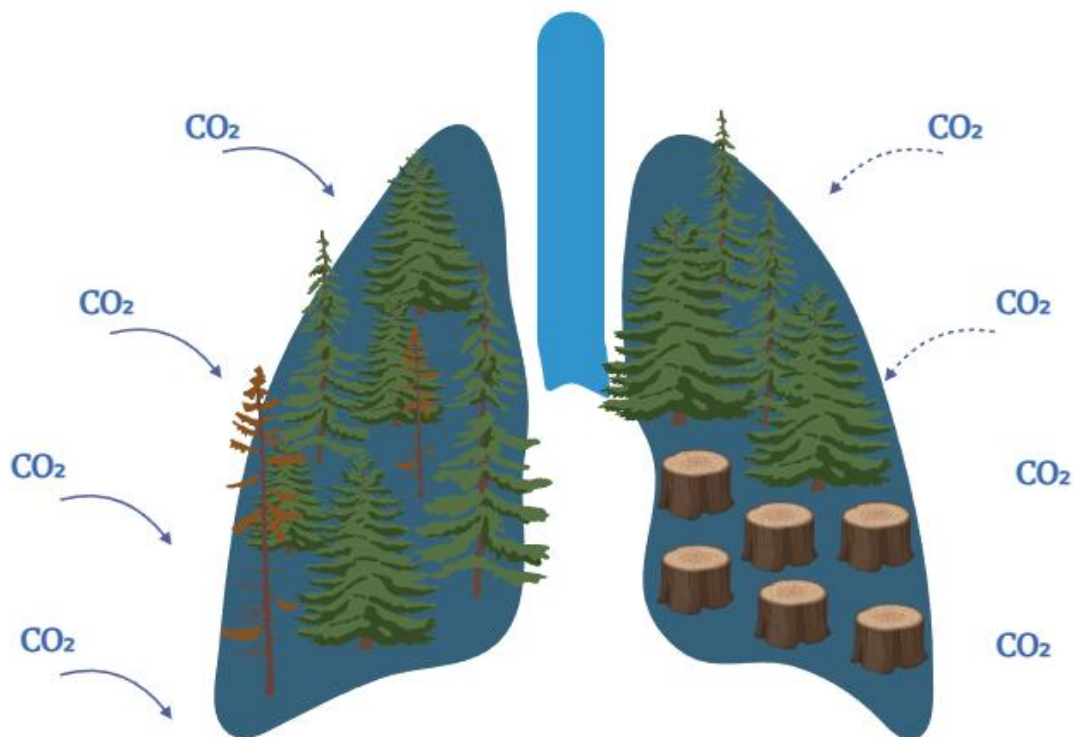


The Role of LULUCF in Sweden's Energy Transition



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Abstract

The land use, land-use change, and forestry sector (LULUCF) has historically been rather unregulated. Recent political developments have put pressure on countries to implement practices that increase net greenhouse gas (GHG) removals and improve the state of carbon sinks. One of these political developments is the European Union's (EU) LULUCF Regulation, which as of now obligates Member States (MS) to meet binding removal targets. Another political development on the climate front is the energy sector's ambition to reach net-zero. Sweden is an interesting case as the country has one of the largest forest carbon sink and the highest share of renewable energy sources in the EU. Within the total energy-mix, around 30% consists of biomass where forest products account for over 80%. On these grounds, this study examines how the energy sector may be affected by the integration of the LULUCF Regulation. This is done by examining the Swedish Energy Agency's report which outlines four scenarios that predict how the energy system will reach net-zero GHG emissions by 2050. The analysis examines opportunities and challenges which arise when the sector becomes more regulated. Adopting a mixed-methods approach, the study assesses the extent to which each scenario may need to adapt to a future where biomass availability changes and carbon sinks are increasingly regulated. The findings reveal that the energy transition may be on firmer footing than previously assumed, however, the continued reliance on biomass without integration of the LULUCF sector risks undermining climate targets and intensifying conflicts of interest. If Sweden is to maintain its path toward a net-zero energy system, it is essential for harmonisation across climate, forestry and energy policy.

Hur många roller ska skogen ta sig an?

Skogen *kan* ta an många olika roller. Den kan vara en vacker vandringsmiljö. Kanske ett förvaringsutrymme för koldioxid? Eller till och med en viktig källa för bioenergi. Skogens förmåga att bidra med flera funktioner är fantastiskt men precis som andra naturresurser är förrådet begränsad. Dessutom är skogen en central del i klimatarbetet där dess funktion som kolsänka kan bidra till klimatmål. Historiskt sett har markanvändning och skogsbruk, den så kallade LULUCF-sektorn, varit svagt reglerad. Vad händer då när EU ställer hårdare krav på hur mark och skog får brukas? Denna studie undersöker relationen mellan skogssektorn och energisektorn i Sverige. Det visar sig att landet behöver stärka insatserna för att nå de nya målen för kolsänkor. Å andra sidan pekar studien på att energiomställningen kan vara mer robust än vad man kan tro.

Skogssektorn och energisektorns samband är möjligtvis inte uppenbar vid första anblick. I Sverige kommer omkring 30 procent av den totala energitillförseln från biomassa, där mer än 80 procent har sitt ursprung från skogen. Samtidigt är Sverige ett av de mest skogsrika medlemsländerna i EU. Detta gör landet till ett spännande fall: det har både en av EU:s största skogliga kolsänkor och en av de högsta andelarna förnybar energi. För att ytterligare röra om i grytan har EU infört en LULUCF-förordning. Lagen sätter bindande mål för hur mycket koldioxid som ska tas upp i skog och mark över hela unionen. I samma veva har Sverige satt upp planer för att energisektorn ska nå nettonollutsläpp till år 2050.

Studien gör ett försök att reda ut den knepiga situationen genom att tillämpa både kvalitativa och kvantitativa metoder. Fokuset ligger på hur EU:s LULUCF-förordning kan påverka energisystemets omställning, särskilt tillgången på bioenergi. Analysen bygger på Energimyndighetens fyra framtidsscenarier som beskriver hur Sverige ska nå ett klimatneutralt energisystem till år 2050. Flera av de framtida scenarierna visar en minskad användning av biomassa, vilket kan underlätta föreningen av klimatmål för både skog och energi. Samtidigt visar resultaten att utvecklingen är beroende av hur EU:s klimatpolitik utformas i praktiken. Om efterfrågan på bioenergi ökar, exempelvis till följd av nya styrmedel, kan det skapa målkonflikter mellan skogens roll som kolsänka och dess användning som energiresurs. Genom att bättre samordna regelverk för markanvändning, skogsbruk och energi kan politiken bidra till både minskade utsläpp och ett hållbart nyttjande av skogen.

Ett viktigt fynd är att en ökad reglering av skogssektorn inte nödvändigtvis står i konflikt med energiomställningen men att den kräver bättre samordning mellan politikområden. Till exempel, myndigheter uttrycker oro kring osäkerheter om genomförande och rapportering. Myndigheterna visar sig vara överens om att det krävs en bättre samordning mellan aktörer för att underlätta införandet av LULUCF-lagen. En kanske inte så överraskande insikt är att skogens olika roller kan komma att ändras. När fler aktörer vill nyttja skogens resurser för olika ändamål, blir målkonflikter oundvikliga. Studien trycker därmed på vikten av att se klimat-, skogs- och energipolitik som delar av samma system, snarare än som separata.

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Abbreviations

LULUCF - Land use, land-use change, and forestry

SEA - Swedish Energy Agency

SEPA - Swedish Environmental Protection Agency

SFA - Swedish Forest Agency

EU - European Union

MS - Member States

COM – European Commission

CO₂ - Carbon dioxide

CO_{2e} - Carbon dioxide equivalents

TWh - Terrawatt Hour

MWh - Megawatt Hour

Mt - Million tonnes

GHG - Greenhouse gas

BECCS - Bioenergy with carbon capture and storage

LEC - Local Environmental Consideration

GEP - Global Environmental Perspective

RS - Regional Supply

IG - International Growth

1. Introduction

The pressing challenges of climate change and environmental degradation has become a greater political priority over the past decade. These issues pose a substantial risk of harming integral parts of our society. As a response, various sectors have increased their efforts to achieve sustainable transitions with the goal of reaching net-zero greenhouse gas (GHG) emissions. An example of this is the energy sector, which is responsible for the largest source of carbon dioxide (CO₂) emissions globally (IPPC, 2023). Countries such as Sweden have become a frontrunner in decarbonising its energy system, with renewable sources such as wind, solar, hydrogen, and biomass accounting for 68% of the total energy supply in 2023 (SEA, 2025a). However, the energy sector is not alone in implementing measures to achieve a sustainable transition.

LULUCF stands for land use, land-use change, and forestry, and the sector has potential to contribute to climate and environmental targets by functioning as both a source and sink for GHG emissions (Kostevica and Blumberga, 2024). The sector has historically been quite unregulated until recently, with policies starting to be implemented to regulate emissions and removals (Sasso, Savaresi and Vesa, 2025). An example of this is the LULUCF Regulation which was first implemented as part of the European Union's (EU) Fit for 55 package. The Regulation was later revised in 2023 to involve binding targets for MS to achieve by 2030, collectively aiming to increase the net carbon sink to 310 Mt CO₂e for the whole EU (European Parliament and Council, 2023).

At first glance, these two sectors may not appear to be closely related. However, let us take the example of Sweden which has set ambitious climate and energy goals. The Swedish Energy Agency (SEA) has in a report outlined four different scenarios that predict how the country will achieve net-zero GHG emissions within their energy sector by 2050. At the same time, the country's renewable energy supply consists of 30% bioenergy in which forests account for over 80% of this production (SEA, 2025a). This brings us to the important intersection between the energy and LULUCF sectors. Sweden is one of the EU's most forested MS which faces challenges of balancing bioenergy production with the management of its forest carbon sink under the revised LULUCF Regulation. At the same time, the SEA's possible outcomes have decided to not consider the LULUCF sector in the scenario assessments. The current situation leads to various questions left unanswered, and this study aims to fill the knowledge gap.

Understanding the relationship between Sweden's energy transition and the LULUCF sector requires a review of current research. Therefore, the following sections presents a brief background to map out the building blocks of the research field by identifying key concepts and central findings. The section is structured by first a contextualisation of Sweden's energy system and the role of bioenergy, followed by an examination of LULUCF, the broader energy transition and the competing interests which shape governance.

1.1 The Swedish energy system

Sweden has come far in its energy transition, with national electricity production essentially being fossil-free (SEA, 2025b). Electrification has been one of the primary tools to replace fossil fuels, and the government emphasises on the continued expansion of fossil-free electricity being central to the transition. The SEA's system consists of a mix of supply of renewable sources such as water, wind, sun and biomass, as well as import of energy products such as nuclear fuels, biomass, fossil fuels, and natural gas (SEA, 2025a). The total energy supplied for the year 2023 was 508 TWh and this is expected to increase to 520 TWh by the year 2028. Historically, the supply of bioenergy has increased steadily since the 1980s and has tripled over the past 40 years (SEA, 2025a).

As a guideline for the energy transition, the SEA has presented four exploratory scenarios which visualise the path to a net-zero emissions energy system by 2050 (SEA, 2025b). The main purpose of these four scenarios is to increase the understanding of potential opportunities and challenges facing the energy transition. Each scenario considers two main variables: different levels of globalisation and environmental concern. These scenarios are used throughout this study as a foundation to understand the complexity of integrating the LULUCF sector in Sweden's energy transition.

1.2 Bioenergy

While the energy transition has been widely examined and discussed (Ellison, Lundblad and Petersson, 2014; Christiansen and Carton, 2021; Petersson et al., 2022), less attention has been given to how it interacts with the LULUCF sector and the implications this may have for national energy and climate targets. The interlinkages between forest management, bioenergy production, and carbon accounting under the revised LULUCF Regulation remain complex and underexplored. Understanding these dynamics is crucial for ensuring Sweden's transition toward a fossil-free energy system does not compromise its forest carbon sink or its ability to meet EU climate commitments.

There may appear to be two main arguments why this interaction is underexplored; the energy transition is more dependent on electrification, and there are various uncertainties regarding the development of future biomass supply. However, biomass continues to be a central component in Sweden's energy system and forest-based bioenergy is a key contributor to district heating, combined heat and power, industrial process heat, and the production of transport biofuels (Börjesson and Björnsson, 2024).

Sweden's long-term climate strategies also assign an important role to bioenergy with carbon capture and storage (BECCS), which is expected to deliver a significant share of future negative emissions (SEA, 2025b). As a result, demand for forest biomass is shaped not only by energy needs but also by national climate mitigation planning. However, the larger part of bioenergy supply is ultimately dependent on forest growth and harvest levels. Recent developments, such as declining net removals, increased natural disturbances, and stricter EU land-use regulation, suggest that biomass availability cannot be assumed to remain constant (Nabuurs, Arets and Schelhaas, 2013; Borovics, Király and Kottek, 2024; Sasso, et al., 2025). Under the revised LULUCF Regulation (EU) 2023/839, harvested biomass reduces the net carbon sink, meaning that higher extraction for energy can constrain Sweden's ability to meet its binding removal targets.

1.3 LULUCF

There seems to be a consensus within the literature that the LULUCF sector plays a crucial role in achieving the 2050 climate neutrality goal (Kostevica and Blumberga, 2024; Jonsson and Sotirov, 2025; Sasso, et al., 2025). The sector accounts for both CO₂ emissions and removals due to the wide range of land management practices it covers, such as croplands, grasslands, wetlands, forests and settlements (Kostevica and Blumberga, 2024). Further agreement among researchers is that forests represent one of the most significant carbon sinks which makes it essential in offsetting emissions from other sectors (Sasso, et al., 2025; Jonsson and Sotirov, 2025). However, the capacity of forests as sinks is influenced by several factors, such as forest age, management practices, and natural disturbances such as wildfires or pest outbreaks. Furthermore, land-use changes like deforestation or conversion to other land types can reverse the sink function and may instead turn forests into sources of GHG emissions (Savaresi, Perugini and Chiriaco, 2020).

Due to the importance of the LULUCF sector, certain policies have been implemented to improve the current and future situation. As part of the Fit for 55 package, a proposal was put forward to revise EU Regulation 2018/841 on GHG emissions and removals from the LULUCF sector, which was adopted as Regulation 2023/839 in 2023. The revised Regulation introduces binding targets for MS to increase the net carbon sink to 310 Mt CO₂e for the whole EU. This commitment is an increase of 42 Mt compared to the reference period 2016-2018 (Hyyrynen, Ollikainen and Seppala, 2023). The revised Regulation maintains several flexibilities available to MS, most notably the possibility of excluding the impacts of natural disturbances on the carbon sink and the option to transfer surplus targets to either the ESR or other MS (SEPA, 2025a).

Even though the revised Regulation is an important step towards strengthening the LULUCF sector and its contribution to the EU climate goals, various challenges remain. For example, Kostevica and Blumberga emphasise on the necessity for collectively addressing GHG emissions by profitable economic strategies (2024). They address how challenges arise due to the economic, social and geographical differences of MS which leads to competing interests. Furthermore, achieving the increased targets will require extensive efforts from MS, including improved land management practices and the restoration of degraded ecosystems (Hyyrynen et al., 2023). In conclusion, while the revised framework provides a stronger regulatory basis, its successful implementation will depend on effective national policies and coherent integration with existing climate strategies.

1.4 Energy transition

Reaching the topic of coherent integration with existing climate strategies, certain factors are compelling to dig further into. Let us take the example of energy, where Sweden's energy and climate policies combine market-based instruments with regulatory measures and strategic investments. Since the 1980s, the supply of biomass has tripled and around 30% of energy in 2023 comes from biomass (SEA, 2025b). Forests account for over 80% of this bioenergy (SFA, 2020). This demonstrates an important link between the forestry sector, the LULUCF framework, and the energy transition.

Booth and Giuntoli perform a study examining the adopted EU criteria which consider “sustainable” forest biomass to have net-zero carbon emissions (2025). The authors discuss how policy incentives for bioenergy such as carbon capture and storage (BECCS) may lead to increased pressure on forests (Booth and Giuntoli, 2025). Their study is concluded with three recommendations; 1) integration of biomass regulation with climate targets and cease the definition of forest biomass as “renewable energy”, 2) end subsidies for forest biomass in renewable energy production, and 3) manage forests with nature and climate as primary considerations. The authors emphasise on the importance of re-naturalising forests as a strategy for addressing climate change and biodiversity loss (Booth and Giuntoli, 2025).

Other research has reached similar conclusions as Booth and Giuntoli. For example, Hyvönen et al., examine northern European countries and their national energy and climate plans (NECPs) (2024). The study assesses how exposed the NECPs are to resource limitations and techno-economic risks by comparing the plans to national statistical energy use data. They discuss the problematic factors of biomass consumption as being one of the main sources of renewable energy and the high reliance on biomass in the NECPs. For example, Finland’s high usage of biomass in the national carbon neutrality strategy could substantially reduce available carbon sinks in the LULUCF sector (Hyvonen et al., 2024)

On the other hand, some scholars argue that forest biomass may support climate mitigation if applied under good conditions. McKeough (2019) proposes a global strategy for forest utilisation which balances mitigation with continued forestry. The study claims that while biofuels from stem wood initially cause net emissions, their long-term use and replacement of fossil fuels can lead to cumulative CO₂ reductions. The duration of this initial emission period depends on factors such as forest growth rates, the type of fossil fuel replaced, and whether residues are used or not. The study also critiques current EU policies for penalising producers rather than consumers and suggests that climate-beneficial biomass options should be more incentivised (McKeough, 2019)

The current literature indicates that climate impacts of biomass within the energy transition vary depending on the source, national context and policy framework. This underscores the need for governance which aligns bioenergy use with the LULUCF objectives, biodiversity protection, and long-term carbon storage.

1.5 Competing interests

1.5.1 The EU

As a result of the current situation, there is an active debate about the role of the forests in the energy transition as a measure of moving away from fossil fuels towards more renewable resources (Börjesson and Björnsson, 2024). Forests are expected to deliver several different services simultaneously which leads to competing interests among participating actors. For example, some researchers emphasise on the risk of forests being caught in a demanding situation due to the conflict between societal demands and political necessities. Therefore, the EU should prioritise policies which have broad social consensus in which no specific interests should necessarily dominate (Köhl et al., 2021). Nevertheless, the EU has taken an important step to regulate the LULUCF sector which previously was heavily unregulated. Whether these efforts will be met remains uncertain, and cultural, economic, social, political and scientific factors play an essential role in determining their success (Sasso et al., 2025)

Furthermore, while the LULUCF sector currently accounts for a relatively small but stable share of total EU GHG removals, around 6.5% on average, this contribution has been decreasing in recent years (Dagiliūtė and Kazanavičiūtė, 2025). EU's climate goal to reduce GHG emissions by 80% by 2050 puts increasing expectations on the sector, especially as the remaining 20% of emissions are expected to be offset through land-based carbon sinks which thereby supports the transition to a carbon-neutral economy (Dagiliūtė and Kazanavičiūtė, 2025). This raises the concern of the continued reliance on wood as a major energy resource which leads to risks of competition over forest land and biomass (Frank et al., 2016; Lefvert and Gronkvist, 2024).

The governance of forests within the EU is further complicated by the presence of competing policy coalitions and ideological divisions that shape environmental forest policymaking. As, Sotirov, Winkel and Eckerberg (2021) demonstrate, EU forest policy is characterised by a long-standing divide between two major advocacy coalitions; an *environmental coalition* that promotes biodiversity conservation, stricter environmental regulation, and stronger EU-level integration, and a *forest use coalition* that prioritises economic utilisation, bioeconomy growth, and national sovereignty over forest management.

This ideological divergence is also reflected institutionally, as environmental coalitions tend to align with EU bodies such as the Commission's Directorate-General for Environment (DG ENV) and the European Parliament's Committee on the Environment (ENVI), while the forest use coalition collaborates more closely with DG Agriculture and Rural Development (DG AGRI), DG Trade, and the Committee on Agriculture (COMAGRI). Forest-rich member states such as Sweden and Finland typically support the forest use coalition, opposing what they perceive as increasing EU interference in national forestry affairs. In contrast, forest-poor countries like Belgium, Denmark, and the Netherlands often support stronger environmental integration at the EU level (Sotirov et al., 2021)

The resulting policy landscape is therefore one of compromise, where the revised LULUCF Regulation represents not only a technical accounting framework but also a political balancing act between these coalitions. While environmental actors advocate for stricter carbon accounting and conservation-focused policies, forest sector representatives argue that such restrictions undermine the contribution of the forest bioeconomy to climate mitigation through material and energy substitution. These competing interests highlight the difficulty of achieving coherent EU-wide forest governance, as policy developments often reflect shifting power dynamics between coalitions rather than a unified vision for the role of forests in climate policy (Sotirov et al., 2021).

1.5.2 Sweden

Sweden's contribution to the LULUCF sector is considered significant due to the country's vast forested area and international recognition as a climate frontrunner. However, just as other climate-and energy issues, there appears to be competing interests at national level. For example, the factors which affect the future usage of biomass from forests are uncertain (Petersson, et al., 2017; Börjesson and Björnsson, 2024). The demand for biobased material is expected to increase globally whilst the requirements on forests functions as ecosystem services also increase. New legislation, such as the revised LULUCF Regulation, can lead to constraints on forest owners and their land-management practices (Börjesson and Björnsson, 2024). Furthermore, the general view on bioenergy has become more frowned upon in the EU, which can lead to rapid restriction if new legislation is passed. However, the increased focus on energy

security may lead to a more positive view of domestic bioenergy (Börjesson and Björnsson, 2024).

Additionally, Christiansen and Carton analysed the competing perceptions on the role and administration of negative emissions technologies (NETs) in Sweden (2021). The analysis shows a relatively strong consensus regarding the role of bioenergy with carbon capture and storage (BECCS) within Sweden's future energy system. However, the LULUCF sector remains more contentious among policymakers (Christiansen and Carton, 2021). The authors argue that these differences stem largely from how each approach aligns or conflicts with dominant imaginaries of the Swedish bioeconomy. Measures such as BECCS aligns within the country's reliance on bioenergy and its self-image as a climate leader, whereas land-based approaches such as rewetting, afforestation, and forest conservation encounters resistance due to competing interests in the forestry sector (Christiansen and Carton, 2021).

In line with this, Petersson et al. (2022) examines the tension between conservation-oriented strategies and active forest use for bioenergy and material substitution. Their findings indicate that increased forest set-asides for conservation can contribute to GHG reductions mainly in the short term, while sustained forest management and use seem to offer greater long-term climate benefits through carbon substitution and biomass production. Nevertheless, the authors stress that current EU accounting frameworks (such as the LULUCF Regulation) restrict the recognition of substitution benefits, thereby limiting Sweden's potential to fully mobilise its forest sector for climate mitigation (Petersson et al., 2022). These structural limitations may incentivise less active forest usage, potentially reducing future biomass availability and economic value within Sweden's forest-based bioeconomy.

1.6 Research aim

This study aims to analyse how the implementation of the revised LULUCF Regulation may influence Sweden's long-term energy transition pathways, as represented by the SEA's four energy system scenarios (Figure 1). These scenarios reflect combinations of technological developments and geopolitical changes, where uncertainties are reflected in varying degrees of globalisation and environmental consideration. One of the main reasoning behind the research aim is because the LULUCF sector and its regulations have been deliberately excluded from the SEA's long-term energy transition scenarios (SEA, p. 33, 2025b).

By focusing on forested land and harvested wood products within the LULUCF sector (European Parliament and Council, 2023), the study examines how binding land-use and carbon removal targets interact with energy system development. Attention is given to forest-based bioenergy and carbon sinks, as these elements may constitute an interference between land-use policy and energy system planning. The aim is to assess how constraints and opportunities within the LULUCF sector may affect Sweden's pathways towards a net-zero energy system under different scenario assumptions.

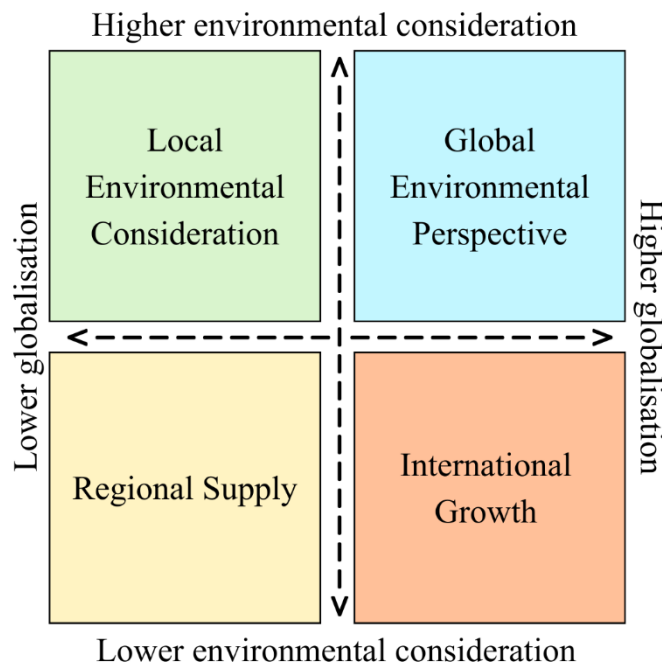


Figure 1. Schematic illustration of the scenarios. Each axis represents a main uncertainty factor, and each quadrant represents a scenario. (SEA. 2025b).

The study is guided by the following main research question:

- The significance of LULUCF in Sweden's energy transition: how might each scenario be influenced by the integration of the LULUCF sector?

The following sub-questions serve as intermediate objectives that provide the analytical basis for answering the main research question:

- a.** What opportunities and challenges may arise from integrating the LULUCF sector into Sweden's climate and energy policy plans?
- b.** What opportunities and challenges may emerge in the energy transition due to changes in the supply of bioenergy?

Sub-question (a) analyses how the integration of binding LULUCF targets affects Sweden's overall climate and energy policy planning. The analysis focuses on identifying potential synergies and conflict of interests between involved government agencies in regard to maintaining forest carbon sinks and utilising forest biomass.

Sub-question (b) examines how the revised LULUCF Regulation may influence Sweden's energy transition through changes in the availability of forest-based bioenergy. By assessing how LULUCF requirements affect biomass extraction under different assumptions, the analysis evaluates the resulting opportunities and challenges for meeting climate and energy objectives whilst at the same time complying with LULUCF targets.

2. Methodology

This study adopts a mixed-methods approach which combines quantitative and qualitative elements. The rationale for employing a mixed-methods approach is that the study addresses both a case study and policy analysis (with a qualitative focus) as well as scenario data and assessments concerning energy, carbon balances and biomass (with a quantitative focus). The methodological design thus enables a more holistic understanding of how the integration of the LULUCF sector affects the scenarios, and the potential implications for the national energy transition.

The mixed-methods design is appropriate when the usage of quantitative data or qualitative data alone is incomplete. Mixed methods make it possible to obtain two different perspectives of a complicated issue: one based on close-ended quantitative data and one based on open-ended qualitative data (Poth, Creswell and Plano Clark, 2023). For this study, the qualitative aspect is to examine policies and legislations relevant to the LULUCF sector and its implementation in relation to the energy transition in Sweden (open-ended). The quantitative aspect is to describe the current data of carbon balances and energy supply to identify how they correspond to the LULUCF Regulation and climate targets in Sweden (close-ended).

According to Poth et al. (2023) there are three basic mixed methods designs which are 1) convergent, 2) explanatory sequential, and 3) exploratory sequential. This research mainly follows a convergent design which aims to collect both qualitative and quantitative data, analyse both datasets and then merge the results of the two (Poth et al., 2023). The purpose is to achieve a comparison of the results and examine how they integrate with one another.

2.1 Case selection

There are various reasons why Sweden is a compelling case to examine. The main reason is because Sweden is one of the member states responsible for the largest cumulative net removals from the LULUCF sector in the past 10 years (EEA, 2024). Due to the country's vast forestry, with forests covering approximately 68% of the land area, it is an important contributor to the EU's overall carbon sink (Nilsson, Markström and Fridman, 2025). In addition, Sweden is a relevant case due to the close link between its forest resources and energy transition. Bioenergy derived from forestry residues and by-products already constitutes a substantial share of Sweden's renewable energy mix. As for the revised LULUCF Regulation, Sweden is a key member state due to its commitment to increase uptake of CO₂ through enhanced land-based carbon sinks and sustainable forest management practices (Jonsson and Sotirov, 2025).

2.2 Qualitative process

2.2.1 Policy analysis

Policy analysis as a research method involves applying evidence to understand the causes and consequences of issues. Furthermore, the method allows researchers to identify advantages, disadvantages, and risks of different ways of dealing with an issue (Majchrzak and Markus, 2017). The evidence consists of facts, data, and experience, which differs from theories, assumptions, opinions and values, which Majchrzak and Markus defines as *meaning* (2017). The authors claim that meaning affects the production and interpretation of evidence. This study involves both evidence and meaning to create an outcome which increases the knowledge of how policies are shaped, justified, and implemented. By acknowledging the interplay between factual evidence and underlying meanings, the analysis will hopefully capture not only the

technical aspect but also the normative dimensions that may influence decision-making in this specific case.

2.2.2 The four scenarios

In this study, the policy analysis takes the form of a case study. The case study makes it possible to explore several perspectives of the complexity and uniqueness of a specific policy in a “real life” context (Simons, 2009). It can provide strong evidence by including different methods where the main aim is to generate in-depth understanding of a certain issue, such as the significance of LULUCF in Sweden’s energy transition. The selected case is used to illustrate requirements, potential conflicts, and synergies relevant to the research question.

The SEA’s report presents four exploratory scenarios which visualise the path to a net-zero emissions energy system by 2050, plus leeway for ten years beyond (2025). The scenarios cover the entire national energy system, from supply and conversion to the end use of energy carriers. The main purpose of the predictions is to increase the understanding of the opportunities and challenges facing the energy transition. This makes them suitable as a basis for planning and further analysis as each scenario has specific conditions and factors which shape their outcomes. The following section describes each scenario:

Scenario 1: Local Environmental Considerations (LEC)

This scenario involves factors of lower globalisation and higher environmental concern, in which the acceptance is limited regarding utilising domestic resources which affect the local environment. The combination of lower globalisation and heightened environmental concern results in the lowest level of energy use in comparison to the other scenarios. The dual requirements of minimising fossil fuel use and limiting environmental impacts lead to an increase in energy prices, including the highest electricity prices among all scenarios, despite comparatively low energy consumption. However, progressive environmental values in forestry and land-use are strongly emphasised in this scenario.

Scenario 2: Global Environmental Perspective (GEP)

This scenario involves factors of higher globalisation and higher environmental concern. The demand for fossil-free goods and energy carriers is higher, both domestically and internationally. There is a strong ambition to combine extensive exports of fossil-free goods and fuels with the lowest environmental impact possible. This scenario is characterised by an essence of coexistence between competing interests. Nevertheless, the resource-use constraints which remain, relative to the high level of energy consumption, leads to an increase in the price of fossil-free energy which results in increased net imports of electricity.

Scenario 3: Regional Supply (RS)

This scenario involves conditions of lower globalisation and lower environmental concern. The energy use is lower compared to the scenarios with higher levels of globalisation. The conditions for meeting demand are favourable, leading to the lowest energy and electricity prices of all scenarios. However, this comes at the cost of a greater reliance on fossil energy sources, which leads to increased use of carbon capture and storage technologies to reach net-zero targets, as well as greater restrictions on environmental values.

Scenario 4: International Growth (IG)

This scenario involves conditions of higher globalisation and lower environmental concern. Energy use is the highest in comparison to the other scenarios, where hydrogen plays a significant role in the production of fossil-free products. At the same time, the capacity is strong to meet demand. As a result, energy prices (particularly for electricity) remain relatively low compared to the other scenarios, and a net export of electricity occurs despite high domestic demand. However, this scenario has a negative impact on environmental values.

2.2.3 Selection of key sources

The qualitative aspect revolves around a review of key literature and documents which serves the purpose to examine and identify specific areas within the research issue. These areas are useful in the sense of categorisation and identifying core themes. The literature is mainly collected through Web of Science where specific “search blocks” are used. The search consisted of two blocks, one covering LULUCF and the other covering biomass.

The selection of policy documents has been conducted systematically to ensure relevance and credibility. First the documents were identified through targeted searches on official websites of the relevant Swedish and EU authorities. Priority was given to documents that are legally binding, form part of official policy frameworks, or provide authoritative interpretations of the LULUCF sector. Second, the selection was guided by the time frame 2018–2024, which corresponds to the implementation and revision phases of the EU’s LULUCF Regulation and Sweden’s current Climate Action Plan. Finally, the documents were screened for explicit references to the LULUCF sector, carbon sinks, and forestry in relation to energy and climate objectives. This systematic approach ensures that the analysis captures both strategic and operational perspectives of policy development to address the research objectives.

Additionally, the author of this study has performed previous research analysing the policy process of the revised LULUCF Regulation (Blume and Hasselstrand, 2025). The previous study aimed to investigate which actors and conflicts have been central to the process, and how the theory of Multiple Streams Framework can be applied for understanding its policy development. The paper is unpublished and was an assignment within a course of the master programme Environmental Science, Applied Climate Strategies at Lund University. The study included an extensive systematic literature review and therefore certain key references will be reused as a complementary foundation for the qualitative side of this study. The literature was collected by using Web of Science.

2.3 Quantitative process

The quantitative part of the study focuses on describing and evaluating key data related to Sweden’s energy system, carbon balances, and biomass usage. The purpose is to understand how the integration of the LULUCF sector and its revised Regulation may influence the national energy transition in the future scenarios. The analysis draws on secondary data from official national and European sources. The datasets include indicators such as annual greenhouse gas emissions and removals (expressed in CO_{2e}), national energy balances, and the distribution of biomass across different end uses.

2.3.1 Three components

The quantitative process involves three main components;

1. Carbon balance analysis - examines reported data on carbon sinks and sources within the LULUCF sector to assess the contribution to Sweden's overall climate targets.
2. Energy system overview - compiles and interprets data on national energy production and the role of bioenergy within the current energy mix.
3. Scenario-based assessment - explores how potential changes in biomass allocation could affect Sweden's carbon balance and progress towards climate targets.

The results of this quantitative assessment will be integrated with the qualitative findings to provide a comprehensive understanding of how the inclusion of the LULUCF sector could shape Sweden's future energy pathways.

2.3.2 Basis of analysis

The baseline scenario of this study is defined by Sweden's binding commitments under the revised LULUCF Regulation (European Parliament and Council, 2023). For 2021–2025, the no-debit rule applies, implying that net emissions must not exceed net removals. For 2026–2029, a linear carbon uptake budget of approximately 45.7 Mt CO_{2e} per year is assumed. The 2030 target requires an increase of around 4 Mt CO_{2e} relative to the 2016–2018 reference period (≈46.2 Mt CO_{2e} per year). All other assumptions follow the SEPA's projections which follow with existing measures (WEM) and are based on the policies and measures adopted by the Swedish parliament prior to December 2024 (SEPA, 2025b). Changes in carbon uptake are considered solely in relation to the energy transition scenarios throughout the study. Additionally, the carbon balance analysis is based specifically on forest uptake and not land uptake in general, which is worth clarifying due to the vast categories and attributes of the LULUCF sector.

Forest growth varies naturally between different years due to seasonal variations in rainfall, draught, temperature etc, thus this leads to corresponding yearly variation in carbon storage. Furthermore, forest growth may also be subject to natural disturbances such as fires, insect outbreaks and windthrow (Ellison, Lundblad and Petersson, 2011). This study therefore includes a basic sensitivity analysis containing indicators of two different growth levels to examine the impact of reduced biomass on Sweden's ability to comply with the LULUCF targets. These growth levels are based on estimated shortfalls in net removals which may impact the potential supply of forest-based primary energy.

2.3.3 Assumptions

Various assumptions were used in this study as a help to reach the research objectives. To increase the transparency and replicability of the study, the following box outlines a total of six key assumptions which were used. These assumptions originate from established carbon-accounting conventions, national forestry statistics, and standard bioenergy assessments. Rather than introducing new parameter values, the assumptions reflect commonly applied practices used in Swedish and international assessments. The assumptions are not meant to provide exact projections of future outcomes, but rather to develop consistent translation of policy-level LULUCF targets into physical quantities of forest biomass and energy. Taken together, these assumptions define the analytical boundary of the study and should be considered when interpreting the results.

Key assumptions

1. Binding LULUCF compliance: Sweden is assumed to meet the LULUCF target through domestic net removals (European Parliament and Council, 2023; Wikberg et al., 2023).
2. Fixed baseline and accounting framework: The 2016-2018 average net removals are treated as a baseline (European Parliament and Council, 2023; SEPA, 2025a).
3. Standard biomass conversion: Forest biomass is assumed to consist of 50% carbon by dry mass, with a conversion factor of 0.75 tonnes of dry biomass per cubic metre of standing volume (m³sk) (SFA, 2020).
4. Average forest growth conditions: The core analysis assumes average forest growth, while uncertainty related to lower growth rates is explored through the sensitivity analysis (Wikberg et al., 2023; SEPA, 2025a).
5. Bioenergy share of biomass: Approximately 50% of the forest biomass associated with removals is assumed to be available for bioenergy (SEA, 2025b; Svebio, 2025).
6. Constant energy content: Forest biomass is assumed to have an average lower heating value of 2.15 MWh per m³sk (Börjesson, 2016).

2.4 Limitations of method

It is important to mention and discuss the limitations of selected research design. While the mixed-methods approach allows for correspondence between qualitative and quantitative findings, it also brings risk of imbalance. For example, one strand of data may dominate the analysis (Poth et al., 2023).

Furthermore, the quantitative data is a secondary source which can be viewed as a limitation because collected primary data often provides greater control over data quality, scope, and precision. However, the quantitative data is taken from official authorities such as Swedish agencies, which improves the credibility and relevance.

The qualitative design also has its limitations. For example, the state of the art is constrained by the availability of peer-reviewed research within the chosen scope, which focuses on studies in the EU. This geographical delimitation may exclude valuable perspectives from non-EU contexts that face similar policy and governance challenges. Additionally, the interpretation of policy documents involves a degree of subjectivity, as it requires the researcher to infer meanings from the text.

While the case study design provides deeper insight into the Swedish context, it may limit the generalisability of the findings. For example, the conclusions drawn may not be directly applied to other member states with different environmental structures, policy priorities, or energy system characteristics. Instead, the findings should be understood as context-specific knowledge which hopefully contributes to a broader understanding of the LULUCF sectors' integration and how it impacts the energy transition.

3. Policy analysis and integration of SEA scenarios

The aim of the policy analysis is to obtain a comprehensive understanding of the LULUCF sector part in Sweden’s energy transition. This will be done by reviewing and analysing official policy documents where the main foundations are the four exploratory scenarios for achieving a net-zero emissions energy system by 2050. Additional elements involve opportunities and challenges which arise or emerge by the integration of the LULUCF sector, as well as its impact due to changes in the supply of bioenergy.

3.1 Scenarios for Sweden’s energy system

Various cross-cutting trends can be observed across all scenarios. These include a decline in the usage of fossil fuels, with final consumption falling by 79-93% by 2050 compared to 2023. Electricity use increases in all scenarios, albeit to varying extents. This includes significant electrification of the transport sector and a growing deployment of heat pumps. Onshore wind power accounts for the largest expansion in capacity, while the operational lifetimes of existing nuclear power plants are fully utilised. Finally, the production, export, and usage of fossil-free fuels increase across all scenarios. Please view figure 2 for visualisation regarding final energy consumption per sector in each scenario, including the current situation.



Figure 2. Final energy consumption per sector by each scenario (SEA, 2025c).

3.2 Integration of the LULUCF sector within climate and energy targets

Following the implementation of the revised LULUCF Regulation, Sweden has not much leeway left than to pursue stronger integration of the LULUCF sector in their climate and energy targets. Despite this, the report from the SEA explicitly states that the prognosis and analysis deliberately exclude the LULUCF sector (SEA, 2025b). Additionally, there are no thorough explanations provided as to why the sector has been excluded. The report states;

“The scenarios do not take into account, for example, storage in forests and land (the so-called LULUCF Regulation) or non-energy related emissions from agriculture. The emissions presented should rather be seen as how the energy system can potentially contribute to Sweden’s overall climate goals without any further assessment of whether the emission trajectories presented are sufficiently ambitious or not.” (SEA, p. 33, 2025b).

The weak reasoning of the exclusion leads to various questions left unanswered. As mentioned previously, Sweden’s energy system supply consists of 30% bioenergy in which forests account for over 80% of this production (SEA, 2025b). Just by stating the numbers whilst at the same time considering the implemented revised LULUCF Regulation, one could say that it should be in Sweden’s interest to consider the sector in the future scenarios for the energy transition. However, the purpose of this study is not to point any fingers but to provide knowledge and guidance in how to succeed in the path to net-zero in the energy system, considering all relevant perspectives.

3.2.1 Reasoning behind exclusion

At first hand, the exclusion of the LULUCF sector is somewhat reasonable due to certain factors. For example, the SEA makes the assumption that around six million tonnes of biogenic carbon dioxide (bio-CCS) will be captured and stored in all scenarios. These six million tonnes contribute to the emission target, which allows for some CO₂ emissions from fossil fuel even after 2050 (SEA, 2025b). Furthermore, the increased Regulation of the LULUCF Regulation has been contested where the Swedish government’s stance has been critical towards measurement, reporting and follow-up requirements (Swedish Government, 2023).

For example, the Climate Action Plan underscores that absorption and emissions from forests are subject to greater uncertainties than other sectors. This is mainly due to the difficulty of measuring carbon flows and large variation in annual CO₂ flow which may be affected by varying weather conditions and natural disturbances (Swedish Government, 2023). Therefore, the captured statistics involve high uncertainties which may distort the assessment which is an integral requirement of the LULUCF Regulation.

3.2.2 The necessary need for flexibilities

By viewing and analysing official documents and policy statements, one common theme appears to be the need for using flexibilities within the LULUCF Regulation as means to handle various uncertainties. The Climate Action Plan (2023) emphasises the use of flexibilities which may be required to cover any large deficits in the sector during respective commitment periods. Articles relating to flexibilities which are particularly important for Sweden are those that cover provisions on general flexibility, regulations of natural disturbances, and flexible management of forest land. Specifically, the main articles of interest are articles 10, 11, 13, and 13b (European Parliament and Council, 2023). The new land-use mechanism (Article 13b) offers limited temporary relief by allowing MS to access a Union-level reserve, but its strict conditions result in inability to compensate for sustained declines in the national forest sink. Updated rules on natural disturbances (Article 10) and the managed-forest flexibility (Article 13) may help Sweden address variability from storms or pests, yet they also require more detailed reporting.

3.3 The stance of agencies

As the LULUCF sector appears to be a sensitive issue for Sweden, it is necessary to understand the perspectives of national authorities in order to start the process of integrating the revised LULUCF Regulation. The reasoning behind this is to grasp the challenges and opportunities which arise from aligning national priorities with EU-level climate targets. Understanding these issues is essential to assess how Sweden can balance its reliance on bioenergy whilst ensuring the sustainability of forest resources. The following section uses the interim report as a foundation which was adopted by Miljömålsberedningen in 2025, where involved agencies submitted their comment letters to the proposals. Miljömålsberedningen is a parliamentary committee that develops the national climate goal strategies.

The interim report specifically focused on how the country should reach its commitments in terms of biodiversity and net GHG from the LULUCF sector. Examples of strategies include that forest management should take into account both climate and natural values. The proposed measures should use existing infrastructure relating to measurement and reporting so that the effects can be seen early on, preferably as early as 2026. Two specific measures are mentioned with a quantified effect on carbon storage; 1) increased support for forest fertilisation, and 2) increased support for forest owners who extend the harvest rotation period. Together, these strategies are estimated to contribute to an increase in net uptake of approximately 5.5 million tonnes of CO₂e, which is more ambitious compared to the LULUCF target of 4 million tonnes of CO₂e (Miljömålsberedningen, 2025).

Comment letters are used to gather the views of agencies and stakeholders on legislative proposals such as the interim report by Miljömålsberedningen. These comment letters can be insightful to understand perceived opportunities, risks and trade-offs relating to the integration of LULUCF targets into national climate planning. The selected agencies represent the core policy areas that intersect with LULUCF and energy system planning; the Swedish Energy Agency (SEA), the Swedish Environmental Protection Agency (SEPA), and the Swedish Forest Agency (SFA). These documents are central to the qualitative analysis, as they reflect the official agency positions (SEA, 2025d; SEPA, 2025c; SFA, 2025).

3.3.1 The Swedish Energy Agency

Overall, the SEA welcomes the approach to increase net-GHG removals in the LULUCF sector. However, the agency notes that the report contains significant uncertainties which makes it difficult to take an official stance on the proposed measures. The agency identifies two main risks; 1) the implementation of the measures may have consequences for the energy system, especially through competition of forest raw materials, and 2) if the measures are not implemented or are less extensive, the need for emission reductions in the ESR sectors will increase, which may further affect the energy system (SEA, 2025d). However, by reviewing the literature and analysing government documents, an important risk factor seems to be conflicts of interest relating to the sector.

Furthermore, the SEA raises the issue of uncertainties regarding impact assessments of the LULUCF Regulation. The agency is critical towards the general view of the system in the Regulation and how system boundaries may have a negative impact on the energy system (SEA, 2025d). The agency stresses the need for a comprehensive overview of system effects. For example, exports may appear to have a negative impact on national target achievement within the ESR and LULUCF, even though the measure may contribute positively to the EU's overall

climate target. The system boundary applied in the Regulation therefore risks giving a misleading view of the climate benefits of certain measures (SEA, 2025d).

Similar concern applies to forestry products where the decreased extraction of biomass and timber may have a direct negative impact on the national energy system (SEA, 2025d). The agency appreciates the intention of the LULUCF target regarding protection of forested land, however, as 80% of forest products are exported to other countries, with more than half to other EU countries, concerns arise relating to cross-border effects of forest product trade. As a result, emission reductions achieved through decreased harvesting in Sweden may be offset by increased harvesting in other countries, thereby undermining the overall climate efficiency of the measures (SEA, 2025d).

3.3.2 The Swedish Environmental Protection Agency

As for the SEPA's response to the interim report, it had a slightly different perspective compared to the SEA. The agency appears to be more positive towards the presented proposals that contribute to biodiversity targets and increased CO₂ uptake in the land-use sector. However, the SEPA notes that the proposal is still not sufficient to achieve the targets (SEPA, 2025c). For the LULUCF sector, the concern revolves around uncertainty relating to voluntary policy instruments and risk of deviation from the approach to improve nature conservation. First, the SEPA agrees with the committee's opinion that the risk of leakage is high and that additionality is uncertain, where there is a need for more cost-effective policy instruments that involve lower risks for landowners. Second, as there are ongoing legislative processes around nature restoration that are yet to be unfolded, the agency points out the risk of creating displacement effects that will have a negative impact on other environmental work such as biodiversity (SEPA, 2025c).

In addition, the SEPA agrees with the proposal relating to efforts to increase net CO₂ uptake within the LULUCF sector. These efforts are highly needed to achieve national and EU climate targets. One proposal urged Sveaskog, which is the state's largest landowner, to increase net uptake of just over 600,000 tonnes CO₂e. Requirements for the state to take the lead is welcomed by the agency. Furthermore, the SEPA is positive towards increased biogas support which will also cover grassland. The inclusion of grassland in the support system for biogas production increases climate benefits, however, it will also lead to pressure on the demand for grassland which is an additional factor to consider (SEPA, 2025c).

3.3.3 The Swedish Forest Agency

The interim report and its proposals related to the revised LULUCF Regulation is of utmost importance to the SFA. The agency's official opinion is not focused on bioenergy; however, it reflects matters of forests and its resources. Overall, the SFA note the insufficiency of the proposal for Sweden to meet its commitments under the LULUCF Regulation by 2030. They doubt that the measures proposed can create conditions for such an increase in net uptake as the committee has assessed. Furthermore, the SFA believes that the responsibility lies upon the Swedish government to reach the LULUCF targets, and not the forestry industry. The forestry industry shall instead be a prominent actor that contributes to resilient forests within the framework of long-term sustainable forestry (SFA, 2025).

The agency is positive towards the overall aim of the proposal; however, the content of the strategy is insufficient for Sweden to fulfil its commitments to biodiversity and carbon storage

in the LULUCF sector. The SFA agrees that different types of instruments are needed to complement and reinforce each other to form a coherent contribution to the targets. The reasoning behind this goes hand in hand with the concern of other authorities, namely the uncertainties relating to reporting or modelling for certain carbon storage, but also natural weather variations and the development of harvesting levels in the long term as a result of variations in tree growth. The potential for using flexibilities within the LULUCF Regulation is also difficult to assess in the current state (SFA, 2025).

3.4 Conflict of interests

There is an active debate regarding the role of forests in the sustainable transition of our energy system. As forests are expected to deliver several different values simultaneously, it results in various interests conflicting with each other (Börjesson and Björnsson, 2024). As the LULUCF sector is becoming more regulated, it may develop additional conflicts of interest.

3.4.1 Local level

Around half of Sweden's forests are owned by approximately 300,000 small private forest owners, each with their own perspectives and priorities regarding forest management (Börjesson and Björnsson, 2024). Adding to this, pressure from both industry actors and policymakers is increasing as forests are expected to simultaneously deliver economic profit, renewable energy resources, carbon sequestration, and biodiversity protection. This creates a complicated balance for local landowners, who often face conflicting incentives (Booth and Giuntoli, 2025). On one hand, bioenergy markets and climate policies encourage somewhat intensified harvesting to supply renewable energy and biobased products (Petersson et al., 2022). On the other hand environmental regulations, certification systems, and local conservation efforts call for stronger restrictions and preservation of high conservation.

In practice, these competing demands can lead to local tensions between landowners, municipalities, and environmental groups. While some forest owners welcome the economic opportunities associated with the bioeconomy, others express concern over increasing regulatory control and reduced autonomy in forest management decisions (Christiansen and Carton, 2021). Moreover, the growing emphasis on the LULUCF sector in national and EU climate policy introduces new monitoring and reporting requirements, which may be perceived as bureaucratic by smaller landowners.

3.4.2 National level

At the national level, the conflicts of interest are primarily institutional and political, reflecting differing priorities between agencies, industries, and policy sectors. The SEA indicates a promotion of bioenergy as a cornerstone of the renewable energy transition, emphasising its role in achieving energy security and supporting industrial competitiveness. In contrast, the SEPA highlights the ecological limits of forest exploitation and the importance of maintaining long-term carbon sinks and biodiversity. Meanwhile, the SFA tends to prioritise forestry as an economic activity, advocating for flexible management practices that sustain timber production and rural livelihoods.

This pattern can be linked to Sotirovs et al. (2021) research on the ideological divergence regarding environmental forest policy which can be found both among MS authorities and within EU institutions. The institutional differences mirror a broader division within Sweden's climate and environmental strategies. It appears to be a struggle to balance the goals of

economic growth, energy independence and ecological sustainability. Some actors frame forests as a renewable resource that should be fully utilised to meet climate and economic targets, whereas other actors emphasise on the need for improved conservation and progressive management of forests.

3.4.3 European level

Similar to developments at the national level, the governance of forest and environmental policy within the EU reflects a clear ideological and institutional divergence. Sotirov et al. (2021) demonstrate that this divide manifests in two competing advocacy coalitions within EU policymaking arenas. The environmental coalition is primarily composed of environmental NGOs that engage in close collaboration with supportive EU institutions, such as the European Commission's Directorate-General for Environment (DG ENV), the European Parliament's Committee on the Environment (COMENVI), and the Council's ENVI configuration. This coalition is united by shared normative beliefs in biodiversity conservation and a commitment to addressing global sustainability challenges. Conversely, the forest use coalition comprises forest owner associations, industrial actors, and state forestry authorities from forest-rich countries with well-established forest sectors, such as Sweden and Finland, alongside Austria, France, Germany, and several Eastern European member states. These actors maintain alliances with EU institutions oriented toward agricultural and trade interests, notably the Commission's DG AGRI and DG Trade, the Parliament's COMAGRI, and the Council's AGRI formation (Sotirov, et al., 2021).

In addition, recent geopolitical developments have influenced both the energy sector and the trajectory of bioeconomy development within the EU. These shifts have reshaped the policy discourse surrounding the role of forests in the sustainable transformation of the union's energy systems. As noted by Jonsson and Sotirov (2025), the ongoing conflict between Ukraine and Russia has disrupted the availability and demand for woody biomass across the EU, highlighting the sector's vulnerability to geopolitical instability. In addition, increased electricity prices, driven by post-pandemic economic recovery, an increasing reliance on intermittent renewable energy sources, and further intensified by sanctions on Russian hydrocarbons as well as the sabotage of the Nord Stream gas pipelines, have exacerbated the pressure on energy markets. This situation has reduced the competitiveness of energy-intensive industries relative to regions with lower energy costs and has, in turn, intensified competition for wood-based raw materials between energy producers and traditional forest industries.

3.5 Integration of the LULUCF sector within the scenarios

The debate over the role of forests and its contribution to the energy transition can be linked to the Sweden’s future energy targets. By using the four exploratory scenarios presented and discussed in the SEA’s report (2025b), it is possible to examine the significance of the sector and how each scenario might be influenced. View figure 3 to obtain a clear image of the energy source distribution in each prospective scenario.

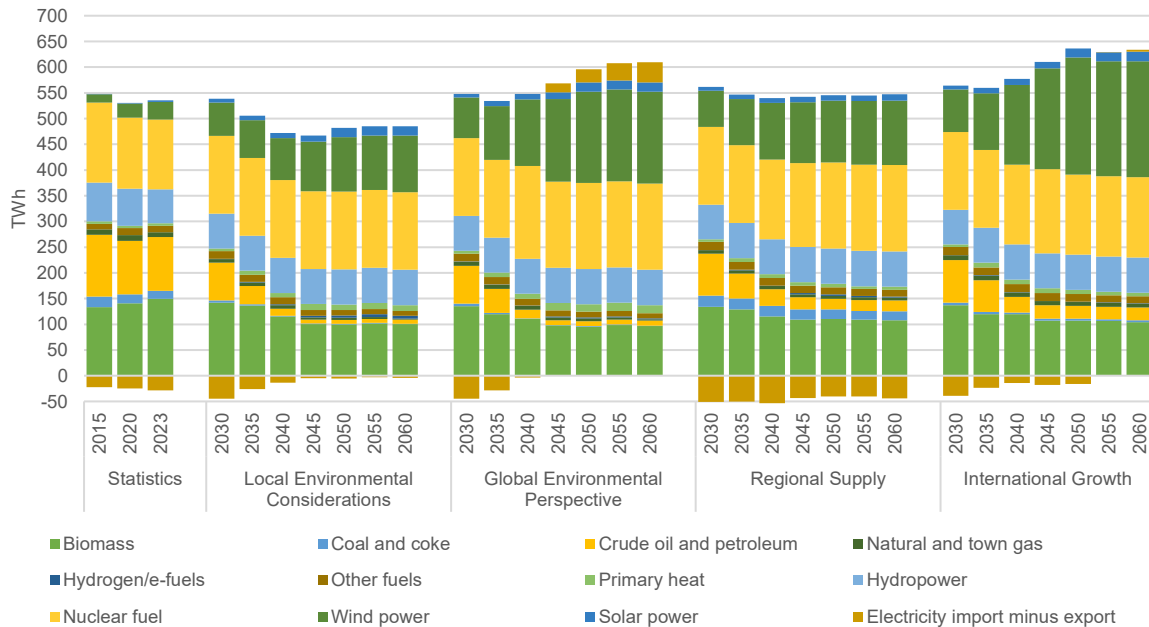


Figure 3. Total energy of supply per scenario (SEA, 2025c).

3.5.1 Local Environmental Consideration

In the LEC scenario, lower globalisation is combined with stronger environmental values and limited acceptance of activities that negatively affect local ecosystems. This scenario puts stronger emphasis on the preservation of biodiversity, leading to perhaps stricter sustainability standards for forestry and land use. While this approach can benefit the LULUCF sector by prioritising traditional conservation practices, it may also constrain the domestic supply of bioenergy. Furthermore, this scenario is the costliest of them all regarding electricity prices. In terms of biomass supply, the LEC scenario assumes 142 TWh of biomass by 2030 within the total energy system. This share will annually decrease and reach 100 TWh by the year 2060.

As for the chances of Sweden reaching its binding targets within the LULUCF Regulation, this scenario can be considered as the most optimal. Progressive environmental values in forestry and land-use are strongly emphasised; however, one concern may perhaps be the lower globalisation regarding the bioenergy supply. This scenario considers the rapid changes of geopolitics where countries obtain protectionist tendencies which can lead to deadlocks in international cooperation and trade. For Sweden, the need for national self-sufficiency increases where the main alternative is to increase energy extraction from natural resources such as forests. This clashes with the emphasis on local environmental considerations alongside stronger regulations of the LULUCF sector which limits opportunities to extract biomass for energy purposes.

3.5.2 Global Environmental Perspective

The GEP scenario combines high globalisation with a strong environmental concern. Under these conditions, Sweden benefits from open trade, stable geopolitical relations, and a high degree of international cooperation. The global approach to environmental issues is challenged by economic growth and increased demand for fossil-free energy, which leads to the risk of conflicting goals as expansion plans add pressure on natural resources. Electrification and energy efficiency is a political priority, which is driven by the ambition to balance environmental concern with economic growth. This leads to more focus on renewable energy sources such as wind and solar power. The GEP scenario assumes a biomass supply of 135 TWh by 2030 which will annually decrease to 97 TWh by 2060 within the total energy supply.

Biomass availability remains relatively low, and the overarching principle is that forest resources should be managed primarily for long-term climate mitigation and biodiversity conservation rather than intensive extraction. Sustainable forest management practices are emphasised, and although biomass continues to play a role in the energy system, it is more supplemented by alternative renewable sources. This reduces pressure on domestic forests and aligns with the broader environmental ambition to maintain stable carbon sinks.

For Sweden's ability to meet its LULUCF Regulation targets, the GEP scenario is generally favourable. High international cooperation supports sustainability criteria and facilitates knowledge exchange on best practices for forest management. At the same time, the reduced dependence on domestic biomass for energy lowers the risk of overexploitation of forest resources (Booth and Giuntoli, 2025). However, the combination of strong economic growth and expanding industrial electrification may still generate indirect land-use pressures, for instance through increased infrastructure development, mining for critical minerals, or competition over land between involved actors.

3.5.3 Regional Supply

The RS scenario consists of lower degrees of both globalisation and environmental concern. In this scenario, the geopolitical situation is characterised by international rivalry and countries prioritising self-sufficiency and national security. Cooperation among countries is primarily regional, and global partnerships are scarce. The need for a resilient and secure energy system is of utmost importance which leads to less priority being given to environmental considerations. At the same time, there is an increased willingness to exploit national resources to achieve energy sovereignty and meet demand at regional level, particularly within the EU. Biomass availability is stable, and forest management is assumed to follow a model which makes forests more resilient to climate change whilst enabling continued extraction of biomass. As for the biomass supply, the RS scenario assumes 134 TWh of biomass by 2030 within the energy supply system, which will decrease to 108 TWh by 2060.

This scenario can be challenging for Sweden's ability to reach LULUCF targets. First, the low level of environmental concern may have negative impact on the state of forests and its carbon uptake capacity. With national security and energy independence prioritised over ecological protection, forests risk being increasingly managed for short-term purposes rather than long-term carbon storage and biodiversity. This could reduce net carbon removals within the LULUCF sector, especially if harvesting intensifies to support domestic bioenergy production (Booth and Giuntoli, 2025). Moreover, weaker international cooperation may hinder knowledge

exchange and coordinated forest protection efforts, further challenging Sweden's capacity to meet its long-term climate goals.

3.5.4 International Growth

In the IG scenario, lower environmental consideration together with higher globalisation is the result of a world characterised by strong global cooperation, free trade and increased technological innovation. Forces from the global market are viewed as the solution for tackling climate and energy challenges, and technology is an essential part of the transition. For Sweden, this scenario revolves around the country's contribution of domestic natural resources to achieve global climate and energy targets. The high priority of economic growth leads to increased extraction of biomass from forests to meet the global demand for renewable resources. The expansion of industry and large-scale extraction of biomass enables Sweden to supply itself and the world with innovative technology. However, this may hinder the country's ability to maintain local environmental values. This raises questions about whether intensified harvesting pressures could compromise carbon sinks or biodiversity in practice; factors that directly influence LULUCF accounting outcomes (Sasso et al., 2025). The IG scenario assumes a biomass supply of 137 TWh by 2030 which will annually decrease to 104 TWh by 2060 within the total energy supply.

The IG scenario appears to overlook factors that play an important part in the LULUCF sector, which may negatively impact Sweden's ability to reach its targets. Even though the SEA report claims that this scenario utilises forests in the way that biomass extraction is linear with annual growth, biomass availability is still the highest among all scenarios. Additionally, the development of land-based wind power is emphasised in this scenario where the realisable potential is predicted to supply 200 TWh annually. While this scale of development is beneficial for meeting climate-neutrality goals and reducing reliance on fossil fuels, it may also risk exacerbating land-use competition. The construction of large-scale wind farms can lead to habitat fragmentation, displacement of forestry activities, and increased pressure on sensitive landscapes (Hyvonen et al., 2024). These land-use conflicts may further complicate Sweden's ability to preserve ecosystems and maintain the integrity of its LULUCF reporting.

4. LULUCF's effect on biomass supply

To achieve a comprehensive understanding of the significance of LULUCF in Sweden's energy transition, it is necessary to examine opportunities and challenges which may emerge. The study attempts this by translating the numerical carbon targets which are set within the LULUCF Regulation into the physical quantities of forest volume required to sustain them. In the following section, a stepwise analysis links the annual net removal obligations to the corresponding forest biomass, the potential share available for energy use, and the land area required to supply these volumes under average growth assumption. The stepwise analysis follows national standard carbon-accounting conventions.

As a brief reminder of the main and binding LULUCF target; Sweden reported average annual removals of approximately 46.2 million tonnes of CO_{2e} during the first compliance period of 2016-2018, which constitutes the baseline level used in the revised LULUCF Regulation. If Sweden were to achieve the binding targets, removals must increase with 4 million tonnes higher than the 2016-2018 baseline by 2030. This sets a target for Sweden to reach approximately 50.2 million tonnes of CO_{2e} in total removals as of 2030.

Based on the most recent assessment from the SEPA (2025a), Sweden is not on track to meet the 2030 target. The gap to reach the target is estimated at around 15 million tonnes based on the scenario which assumes an average forest growth rate. Already in 2023, which was the most recent reporting year, net removals were 15 million tonnes lower than the 2016-2018 average, and the distance to the 2030 target was approximately 19 million tonnes. The gap of 19 Mt CO_{2e} is treated as the worst-case scenario throughout the analysis.

Table 1. Stepwise conversion of Sweden's 2030 target of the LULUCF Regulation into forest biomass and bioenergy supply potential

<i>Step</i>	<i>Variable</i>	<i>Value</i>	<i>Calculations</i>
1. LULUCF target	Required net removals (2030)	50.2 Mt CO _{2e}	Based on 46.2 Mt baseline + 4 Mt required increase
	Converted to carbon	13.7 Mt C	50.2 / (44/12)
2. Biomass volume	Convert carbon to dry biomass	27.4 Mt dry mass	13.7 / 0.5
	Convert dry mass to volume	36.5 million m ³ sk	27.4 / 0.75
3. Bioenergy volume	Energy share (50%)	18.3 million m ³ sk	36.5 x 0.5

4.1 Biomass volume

To understand the physical implications of Sweden's LULUCF target, the first step is to translate the required carbon removals into the corresponding volume of forest biomass. The 2030 target specifies that Sweden must reach approximately 50.2 million tonnes of CO₂e net removals, which translates into 13.7 million tonnes of carbon when applying the established IPCC conversion factor of around 3.7 tCO₂ between carbon and carbon dioxide (IPCC, 2006; 2019; Hannerz, et al., 2024). Given that roughly 50 percent of forest biomass consists of carbon, this storage requirement implies a total need for approximately 27.4 million tonnes of dry biomass (SFA, 2020).

To connect this mass to a physical quantity of forest, the analysis applies the national biomass conversion factor used by the SFA (2020) which states that one cubic metre standing volume (m³sk) contains on average 0.75 tonnes of dry mass when including stems, bark, branches, tops, and root fractions. Using this relationship, the biomass requirement of 27.4 million tonnes corresponds to an estimated 36.5 million m³sk of forest volume (Table 1). This provides an indicative estimation of the forest resources required to sustain Sweden's LULUCF removals under current accounting conventions. Importantly, this does not represent a recommended harvest level, but rather the scale of additional biomass that, in carbon-equivalent terms, would be needed to match the net removal target for 2030.

4.2 Bioenergy volume

Not all forest biomass linked to Sweden's carbon removal targets is available for energy use. In practice, roughly half of the harvested forest volume becomes available as bioenergy supply after accounting for other products such as paper and wooden goods (Svebio, 2025). Applying this commonly used ratio, approximately 50 percent of the total biomass volume linked to the LULUCF obligation can be interpreted as a potential estimate of bioenergy supply.

From the total of 36.5 million m³sk associated with the 2030 removals, this corresponds to approximately 18.3 million m³sk of biomass that could be utilised for energy production (Table 1). This volume includes residues, low-quality roundwood, and processing by-products that typically enter Sweden's existing district heating, combined heat and power, and industrial energy systems (SEA, 2025b). While this is not a forecast of actual future supply, it illustrates the potential interactions between land-use policy and the availability of forest-based bioenergy. The result highlights how future constraints on biomass availability (which is influenced by factors such as the LULUCF Regulation) may have implications for Sweden's broader energy transition and its reliance on biomass.

4.3 Bioenergy supply

To translate the estimated biomass volume into a measure of Sweden's potential bioenergy supply under the LULUCF Regulation, the following step applied standard energy assumptions used in assessments of bioenergy derived from forests. The Swedish forest biomass average is estimated to be equivalent to 2.15 MWh of primary energy per m³sk (lower heating value) (Börjesson, 2016). Thus, the 18.3 million m³sk available for energy production corresponds to roughly 39 TWh of potential primary bioenergy. Compared with the LULUCF target 2030, the distance is estimated today (2023) to be equivalent to some 19 Mt CO₂e compared with the reference period 2016-2018 (SEPA, 2025a), which is correspondent to approximately 38% of the total target of 50.2 Mt CO₂e 2030.

Table 2. Conversion from biomass volume to primary energy content

<i>Variable</i>	<i>Value</i>	<i>Assumptions</i>
Biomass volume available for energy	18.3 million m ³ sk	50% of total biomass associated with LULUCF-related biomass volume (36.5 million m ³ sk)
Energy content per m ³ sk	2.15 MWh/ m ³ sk	Lower heating value for Swedish forest biomass
Total primary energy potential	≈ 39 TWh	18.3 million m ³ sk x 2.15 MWh/ m ³ sk

In biomass terms, this increase in carbon storage is equivalent to some 15 TWh per year. During the reference period (2016–2018), Sweden reported average net removals of 46.2 Mt CO_{2e}. The target requires removals to increase by an additional 4 Mt CO_{2e} by 2030. If removals had remained at the reference level, these 4 Mt would correspond to roughly 8% of the 2030 target of 50.2 Mt CO_{2e}. Using the biomass-to-energy relationship applied in this analysis, the increase translates to approximately 3 TWh of primary bioenergy (0.08×39 TWh) for the base case (Table 2).

However, the most recent assessments indicate that Sweden is not only failing to achieve the required increase; removals have instead fallen substantially. In 2023, net removals were already 15 Mt CO_{2e} below the 2016–2018 average, creating a total shortfall of approximately 19 Mt CO_{2e} relative to the 2030 target when including the required 4 Mt increase. Based on the energy conversion assumptions used in this analysis, the 19 Mt removal gap is equivalent to a potential reduction of roughly 15 TWh of primary bioenergy.

This estimate is recommended to be viewed as a rough indication rather than a precise projection. While the base case implies a relatively modest shortfall of around 3 TWh of primary bioenergy, the worst case reflects a greater loss of roughly 15 TWh of primary energy. The scale of the implied reduction is noticeable: a decrease of 15 TWh corresponds to around 10% of Sweden’s total bioenergy supply in 2023 (150 TWh). Even under conservative assumptions, the analysis suggests that both the increase in required carbon storage under the LULUCF Regulation and the accompanying decline in actual removals may have material implications for the availability of bioenergy derived from forests.

By focusing on the change in required removals rather than the total removal level, the results highlight that the LULUCF Regulation can restrict the amount of biomass which can be extracted without compromising compliance. Examining the relationship between the current situation and potential consequences of the LULUCF Regulation is important for Sweden’s energy and climate targets. If the ability to extract bioenergy from forests decreases due to the Regulation, Sweden must improve its preparedness to secure the consistency of its energy transition. The analysis therefore demonstrates the necessity for harmonisation across climate, forestry and energy policy domains to ensure that Sweden’s net-zero energy transition remain coherent.

4.4 Sensitivity analysis

Forest growth is subject to natural interannual variability, as illustrated by the worst-case scenario in the preceding section which reflects current decline in net removals. Beyond this, climate change is expected to increase the frequency and severity of natural disturbances, including fires, insect outbreaks and windthrow (Ellison et al., 2011; Sasso et al., 2025). Combining the factors of natural variability and disturbances, forests may experience lower average growth rates in the future.

It is therefore important to consider levels of lower growth to understand the impact that reduced biomass may have on Sweden's ability to comply with the LULUCF Regulation. To assess the implications, a sensitivity analysis is applied using alternative growth assumptions. Depending on future growth conditions, the estimated shortfall to the 2030 target ranges from 15 million tonnes CO_{2e} under average growth to 21 million tonnes under lower growth, while the distance from the most recent inventory year (2023) to the 2030 target is estimated at 19 million tonnes (SEPA, 2025a). While the worst-case scenario shows current outcomes, the sensitivity analysis illustrated how continued or intensified disturbances could lead to additional compliance challenges in the future.

The SEPA has developed two alternative growth scenarios for productive forest land: average growth and lower growth. To isolate the effect of growth uncertainty, harvesting volumes are assumed to follow the same trajectory in both scenarios, increasing from the current level of approximately 90 million m³sk by 5 million m³sk by 2030, and thereafter by 0.35 million m³sk per year (SEPA, 2025a). The lower growth scenario uses relative growth rates observed during 2015-2019, which represents a period of below-average increase. Total productive forest area is estimated at 20.46 million ha, while total simulated forest area is 23.13 million ha (SEPA, 2025a). Reusing the biomass-to-energy conversion applied in this analysis (2.15 MWh per m³sk and 50% energy share), these shortfalls translate into potential reductions in primary energy supply from forest biomass depending on growth rate scenarios. Differences in projected biomass availability and carbon removals thus arise from growth assumptions rather than from harvesting levels, as illustrated in Table 3.

Table 3. Sensitivity analysis of lost primary energy from biomass depending on forest growth level

<i>Scenario</i>	<i>Shortfall (Mt CO_{2e})</i>	<i>Corresponding biomass volume (million m³sk)</i>	<i>Energy-share volume (million m³sk)</i>	<i>Lost primary energy (TWh)</i>
Lower growth	21	15.2	7.6	16.3
Average growth	15	10.9	5.4	11.6

This sensitivity analysis indicates that shortfalls in net removals reduce the potential supply of forest-based primary energy, with reductions ranging from roughly 11 TWh for average growth and 16 TWh for lower growth (Table 3). For context, Sweden’s total bioenergy supply in 2023 was 150 TWh and this analysis represents 7% (average growth) to 11% (lower growth) in primary energy reduction. This analysis hints that reduced forest growth may have implications for the national energy system.

4.4.1 Comparison to the scenarios

As demonstrated in the previous analysis, the level of growth can have an impact on the supply of biomass energy. The SEA’s scenario report estimates different biomass supply depending on the scenario; however, the overall theme shows an assumed decreasing trend in biomass within the total energy system. If compared with today’s biomass supply at 150 TWh, the scenarios estimate the following reductions by 2030:

Table 4. Decrease in biomass energy in each scenario when compared to biomass supply in 2023.

<i>Scenario</i>	<i>Decrease in biomass energy</i>
LEC	150 – 142 = -8 TWh
GEP	150 – 135 = -15 TWh
RS	150 – 134 = -16 TWh
IG	150 – 137 = -13 TWh

Applying this trend to the sensitivity analysis, the result shows that the SEA scenario results does not divert too much. According to this analysis, shortfalls in forest net removals would reduce primary energy from biomass by around 11 TWh to 16 TWh depending on growth level (Table 3). This suggests that the SEA’s scenarios do not significantly diverge from the expected impacts of this analysis, view table 4 as means of comparison. Rather, both approaches indicate that declining forest growth and reduced removals are likely to generate constraints on the availability of forest-based bioenergy.

Besides the scenario analysis, the SEA expects a general decrease of bioenergy from 150 TWh to 137 TWh by 2028 (SEA, 2025b). However, this projected reduction can reflect the lower use and import of liquid biofuels in the transport sector following revisions to the reduction obligation, rather than a decline in domestic forest biomass supply (SEA, 2025a). Furthermore, other policy developments, such as the establishment of Emissions Trading System 2 (ETS2), may increase the demand for biofuels which can indirectly affect the balance between LULUCF and biomass.

5. Discussion

The analysis of policy documents shows that the LULUCF sector is largely absent from Sweden's four exploratory scenarios which outlines the path to a net-zero emissions energy system by 2050. Across all key documents, no definitive integration of the binding LULUCF targets is made. The SEA explicitly states that the scenario report excludes the LULUCF sector from quantitative modelling, and no adjustments are made to reflect potential reductions on biomass extraction. The reasoning behind the exclusion is based on uncertainties regarding measurement, reporting and follow-up requirements. The scenarios assume a somewhat continued access to forest biomass on varying levels and emphasise the usage of technological carbon-removal processes, such as bio-CCS.

As such, this discussion interprets how Sweden's energy transition scenarios interact with emerging LULUCF obligations, focusing on institutional positions, scenario alignment, and policy coherence. The findings reveal a somewhat structural disconnect between binding land-use regulation and long-term energy planning, which can impact the government's climate ambitions. On the other hand, the SEA's scenarios assume a gradual decline in biomass energy which indicates a stronger sense of preparedness. These findings unveil the complex dimensions behind sustainable transitions.

5.1 Institutional positions and conflicting priorities

Some agencies have integrated the LULUCF sector more than others. For example, the SEPA appears to have a more positive stance regarding the Regulation's contribution to biodiversity targets and increased CO₂ uptake. At the same time, the agency highlights the difficulty for Sweden to reach its removal target and emphasises that current proposed measures by Miljömålsberedningen are insufficient. The SFA is overall supportive of the proposal's ambition but argues that the strategy remains inadequate. The agency echoes similar uncertainties as the SEPA such as uncertainties relating to reporting and modelling, as well as natural variability due to climatic changes. As for the SEA, the agency welcomes the objective to increase net GHG removals in LULUCF but highlight uncertainties and risk, especially potential negative impacts on the energy system. It also warns that the LULUCF Regulation's system boundaries can give a misleading picture of climate benefits, as reduced Swedish harvesting levels may simply shift emissions abroad.

Miljömålsberedningen expects to achieve a net uptake of 5.5 million tonnes of CO₂-equivalents through the proposed strategies, which is an increased target compared to 4 million tonnes set out in the LULUCF Regulation. By reviewing the responses of three agencies, there appears to be some hesitation towards the level of ambition from Miljömålsberedningen. For example, one common denominator among the agencies is the possibility for using flexible mechanisms within the LULUCF Regulation. This shared emphasis on flexibility reflects broader concerns about the feasibility of meeting the increased uptake target and the following risks of unintended consequences for other sectors. Taken together, the agencies' positions reveal a tension between supporting higher climate ambition and recognising ecological and systemic constraints. This suggests that successful implementation of the strategy will depend not only on additional measures, but also on clearer governance and a more robust assessment of cross-sectoral effects.

The stance of authorities and the following conflicting interests can be linked to the existing research. For example, the EU forest policy has shown to be divided by two advocacy coalitions; an *environmental coalition* that promotes biodiversity conservation, stricter environmental regulation, and stronger EU-level integration, and a *forest use coalition* that prioritises economic utilisation, bioeconomy growth, and national sovereignty over forest management (Sotirov et al., 2021). By reviewing the agencies position on Miljömålsberedningens (2025) proposed strategies, it appears to reflect the broader divide between the two advocacy coalitions. From one point of view, the agencies express support for increased climate ambition and the integration of biodiversity considerations. These are factors that are consistent with the environmental coalition. From another point of view, the concerns relating to modelling uncertainties, natural variability, and economic implications links more towards the forest use coalition. The Swedish agencies' responses can be understood as reproducing the similar tensions which characterise EU forest policy. Overall, the agencies do not take a stance against or for the increased regulation of the sector, rather, they appear to be strategically cautious.

5.2 Scenario implications for the LULUCF sector

Given that the LULUCF sector is becoming increasingly regulated, it is necessary for the Swedish government to integrate the sector into existing policy strategies. This becomes more evident by reviewing the SEA's (2025b) scenarios which assume varying but consistent access to domestic biomass. If net carbon uptake must increase whilst harvest levels may consequently be reduced, each scenario is affected differently depending on its level of biomass dependency and flexibility in energy supply.

However, the scenario results become considerably more complex when the constraints of the LULUCF Regulation are taken into account. If Sweden is required to increase net removals whilst current removals continue to decline, the implication is that a larger share of standing forest biomass must remain unharvested to meet regulatory compliance. In practice, this restricts the volume of biomass that can be mobilised for energy use, thereby challenging the assumptions underpinning all four scenarios.

The scenarios differ in their degree of biomass dependency, and this influences how sensitive each pathway is to reduced forest harvest potential. For example, scenarios with extensive electrification and lower bioenergy reliance (such as LEC) may be better positioned to handle reduced access to forest biomass. In contrast, scenarios that rely heavily on bio-based fuels, industrial biomass use, or bio-CCS to achieve climate neutrality (such as GEP or RS) become particularly vulnerable under conditions of declining forest growth.

Besides the scenario analysis, the SEA expects a general decrease of bioenergy from 150 TWh to 137 TWh by 2028 (SEA, 2025b). However, this projected reduction can reflect the lower use and import of liquid biofuels in the transport sector following revisions to the reduction obligation, rather than a decline in domestic forest biomass supply (SEA, 2025a). The projected decrease in bioenergy should not be viewed as evidence of a structural shift away from forest biomass driven by resource constraints. Instead, it mainly reflects other policy changes with limited links to forest growth or LULUCF compliance. As a result, the LULUCF Regulation may reinforce this assumed shift rather than creating an entirely new one.

5.2.1 The possibility of flexible mechanisms

Throughout the analysis, there is one factor which continues to surface: the possibility of using flexible mechanisms. The Swedish government and agencies press the issue of uncertainties regarding reporting, measurement, and assessment within the LULUCF sector. There are certain articles in the Regulation which are particularly relevant, such as provisions on general flexibility, regulations of natural disturbances, and flexible management of forest land. While these flexibilities offer short-term support, they do not replace the need for structural policy adjustment and coordination among agencies. The flexibility mechanisms do indeed provide Sweden with some room for manoeuvre; however, they also reveal structural issues. Flexibilities are not meant to allow MS to maintain their business-as-usual, instead they should be seen as temporary stabilisers. For Swedish agencies, this should be considered as a transitional strategy rather than a long-term support.

5.3 Opportunities and challenges

The analysis indicated results which can be considered as opportunities and challenges following the integration of the LULUCF sector. These opportunities and challenges can be linked to possible changes in supply of bioenergy. As for changes in bioenergy supply, this study made the assumption that change was driven by the binding LULUCF target for CO₂ uptake but also taking into account different growth levels of forest.

5.3.1 Opportunities

The most comprehensive opportunity for Sweden is its vast forested area. This opportunity takes form as both the forest as a carbon sink but also its potential for biomass extraction. Some scholars argue that forest biomass may support climate mitigation if applied under cautious practices (McKeough, 2019). These practices are dependent on improved forest management practices which prioritise long-term carbon sequestration whilst allowing residual biomass extraction. This opportunity revolves around a stronger policy coherence between targets of LULUCF and the energy transition.

In addition to this, Sweden has one of the largest supplies of renewable energy within the EU (EEA, 2024). The potential decline in bioenergy supply could create opportunities for scaling up other renewable energy sources such as wind, solar, and electrification in sectors that are currently more dependent on bioenergy. Adding to this, some researchers argue that forest biomass should not be considered as a renewable energy (Booth and Giuntoli, 2025; Hyvonen et al., 2024). Based on this argument, reducing the reliance on forest biomass may create potential solutions for a more sustainable energy transition.

5.3.2 Challenges

Swedish agencies have expressed in unison the need for integrating the LULUCF sector across sectors to improve cross-sectoral cooperation and to reduce conflict of interests. A central challenge revolves around uncertainties relating to measurement, reporting and impacts of natural disturbances. For example, as forest growth becomes more affected by climate change, these uncertainties complicate both regulatory compliance and the incorporation of LULUCF targets into long-term energy planning. In practice, this uncertainty can be seen as a contributing factor that reinforces cautious approaches among agencies.

Further challenges are related to system boundaries and displacement effects. National compliance with LULUCF targets may lead to unintended consequences both within but also beyond Sweden's borders. Some research indicate that reduced domestic harvesting risks increasing imports of biomass or forest products, potentially shifting emissions to other countries rather than reducing them globally (Sasso et al., 2025). This challenge can be linked to broader critiques that EU climate governance, including the LULUCF sector, remains largely territorial and insufficiently equipped to address cross-border market responses (Dagiliūtė and Kazanavičiūtė, 2025).

Taken together, these challenges suggest that the overall obstacle to integrating LULUCF into Sweden's climate and energy strategy is not a lack of regulatory ambition, but a mismatch between targets, land-use practices, and energy system dependencies. Without stronger alignment between LULUCF objectives and long-term forest management, there is a risk that forests are expected to deliver multiple services simultaneously to an even greater extent.

5.4 Final reflections

It is worth discussing the applied methods in this study to identify relevant uncertainties. For the quantitative aspect, various assumptions were made in order to illustrate relationships or patterns which would help answer the research objectives. These assumptions were taken from established data or measurements from official agencies and research. However, as the revised LULUCF Regulation is yet in its early stages, the findings derived from this study is thereby hypothetical. The assumptions used have been a helping hand to examine and understand a complicated context and it is thereby important to recognise the uncertainties. Therefore, this study should be considered as an illustrative rather than a predictive attempt to integrate the LULUCF sector into the Swedish energy transition. Despite these uncertainties, the assumptions used have enabled this study to explore how LULUCF obligations may interact with energy transition strategies, where opportunities and challenges have been identified.

First of all, the future scenarios for reaching a net-zero energy system by 2050 are based on assumptions regarding factors such as technological development, energy demand, geopolitical changes, and resource availability. While these assumptions are grounded in established modelling practices, they do not fully account for emerging constraints from the LULUCF Regulation or for potential non-linear changes in forest growth due to natural disturbances. Another key assumption relates to the future development of forest carbon sinks. Declining forest growth and increased disturbance are supported by current research; however, the scale and timing of these changes are uncertain.

Finally, the analysis assumes relative stability in the current policy framework. In practice, the possible use of flexibility mechanisms may alter national pathways. Furthermore, other policy developments, such as the establishment of Emissions Trading System 2 (ETS2), may increase the demand for biofuels which can indirectly affect the balance between LULUCF and biomass. The EU's reliance on forest biomass as a source for its renewable energy is a vital trial for the effectiveness of the LULUCF Regulation's accounting rules (Sasso et al., 2025). The staged implementation of new accounting rules and introduction of strict methodologies from 2026 adds further complexity to the mix. Future research would benefit from examining the interactions between the LULUCF Regulation and other policy developments which may impact national mitigation strategies, including potential trade-offs and synergies.

6. Conclusion

One of the main objectives was to assess how the integration of the revised LULUCF Regulation affects Sweden's future energy transition scenarios, with particular focus on the role of forest-based bioenergy and carbon sinks. This was done by identifying potential goal conflicts between LULUCF targets and climate-and energy targets. In addition, an assessment was carried out to gain understanding of the implications of different levels of biomass extraction for Sweden's net carbon sink and its ability to meet the binding LULUCF removal targets for 2030. This objective was linked to the examination of how changes in bioenergy supply influence various components of Sweden's energy system.

Another main objective was to investigate LULUCF in the policy landscape regarding national and EU climate plans. The policy analysis revealed that there are various opportunities and challenges involved when integrating the LULUCF sector. The responses of the Swedish agencies on Miljömålsberedningen's proposal can be understood as reproducing similar tensions which characterise EU forest policy. Examples of these tensions are conflict of interests between climate mitigation, biodiversity conservation, and economic forestry objectives, as well as questions of governance and policy coherence across levels. Overall, the agencies appear to be strategically cautious.

The findings demonstrate that Sweden is currently far from meeting its binding LULUCF target by 2030. The current base case, with a target of 4 Mt CO_{2e}, corresponds to approximately a reduction of 3 TWh of primary bioenergy. Under the worst-case scenario, the removal gap could reach 19 Mt CO_{2e} which implies a reduction of 15 TWh. As for the future, the sensitivity analysis implied a reduction of 11 to 16 TWh of bioenergy depending on forest growth levels. The analysis emphasises on the sensitivity of LULUCF compliance to assumptions about forest growth and biomass availability. Overall, the findings reveal the high expectations on forests to achieve multiple objectives in climate and energy policy which may create tensions within current transition pathways.

Perhaps revealed by the objectives, this was not a simple endeavour. Climate change and its consequential impacts are and will continue to affect all systems of society. It is therefore crucial to increase knowledge of cross-sectoral relationships and how they are and will interact. Examples of these sectors are LULUCF and energy, where current research is limited. This study's key contribution to current research is the foundational beginning of understanding the relationship between the LULUCF sector and the energy sector. Future research would benefit from exploring this dynamic further, especially following the success or downfall of the LULUCF Regulation.

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