climate adaptation, making a novel contribution to the Nordic adaptation knowledge base. NORD-STAR is funded by the Norden Top-Level Research Initiative sub-programme "Effect Studies and Adaptation to Climate Change".


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