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# Forest-based bioenergy in Norway's green transition: Balancing production and other societal interests


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**Abstract:** This report explores the potential of bioenergy from forests to contribute to the green transition of society. Forest biomass is the largest potential bioenergy source in Norway, in the form of firewood, chips for heating, and biofuels. Firewood and chips for firing can be produced locally and small-scale, whereas biofuels must be produced at industrial and large scale - also implying more industrial logging practices. Bioenergy must compete with other societal needs, especially timber for buildings and fiber for industry, which have higher value. In addition, forests provide eco-services like nature protection for biodiversity, carbon storage as a climate measure, as well as an arena for outdoor activities. In this report I first examine available forest resources for bioenergy in Norway, then assess how bioenergy production can be balanced with nature protection and outdoor activities in Oslo and Viken county. This assessment is based on interviews with stakeholders from forest owners, industry, environmental organizations, and authorities. There are unused forest resources for bioenergy in Norway based on biomass with lowest quality. Increased biofuel production requires large investments in production facilities and depends on higher prices and more taxing of fossil fuels. Local logging and firewood production is easier to combine with nature protection and outdoor activities than industrial logging for biofuels, timber, or fiber production. Conflicts with other societal interests is reduced if more forest areas are protected, especially in the vicinity of cities, whereas other areas are open for logging.

**Language of Report:** English

# Contents

# Foreword

Funding from the INCLUDE FME (The Research Council of Norway, project no. 295704) is highly appreciated. I thank Tor Håkon Jackson Inderberg, Frode Longva and Anders Tønnesen for valuable comments that have improved this report.

# 1 Introduction

Increasing the share of bioenergy is often perceived as a vital part of the green transition of the energy system and societies. Forest is the largest potential source of biomass to produce bioenergy in Norway. The two main categories of bioenergy from forest are *bioheat*, which can be divided into firewood, pellets, and chips for firing, and the other is *biofuels*, which can be divided into bioethanol and biodiesel (bio-oil).[1] Currently the most profitable use of forest biomass is the production of timber for buildings and fiber for industry. Firewood, pellets, and chips for firing have lower value, which is also the case for biofuels from forest biomass such as bioethanol (Treindustrien 2016; TFB 2016). Many homes and cottages in Norway traditionally use firewood for space heating in the cold season, even though production has been substantially reduced over the last decade (SSB 2021).

Active forestry and more use of trees and bioenergy can reduce Norwegian carbon dioxide emissions by 9.5 mill. tons annually in a hundred-year perspective, which can be compared to 18% of current national greenhouse gas emissions (Treindustrien 2016). Regarding the buildings sector, using timber for construction reduces carbon dioxide emissions by 1.6 tonne per $m^3$ tree-based biomass.

Like deployment and production of all energy sources, large-scale production of bioenergy has effects on nature and other societal interests. The ability to meet other sustainability goals will be affected due to trade-offs with alternative land and resource uses. A forest can be used to produce biomass for bioenergy, fiber for industry or timber for buildings, see Figure 1. Forest land can additionally or alternatively be used for storing carbon in trees and soil as a climate measure, protecting ecosystems and biodiversity, and for outdoor activities (Oslo og omland Friluftsråd 2020). Furthermore, logging may indirectly affect climate through changing the albedo effect.[2] Logging practices are important for the potential joint or competing use of forest areas. The green spheres in the figure indicate a clear relation to greenhouse gas emissions and therefore to climate policies.

[1] Biogas is a third category of bioenergy, but the production is based on manure from livestock, waste, and 'prosessavfall skog' (mostly tops and branches from trees), confer Carbon Limits (2019).

[2] The albedo is an expression of the ability of surfaces to reflect sunlight (heat from the sun). For a high albedo or light-colored surface most of the sunlight is reflected, whereas a dark colored surface means that more of sun's energy is absorbed and converted to heat. Thus, forestry practices such as clear cutting and selection of tree species may affect the albedo of land and have an indirect climate effect.

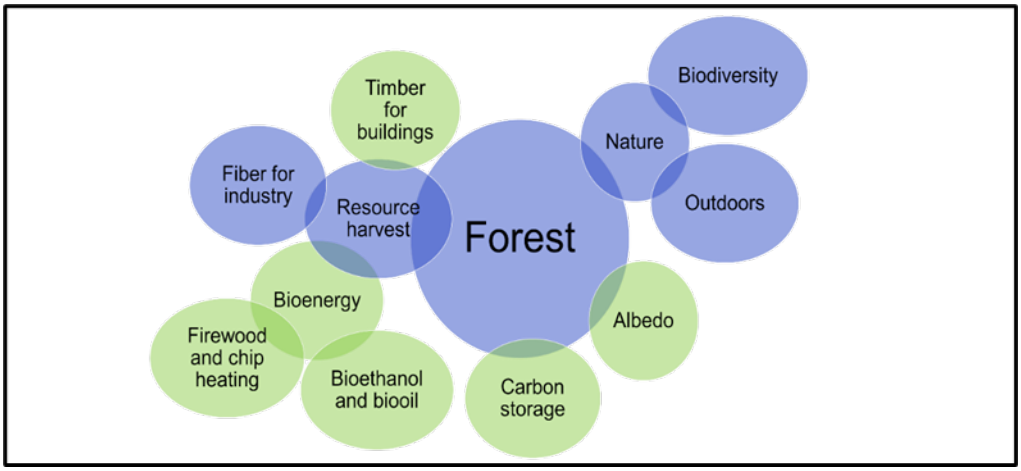


**Figure 1**. Forest management: Land use, nature, resources, and climate. Green spheres have significant climate related implications.

Norway's forest biomass resources allow for more firewood and chip for firing production, based on lower-quality biomass. As part of its climate policies from 2008 Norway has tried to double the use of bioenergy by 2020, but with little success (Bjørnestad 2018).

More recently Norway has introduced a minimum share of biofuels mixing when selling fossil fuels for land-based transportation at 21 % in 2020, which will increase over time and be extended to shipping and construction machines from 2022 (Miljødirektoratet 2021). Since so-called advanced biofuels (based on biogenic waste and forest biomass) receive a double counting in the biofuels mixing regulation, the actual percentage is lower. Norway is importing most of its biogenic resources used for producing biofuels, which may have negative sustainability effects in the exporting countries, e. g. deforestation and lower local food availability (Miljødirektoratet 2021). Against this background Norway is giving priority to advanced biofuels. Given the challenges of certifying sustainability considerations with imports and the availability of forest resources in Norway, this directs attention towards domestic biogenic resources, where forest biomass has the largest potential (Trømborg et al. 2011). However, Norway's industrial capacity to produce bioethanol from forest biomass is very small, and the availability of biofuels at the international market is limited.

Since more countries are interested in biofuel to meet demanding climate targets and due to limited availability of land for biofuel production, the international market will likely become supply-limited, and prices increase. A major reason for low bioethanol production is high cost compared to fossil fuels. The competitiveness of bioethanol will increase alongside an increased carbon price, economies of scale effects that lower the unit production cost, and government regulations such as the biofuel mixing requirement for fuels sold in Norway.

Bioheat production from forest biomass can be done with small investments and at local and small-scale level, whereas biofuels production must be done at large plants and industrial scale to become profitable. Hence bioenergy production from forests can be divided into a local and small-scale type for bioheat and an industrial type for biofuels.

Since biomass from forest may play a larger role for bioenergy production as part of the green transition of Norway, an important research task is to examine the potential for increased production of bioheat and biofuels in a social and local context in terms of consequences for outdoor activities as well as for conservation of nature and biodiversity. In addition, bioenergy production must relate to competition with other and currently more valuable products from forest biomass. This means

that production of bioenergy from forest resources must be balanced with other societal interests, both interests of local people and industry. Against this background the research question is:

**How do local bioheat and industrial biofuel production from forest impact and compare with respect to nature and biodiversity protection, local interest in outdoors activities, and local workplaces?**

I use two methods to examine and compare bioheat and biofuels production and assess their impacts on nature and biodiversity, outdoor activities, and with a view to local employment. The first method is based on a study of documents on Norwegian forest resources and their use, as well as for the region of Viken county and Oslo municipality.[3] The second method used is interviews with stakeholders from forest owners, industry, outdoor and environmental organizations, and authorities. The interviews include questions on impacts from forest-based bioenergy production on competing land uses, and whether there are differences between bioheat and biofuel production. The aspiration is to illuminate different perspectives on bioenergy and differing interests as well as identify opportunities for common ground. To limit the number of interviews I have chosen to focus on stakeholders in the Viken county and Oslo municipality. The findings may be relevant for other Norwegian regions even though there are geographical and context dependencies. Conflicts related to outdoors activities may be more noticeable in Oslo and Viken county than other regions, being the most densely populated area in Norway.

In terms of earlier studies of bioenergy in Norway, Hamilton (2019) presents a broad overview of different biomass sources and energy applications. The potential of bioenergy in an industrial perspective is examined in Norsk Industri og Treforedlingsindustriens Bransjeforening (2016), where the role of forest biomass in a circular economy context is emphasized, but also the dependence on economic and policy conditions that facilitate using this potential. Scarlat et al. (2011) assess the biomass potential of Norway that can be used for bioenergy, discussing experiences from Sweden, Denmark and Finland that can be helpful for Norway, as well as pointing out the importance of industrial integration of bioenergy with other forest-based sectors and the role of support schemes. Trømborg et al. (2011) examine the heat market potentials and technology choices for roundwood harvest and logging residuals in Norway based on data from national forest inventories, which depends on energy prices and support schemes for bioenergy.

In the next section I present an overview of forest resources in Viken county and Oslo municipality as well as for Norway, and how these resources are used for bioenergy purposes. In section three the method in terms of design of interviews is described, followed by a summary of findings from the interviews in section four. In the final and fifth section the main findings are summarized.

[3] Most data sources are referred to in Table 1 and all are included in the reference list.

# 2 Forest resources in Norway and the Viken county and Oslo region

Norway is a country endowed with a large forest covering 37 % of the land area. To assess forest resources in physical and biological terms that could be used for bioenergy we need a closer examination of current production and use as well as future opportunities. I start with the national picture before moving to the region consisting of Viken county and Oslo municipality.

## 2.1 Production and use of forest biomass

Norway's forest area amounts to 12 mill. hectares, out of which 8.6 mill. hectares are considered productive and 6 mill. hectares commercial (Treindustrien 2016). By 2010 the biomass in forests amounted to 900 mill. $m^3$, but the forest is aging and the share of old trees increasing.

The gross annual growth of forest biomass in Norway is at around 25 mill. $m^3$ and the annual logging at around 11 mill. $m^3$, whereas the sustainable use of biomass from Norwegian forests is estimated at about 15 mill. $m^3$ annually, see Figure 2 (Treindustrien 2016). Figure 3 depicts that 46 % of the forest biomass is used for fiber and bioenergy production, around 21 % for timber production, and about 33 % exported (mostly to Sweden) (Prosess21 2020).

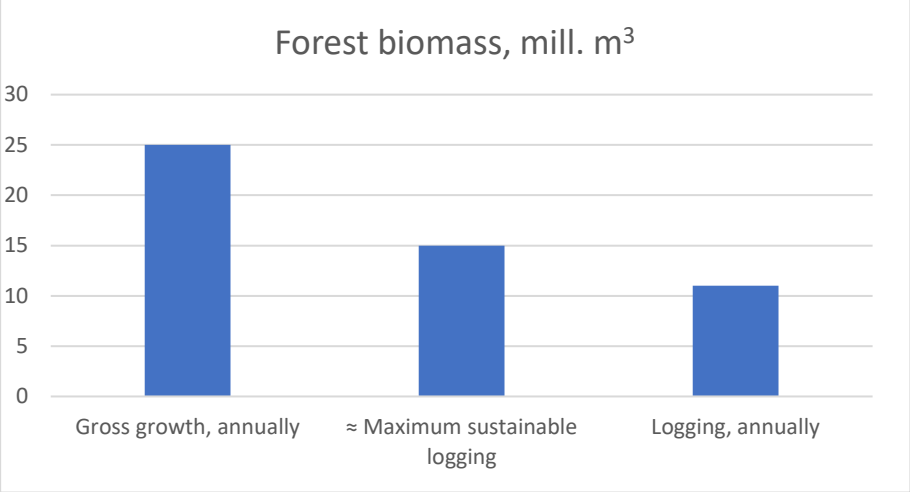


**Figure 2**. Forest biomass and annual logging in Norway, million $m^3$.
Source: Treindustrien (2016).

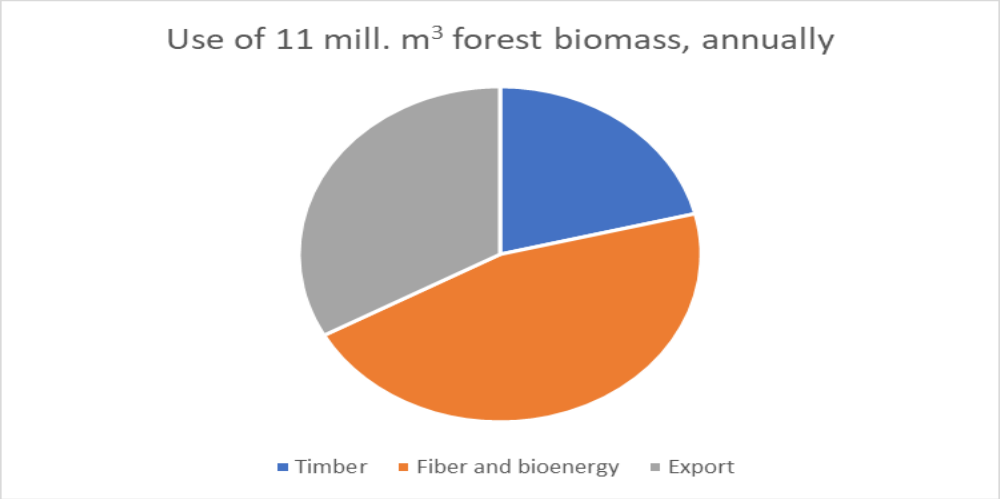


**Figure 3.** Use of forest biomass in Norway, million $m^3$ annually.
Source: Prosess21 (2020).

## 2.2 Bioenergy from forest

In 2019, 18.3 TWh bioenergy was used in Norway, of which 11.9 TWh was produced in Norway and 6.4 TWh imported, confer Figure 4 (Nibio 2021). Two thirds of 8.3 TWh solid biomass came from tree-based biomass, whereas firewood amounted to 5.1 TWh of this, representing 1.8 mill. $m^3$ tree biomass, confer left-hand side of Figure 5. Forest-based bioenergy is supplying about 20% of heating in buildings and industry, representing 72 TWh energy (Treindustrien 2016). In 2016 28% of the bioenergy was used by industry and almost 70% by private households (SSB 2017). 8 TWh was used by district heating and combined heat & power plants, of which 2.5 TWh came from bark, wood chips and trees, representing 1.3 mill. $m^3$ tree biomass, see right-hand side of Figure 5 (Nibio 2021).

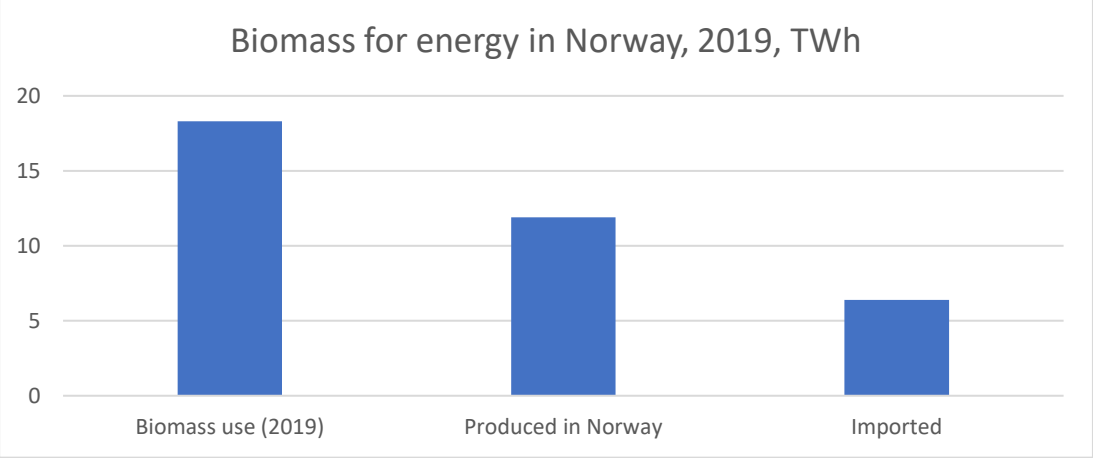


**Figure 4**. Biomass used for energy in Norway, 2019, TWh.
Source: Nibio (2016).

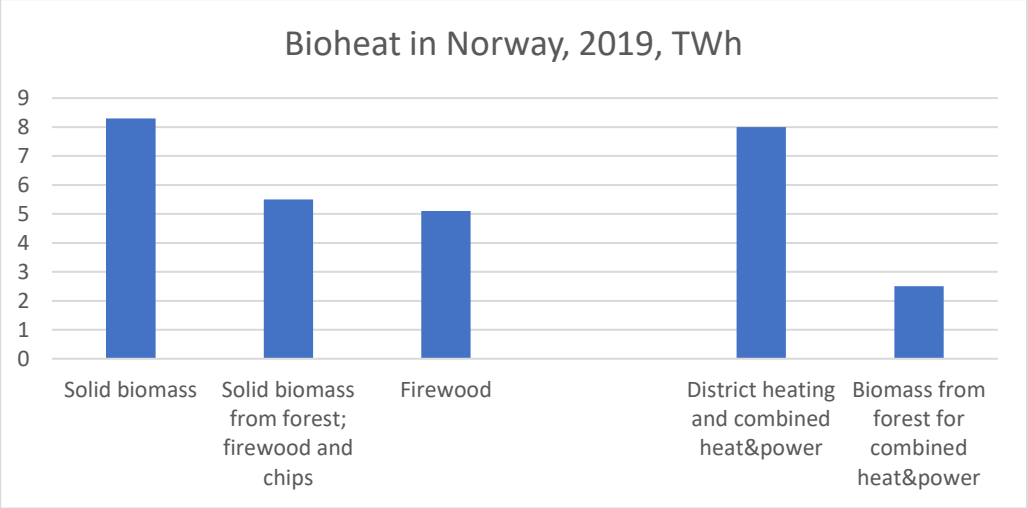


**Figure 5**. Biomass for heat (bioheat) production in Norway, 2019, TWh.
Source: Nibio (2016).

## 2.3 Bioenergy from forest in Viken and Oslo

Moving to bioenergy from forests in Viken county, Table 1 shows some key numbers on growth of forest biomass and its use for energy, including some national figures. Some of these figures comprise both Oslo and Viken county since they are based on reports from 'Fylkesmannen in Oslo and Akershus', and some are referring to the earlier counties Akershus and Østfold.[4] About 20 % of biomass growth in Norwegian forests takes place in Viken and Oslo, whereas logging is at about 25 % of the national level.

Only 20 mill. liters of bioethanol are produced annually in Norway, which are produced as a co-product among other co-products by Borregaard (Borregaard 2021). Out of 1000 kg wood input Borregaard produces about 50 kg ethanol (Klitkou 2013). Borregaard purchases around 1 mill. $m^3$ spruce biomass annually, which is used for a range of products at plants in 16 countries (Borregaard 2020). In addition, the company uses some of the lower-quality materials (such as branches and tops) for fiber production as inputs for the paper & pulp industry.

In most cases biofuels is not price competitive with fossil fuels. Thus, demand for biofuels depends on sufficient pricing of carbon dioxide emissions and other pollutants as well as government support for the development of full industrial industry value chains, such as biofuel refineries (Treindustrien 2016). Large industrial and infrastructure facilities and investments are required for biofuel production, and to make second-generation biofuels (based on waste and forest biomass) attractive for consumers, replacing traditional first-generation biofuels (based on agricultural products).

[4] 'Fylkesmannen i Oslo og Akershus' was renamed to 'Fylkesmannen in Oslo and Viken' after restructuring of Norwegian municipalities and counties in 2017-2020. Later the name was changed to 'Statsforvalteren i Oslo og Viken'.

**Table 1**. Biomass and bioenergy resources from forest.

| **Oslo and Viken** | **Forest biomass and energy** |
|---|---|
| Annual growth | Akershus, Buskerud, Østfold, Oslo:[5] 4.88 mill. $m^3$<br>Akershus and Oslo: 1.2 mill. $m^3$ (2014)[6]<br>Akershus: 0.26 mill. $m^3$ (530 mill. kWh) branches and tops available for bioenergy[7] |
| Annual logging | Goal 2.7 mill. $m^3$ (2020)[8]<br>2.57 mill. $m^3$ (2017)[9]<br>3.11 mill. $m^3$ (2019)[10]<br>0.15 mill. $m^3$ firewood used in Østfold[11] |
| Employees related to forests and forest services | 1,483 (2017)[12]<br>Norway: 5,668 (2017)[13] |
| Norway: Biomass for energy | 18.3 TWh (11.9 TWh produced in Norway) (2019)[14]<br>5.5 TWh of the solid bioheat is tree-based[15]<br>Firewood use: 1.8 mill $m^3$/5.1 TWh (2019)[16] |

[5] Fylkesmannen i Oslo og Viken (2019).
[6] Fylkesmannen i Oslo og Akershus (2016).
[7] Fylkesmannen i Oslo og Akershus (2016).
[8] Fylkesmannen i Oslo og Viken (2020a).
[9] Fylkesmannen i Oslo og Viken (2019).
[10] Fylkesmannen i Oslo og Viken (2020b).
[11] Fylkesmannen i Østfold (2013).
[12] Op. cit.
[13] Fylkesmannen i Oslo og Viken (2019).
[14] Nibio (2021).
[15] Op. cit.
[16] Op. cit.

# 3 Design of interviews

After examining the physical and biological potential of bioenergy production from forest, we turn to interviews with stakeholders to gather assessments of the role of bioenergy in Norway's green transition and the contribution from forest resources. In addition, the interviews include questions on impacts from forest-based bioenergy production on competing land uses, and whether there are differences between bioheat and biofuel production (see Annexes A and B). The interviewees are either directors of their company/organization or have a position with specific responsibility for forest management, use of biomass from forests, or energy and climate. The interview protocol also includes questions on generation of local employment, and the stakeholder's opportunity to and participate in and influence forestry policies and practices. The interview protocol is outlined in Annex A. Altogether eleven stakeholders in Viken county and Oslo municipality are interviewed, representing forest owner organizations, industry, environmental and outdoors organizations, and authorities at county and municipal levels. Considering the limited number of interviewees compared to a much larger number of stakeholders from various organizations and companies in the region the findings from the interviews can only be interpreted as explorative and not representative for Oslo and Viken county. Furthermore, this study does not include data on public opinion in the region, which could have been included through a survey as part of an extended study. The interviews are semi-structured. The answers from the interviews are aggregated and anonymized so individual companies, organizations and individuals cannot be identified. Given the level of generality of questions asked in the interviews the findings may be relevant for other Norwegian regions, even if there will be geographical and context dependencies.

Impacts of logging on nature, biodiversity and outdoor activities depend on forestry practices. Profitable production of timber, fiber and biofuel production requires a larger scale and better-quality biomass as compared to firewood, pellets, and chips for firing production, where the latter bioheat production can be done in a small-scale, local fashion. In both cases impacts to some extent depends on how much tops and branches are removed and whether roots are removed. Roots removal is not common in Norway. Tops and branches can be used for bioheat production but are not suitable as fiber for industry. If large-scale logging is done throughout the year, which has become more common for timber and fiber production, there will be more negative impacts on nature, biodiversity, and outdoor activities due to more soft soil conditions in spring and autumn.

Given the differences between the two logging categories they can with some simplification be coined as Industrial/'plantation' for timber, fiber, and biofuels and local/small-scale for bioheat. Table 2 depicts the two logging modes and the role and impacts of these. This is the basis for questions in the interviews.

**Table 2.** Characteristics of Industrial/'Plantation' logging compared to Local/Small-scale logging.

| **Forestry scenario**<br><br>**Features and consequences** | **Industrial/'Plantation':**<br>**Biofuels, timber and fiber for industry.**<br>Logging: clear-cutting; year around.<br>High biomass quality. | **Local/Small-scale:**<br>**Firewood, pellets, and chips for firing.**<br>Logging: pick harvesting; seasonal.<br>Low biomass quality: branches and tops; deciduous trees. |
|---|---|---|
| Forest-based bioenergy's role in the green transition | | |
| Impacts on outdoor activities | | |
| Impacts on nature and biodiversity | | |
| Impacts on local activity and employment | | |
| Influence on conditions for forestry | | |

As part of the small-scale scenario there is significant firewood production in the informal sector, which is therefore excluded from formal statistics. This includes private and family-based logging and firewood production, sometime in municipality-owned forests by invitation. Some small-scale firewood production by farmers and forest owners sold locally may also be presumed as part of the informal sector.

# 4 Main messages from documents and interviews

I summarize the main findings from the document studies and the interviews in the six categories below. A detailed account of findings from the interviews is given in Annex B.

## 4.1 Bioenergy potential in Norway

- Due to industrial and construction biomass use having higher value, lacking profitability, and small industrial production capacity barriers for bioenergy from forests there are different expectations on the future potential for bioenergy. The general opinion, however, is that bioenergy will play an important but limited role in the green transformation in Norway.
- Bioenergy can reduce some carbon dioxide emissions through replacing black with green carbon.
- Norway has a net forest growth that can contribute to decarbonization of energy.
- Timber and fiber for industry are more valuable products than bioenergy.
- Some interviewees emphasized that biofuels are more expensive and in limited supply and that alternatives such as battery-operation is a better choice for many transportation modes. Against this background there is an argument for prioritizing biofuels for aviation given difficulties of replacing fossil fuels.
- One opinion expressed was that bioenergy from a stable energy system perspective can supplement an increasing share of uncontrollable and intermittent renewable power in Europe.

## 4.2 The role of forest bioenergy

- Forest bioheat production will be based on residual forest biomass.
- Over the next few years bioheat will dominate biofuels since biofuel is not competitive with fossil fuels and production capacity is lacking.
- Given the cost, competitiveness, and production capacity barriers for biofuels in the short term, but a larger carbon dioxide mitigation effect in the long term, some interviewees opinioned that even though it is easier to expand bioheat over the next few years, biofuels may eventually become more important. The demand for biofuels would depend on stricter climate policies, sufficient enabling conditions, and industrial capacity building.
- There are unused resources for bioheat production from lower quality biomass and deciduous trees.
- Bioheat is relevant for buildings, homes, industry, and district heating.
- The carbon dioxide mitigation potential of biofuels is larger than for bioheat due to small use of fossil fuels for heating, compared to dominating fossil-based fuels for transport.
- Some interviewees referred to reports such as DNV (2021), showing that large-scale and sustainable biofuel production (based on waste; for aviation) is not possible due to resource shortage.

## 4.3 Impacts on outdoor activities

- Depends on logging practices, where large-scale 'industrial' logging has more impacts than local and small-scale logging.
- Small impacts and conflicts if logging practices acknowledge other interests, e. g. through reduced clear cutting and more protection of areas with 'nature forest'.
- Most interviewees expressed that there would be fewer conflicts if more forest is protected and logging only allowed in other areas.
- Forest management should be especially sensitive to demand for outdoor activities in the vicinity of cities.

## 4.4 Impacts on nature and biodiversity

- We must establish a balance between forest resource use, profitability, protection of biodiversity, and climate.
- The risk of conflicts with outdoors interests and biodiversity is higher for industrial logging for timber, fiber, and biofuels, requiring higher quality biomass, than for local and small-scale firewood, pellets and chips for firing production.
- Logging practices must respect nature and biodiversity considerations.
- Almost all logging in Norway is biodiversity certified (PEFC, FEC standards).[17]
- Many interviewees think that more of the 'nature forest' areas should be protected to better balance different societal interests.

## 4.5 Impacts on local activity

- Local and small-scale logging activity from farmers and forest owners producing and selling firewood and chips for firing supplement their main agriculture activity.
- Investment in biofuel production will generate employment from a wider district.
- Some interviewees emphasized that although biofuel production will likely become more important in the future, investment in production plants and infrastructure will take several years and depend on favorable business conditions.

## 4.6 Influence on policy development

- Opinions on the ability to influence policies and business conditions for forestry and logging vary among the stakeholders interviewed, although all think that they have some influence. In general forest owners and industry express more confidence in their ability to influence policies than environmental and outdoor organizations.
- There is a challenge to align forest policies with EU since EU is prioritizing eco services from forest as opposed to Norway's higher prioritization of producing biomass for timber, industry, and to some extent bioenergy.

[17] All certification systems have weaknesses and cannot include all elements that some stakeholders consider relevant, and they must be sufficiently adapted to local conditions.

# 5 Conclusions

This study shows that bioenergy based on forest biomass has the potential to become an important although limited part of the green transition of Norway. Currently, however, bioenergy from forest is significantly constrained by the more profitable timber production for buildings and industry use of fiber, leaving the lowest quality biomass for firewood, pellets, and chips for firing production.

Biofuel production from forest biomass is not competitive with fossil-based fuels but is facilitated by Norway's biofuel mixing requirement for diesel and gasoline sold for land transportation. Biofuel production in Norway is also hampered by very low industrial production capacity and a need to import almost all the biogenic resources for production. Over time, with higher carbon taxes and prices, the competitiveness of biofuels compared to fossil fuels will increase.

Due to the necessity of industrial scale production and efficient logging practices, biomass production for timber, industry fiber and biofuels will have more negative impacts on nature, biodiversity, and outdoor activities than bioheat production. Contrasted to this, bioheat production (firewood, pellets, and chips for firing) can be done locally and small-scale due to modest required investments in equipment, thereby providing a valuable additional local employment and income for small forest owners and farmers.

The potential greenhouse gas mitigation effect is higher for biofuels than bioheat since alternative space heating is mostly based on (green) power. Biofuels might be especially interesting as an aviation fuel due to few existing alternatives to fossil-based fuels.

Dependent on logging practices, there are some conflicting interests between forest owners, industry, and outdoor and nature protection organizations, where government at municipal and county levels tries to balance these interests. Generally, forest owners and industry have a more biomass resource-based attitude towards forest management but believe that they have been sufficiently responsive to other societal interests, whereas outdoor and environmental organizations are more concerned about environmental services from forests and find that these interests in some cases are given lower priority than commercial logging. Almost all logging in Norway is biodiversity certified. Potential conflicts with other land uses could be reduced if more 'nature forest' is protected, especially areas in the vicinity of cites since the surrounding forests have a higher societal value for outdoor activities than forests in rural regions.

Forest owners and industry in Norway endow a higher value to forest resources for timber and fiber for industry production than EU, whereas EU emphasizes the environmental and climate services of forests, such as climate mitigation through carbon storage, protection of nature and availability for outdoor activities.

# Annex A. Interview protocol

- A short narrative on the Include project and the bioenergy sub-project as background for the interviews.
- Personal background: Name; home municipality; working place; position. Using firewood in house and/or cottage. Fuel type of car(s). Distance to forest area and involvement outdoors activities.
- How important do you think bioenergy will be as part of a green and climate-friendly transition of Norway?
- How important will bioenergy based on biomass from forest be in Norway's green transition?
- How important do you think bioenergy from forest will be compared to production of timber and fiber for industry?
- Which will have the greatest fossil energy reduction and climate gas mitigation potential, bioheat for buildings in the form of firewood/pellets and biomass for district heating plants, as compared to production of bioethanol for the transport sector?
- What positive and/or negative consequences do you expect from increased forest biomass production at local and national level, especially in terms of outdoors activities, nature, and local activity/employment?
- Do you expect different positive or negative consequences for firewood and biofuel production?
- What is your expectation regarding your company's/institution's/organization's ability to influence the strategy, plans and activities for production of bioenergy from forests?
- Would you expect any differences comparing firewood and biofuel production in terms of your company's/institution's/organization's ability to influence strategy, plans and activities for production of bioenergy from forests?
- Other comments.

# Annex B. A detailed account of the interviews.

**Table B1.** Summary of interviews.

| Stakeholder<br>Potential, effects | Forest owners | Industry | Organizations | Government |
|---|---|---|---|---|
| The potential of bioenergy | Bioenergy will play an important role.<br>Unused potential of deciduous trees.<br>Can supplement variable sun and wind power.<br>Biofuel production requires higher-quality biomass than bioheat.<br>Large-scale biodiesel production is not realistic due to shortage of sustainable resources (waste). | Bioenergy from forest will play a small role since biomass for timber and fiber is more valuable.<br>Prioritize green replacement of black carbon where fossil removal is difficult.<br>A circular economy and efficiency perspective should be applied.<br>Biofuels for aviation should be prioritized.<br>Industry must aim for the highest-value products made from biomass.<br>Large investments in biofuel plants are needed.<br>Resource shortage for sustainable biofuels production (waste based). | Bioenergy may become important but should not be overrated. Bioenergy will be a less important energy source.<br>Biofuels are currently not competitive with fossil fuels.<br>Timber and fiber are more important forest products.<br>Bioheat is lowest on the resource hierarchy.<br>A circular economy perspective is important.<br>Biomass resources will become more valuable. Biofuels require less engine modifications in transport and new infrastructure than electric alternatives.<br>Bioenergy can reduce power demand peaks. | Better energy efficiency should be in focus first. The top of forest biomass value/resource chain should be prioritized.<br>The forest can make a significant contribution to the green transition. Norway has a net forest growth and not all the biomass is suitable for fiber and timber.<br>Large-scale biodiesel production is not realistic due to shortage of sustainable resources (waste). |
| The role of forest bioenergy | More sustainable logging in Norway is possible.<br>More important for green carbon to replace fossil fuels than using forests for carbon storage.<br>Most important forest products are timber and fiber for industry. Bioenergy must be based on residual and lower-quality biomass.<br>In the short term bioheat is more important than biofuels. | Bioheat is more important than biofuels and can be based on less valuable forest resources. Bioheat for big buildings and district heating is interesting.<br>Biofuels can be attractive for airplanes.<br>Currently, biofuels have too low value.<br>For next decade bioheat will be more important than biofuels.<br>The climate effect of bioheat is debatable. | Tree resources such as branches and tops, and areas along road edges can be used for biomass for heat production without competition with higher value uses.<br>The 2 mill. $m^3$ forest biomass exported to Sweden could be processed in Norway.<br>Potentially, biofuels have a larger potential to reduce GHG emissions than bioheat but depends on i. a. climate policies. | Forest bioenergy has an important role but competes with higher value fiber and timber production. Bioenergy from forest should be based on lowest-quality biomass.<br>Biofuels can be used with existing infrastructure and plants, and likely has more emission mitigation potential than bioheat.<br>Bioheat is suitable for larger district heating.<br>Small-scale bioheat production is necessary and important. Smaller market for firewood in cities due to new pollution restrictions.<br>Parks and other green areas in cities could be forested. |

| Stakeholder<br>Potential, effects | Forest owners | Industry | Organizations | Government |
|---|---|---|---|---|
| Effects of bioheat and biofuels production - *Outdoors* | A good dialogue with environmental and outdoors NGOs is important.<br>Logging must adapt to people's outdoor and nature interests.<br>There are some conflicts related to 'nature forest'.<br>Some challenges from environmental NGOs.<br>Avoid big conflicts with other societal interests.<br>Should be more sensitive to outdoor interests around cities. | Logging needs to be acceptable to people.<br>The forestry sector must be sensitive to outdoor interests and nature, especially near cities, e. g. implying more pick harvest. | Increased bioenergy and 'plantation' production can negatively impact nature, biodiversity, and outdoors activities. More conflicts on logging and land use close to high-productivity areas in vicinity of cities. Small conflicts elsewhere.<br>Impacts depend on land use and logging practices.<br>Increased bioenergy production may imply more industrialized forestry.<br>Logging year around has more negative impacts than seasonal logging.<br>People do not like dense forests. | More forest areas should be protected near cities, which would reduce land use conflicts.<br>The relation to outdoors and nature interests is ok since forest management emphasizes smaller logging areas, avoiding nature forest, and removes branches (that make hiking more difficult). Logging year around has more negative impacts than seasonal logging. |
| Effects of bioheat and biofuels production - *Nature* | Need balance between forest resource use and profitability, biodiversity and climate.<br>Timber, fiber and biofuel production require better lumber quality than bioheat.<br>Some areas are protected.<br>Almost all logging is biodiversity certified. | Small effects on nature and since pollution is well handled.<br>Forest management must be sensitive to outdoors activities and biodiversity.<br>Almost all logging is PEFC/FEC biodiversity certified. | Forest management works well with outdoor interests and biodiversity.<br>Logging has few negative biodiversity effects.<br>Clear cutting can reduce soil quality and increase pollution from water runoff.<br>Pick harvest and logging of deciduous trees for bioheat has fewer negative impacts.<br>In need of more research on logging's effects on nature.<br>Imported forest resources must be sustainably produced.<br>In Oslo, forest management is environmental-friendly. | Small negative impacts given sensible logging, e. g. avoiding removal of tree stubs and branches.<br>Nature forest more impacted by fiber and timber production since such production require higher-quality biomass and more clear cutting. Conflicts are mostly caused by industrial logging.<br>Logging in grazing land for sheep and other ruminants ('kulturlandskap') can be important for biodiversity.<br>Oslo portrays its forest management practice and logging as more balanced with other societal interests. |

| Stakeholder<br>Potential, effects | Forest owners | Industry | Organizations | Government |
|---|---|---|---|---|
| Effects of bioheat and biofuels production – *Local workplaces* | Large investments in biofuel production and infrastructure are needed, which are risky due to dependence on i. a. future climate policies. | | Stabile economic/political conditions are important for private investments in forest products.<br>Logging for firewood can be done small-scale and locally, whereas biofuel production is centralized industry.<br>Local compared to central value creation - These can complement each other.<br>Importing biomass for biofuel products can make sense to develop market later for domestic resources. Positive local activity impacts from bioheat production for forest owners.<br>Will take more time to develop biofuels. | Public procurement could be more used to develop bioenergy markets. |

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