Danish Council on Climate Change.

August 2024

Denmark's Climate Transition Towards 2050

Long-term Scenarios for Achieving an Emissions Reduction Target of 100 or 110 Percent

English summary

klimaraadet.dk

This is an abbreviated translated version

This report is an abbreviated version of the original Danish analysis which was published in August 2024. This translated version aims to bring the conclusions of the DCCC to a broader audience. The original analysis is available on the website (klimaraadet.dk), along with the background notes, where you can learn more about the conclusions, assumptions and methodology. If you have any further inquiries, feel free to contact the secretariat at mail@klimaraadet.dk.

Denmark's Climate Transition Towards 2050
Long-term Scenarios for Achieving an Emissions Reduction Target of 100 or 110 Percent
English summary

Published in August 2024 by

The Danish Council on Climate Change

Nikolaj Plads 26, 2nd Floor
1067 Copenhagen K, Denmark
+45 22 68 85 88
mail@klimaraadet.dk
www.klimaraadet.dk

Cover design: B14
Illustration: Fie Sahl Kreutzfeldt

Written By

Peter Møllgaard
Bente Halkier
Niels Buus Kristensen
Brita Bye
Per Heiselberg
Marie Trydeman Knudsen
Marie Münster
Katherine Richardson
Bo Jellesmark Thorsen

About the Danish Council on Climate Change

The Danish Council on Climate Change (DCCC) is an independent body of experts that advises the Danish government on transitioning to a climate-neutral society, aiming to secure a future with significantly reduced greenhouse gas emissions while maintaining the country's welfare and development standards.

The DCCC was established in 2014 as a result of the Danish Climate Act which outlines the Council's tasks. The Danish Climate Act stipulates that the DCCC must:

1. evaluate the status of Denmark's implementation of national climate objectives and international climate commitments,
2. analyse potential means of transitioning to a low-carbon society by 2050 and identify possible measures to achieve greenhouse gas reductions,
3. draw up recommendations to help shape climate policy, including a selection of potential mechanisms and transition scenarios,
4. contribute to the public debate.

The DCCC must, to the extent required in the preparation of its analyses and other work, consult and involve relevant parties, including, among others, business interests, social partners in the labour market and civil society.

Members of the Danish Council on Climate Change

- Peter Møllgaard (Chair), President of Copenhagen Business School
- Bente Halkier (Vice Chair), Professor of Sociology at the University of Copenhagen
- Niels Buus Kristensen (Vice Chair), Director of Institute of Transport Economics, Norwegian Centre for Transport Research
- Brita Bye, Senior researcher at the Research Department at Statistics Norway
- Per Heiselberg, Professor at the Department of the Built Environment at Aalborg University
- Marie Trydeman Knudsen, Senior Researcher at the Department of Agroecology at Aarhus University
- Marie Münster, Professor in Energy Systems Analysis at the Technical University of Denmark
- Katherine Richardson, Professor in Biological Oceanography and Leader of the Sustainability Science Centre at the University of Copenhagen
- Bo Jellesmark Thorsen, Head of Department and Professor of applied economics at the Department of Food and Resource Economics at the University of Copenhagen

Table of contents

Main conclusions

1. **Denmark can achieve a high level of decarbonization using existing measures:** An emissions reduction of 90 percent can be achieved with already known transition elements, such as afforestation and electrification. These measures will be extensive and require a persistent, long-term and immediate political effort. To reach 100 or 110 percent, new transition elements are necessary, requiring new technology and significant societal changes.

2. **There are multiple paths to 100 and 110 percent:** The analysis examines how targets of 100 and 110 percent reduction by 2050 can be achieved by following two fundamentally different transition paths. The two paths, New Lifestyle and New Technology, each point in different directions and have various advantages and disadvantages based on relevant societal considerations. A realistic future will likely be somewhere between the two scenarios.

3. **Both structural changes and new technology are needed:** The two paths balance structural changes in society and the focus on new technologies in different ways. Some of the most effective structural changes include the conversion of agricultural land to forests, grasslands, and nature; a reduction in livestock numbers and changes in dietary habits; and fewer and shorter flights. Among the most important technologies in the analysis are: pyrolysis and storage of carbon in biochar, ammonia as green fuel in shipping, methane-reducing feed additives for cows, biorefining of grass to protein, and, not least, capturing CO_2 from both industrial point sources and directly from the air.

4. **Agricultural emissions are hard to eliminate:** In all the scenarios examined, there will still be emissions remaining in 2050, with agriculture accounting for 80-90 percent of them. To bring total net emissions to zero, significant negative emissions are needed to offset the climate impact of agriculture, in particular.

5. **Negative emissions will be central:** Negative emissions are also necessary to move from 100 to 110 percent reduction. Negative emissions can come from afforestation, storage of biochar, and the capture and storage of CO_2 from biomass consumption or directly from the air. These solutions either require a lot of land or are currently very expensive and untested on a large scale.

6. **There is synergy between climate, environmental, and nature concerns:** A significant climate benefit can be achieved by protecting 30 percent of Denmark's land area for nature and biodiversity, which is the EU's ambition for the union as a whole. For example, unmanaged forests can absorb and store large amounts of carbon in the designated areas without major investments in technology and infrastructure, and the rewetting of lowland soils can stop emissions and make room for more nature. Additionally, increased protection of land and afforestation can contribute to a better aquatic environment and cleaner drinking water.

7. **Denmark has significant potential for biogenic production:** Denmark is well-positioned to produce biogenic products for food, feed, energy, materials, and negative emissions. Therefore, both 100 and 110 percent targets can be achieved while Denmark simultaneously (1) stops importing biomass for energy purposes (2) produces its own green fuels to meet the needs of international shipping and aviation refueling in Denmark, and (3) reserves 30 percent of land area for protected nature.

8. **Climate action can be combined with a surplus of food and feed:** Today, Denmark is, on balance, a net exporter of food and feed measured by energy content, but a net importer measured by protein. In meeting the 2050 target, as outlined in point 7, there is a production surplus of food and feed compared to national consumption, measured in both energy and protein. This surplus is more plant-based and less animal-based than today. The surplus can potentially be exported and thereby displace production and climate impact abroad.

9. **Denmark has the potential to produce large amounts of electricity and hydrogen:** Today, Denmark is, on balance, a net importer of energy. However, the scenarios show that by 2050, there is potential for a significant Danish production surplus of energy if Denmark's plans to exploit the North Sea's wind resources become a reality. This energy surplus can potentially be exported as electricity, hydrogen, or other fuels, thereby contributing to Denmark's global climate efforts.

10. **Increased competition for biogenic carbon:** Photosynthesis in plants produces biogenic carbon, which serves as basis of food and life for all living organisms. It is also needed for materials, energy, and carbon storage to facilitate negative emissions. In a future without the use of fossil carbon, it will become crucial to be more land-efficient, develop technical solutions, and find ways to increase the production of biogenic carbon without compromising environmental and nature considerations. At the same time, we must prioritize the use of carbon and ensure it is recycled as much as possible. Achieving an ambitious 2050 target should therefore be seen alongside our production and consumption of biogenic carbon.

11. **DAC could change the picture:** Direct air capture (DAC) of CO_2 has, in theory, great potential to alleviate the scarcity of biogenic carbon and contribute to negative emissions. However, DAC is still an immature technology that may prove expensive and very difficult to scale to the required dimensions. Therefore, relying solely on DAC is risky.

Recommendations for policymakers

1. **Increased territorial climate target:** The government wants to increase the Danish Climate Act's 2050 target from 100 to 110 percent. The DCCC supports the direction of this ambition and therefore recommends an increase that would result in net-negative emissions from Danish territory by 2050. The world's current path toward over 2 degrees of warming, Denmark's commitments under the Paris Agreement, and the objectives of the Danish Climate Act regarding Denmark's role and responsibility necessitate raising long-term climate ambitions.

2. **Clarity on targets:** There will be greater clarity about the long-term ambitions and elements of climate policy if the government's 2050 climate target aligns with the Danish Climate Act's targets. The government should therefore take the initiative to revise the Danish Climate Act to remove the current ambiguity regarding the 2050 target.

3. **Targets for international transport:** Denmark should take responsibility for its share of international shipping and aviation on par with domestic transport,

which is already covered by Denmark's commitments and national targets. Specifically, the Danish Climate Act should set a 2050 target for zero emissions from the fuel that ships and planes on international routes refuel in Denmark. Alternatively, these emissions could be included in Denmark's territorial target.

4. **Biogenic carbon:** Achieving the Danish climate targets should be done in a way that considers biogenic carbon a scarce global resource. If Denmark bases its emission reduction effort on increased import or reduced export of biogenic carbon, emissions may instead increase abroad, thereby undermining the purpose of an ambitious Danish target. Therefore, achieving the territorial target by 2050 should take the following considerations into account:

    a. **Food and feed:** Denmark should ensure a sufficient domestic production surplus of food and feed, measured in both energy and protein content, to enable exports to the rest of the world. This can be achieved by transitioning Danish agricultural production to less animal-based and more plant-based, thereby freeing up land for other purposes.

    b. **Bioenergy:** Denmark should not base its energy system in 2050 on the net import of biomass and biofuels. Similarly, achieving Danish climate targets should not be based on carbon storage of imported biogenic carbon.

    c. **Land area for nature:** Denmark should reserve sufficient land for nature and biodiversity soon. Otherwise, biodiversity may face increased pressure as agricultural and forestry land is required to produce greater amounts of biogenic carbon.

5. **5. Long-term strategy:** The government should develop a long-term strategy for how we as a society can achieve the desired climate target by 2050. A suitable and timely transition towards the climate target in 2050 requires maximum clarity for stakeholders about the path forward, and actions taken today should, as much as possible, align with the long-term perspective. This requires strategic long-term planning that also addresses the uncertainty surrounding technology development, costs, and behavioral patterns. Due to this uncertainty, the strategy should be revisited and adjusted continuously.

    The long-term strategy should, among other things, address:

    a. The realization of already known and well-tested transition elements.

    b. Spatial planning, particularly regarding:

    - Allocation of land areas to protect biodiversity and ensure the quality of the aquatic environment.
    - Direction for climate-friendly food production and plant-based diets.
    - Concrete plans for timely forest establishment.

c. Denmark's share of emissions from international transport.

d. Expansion and coordination of energy infrastructure for electricity, hydrogen, and CO_2.

e. Important supporting measures:

- The public sector’s role, including its role as a major purchaser.
- The need for research and innovation.
- Ensuring workforce and skills.

6. **Public discussion on upcoming changes:** The government should encourage public discussion about the vision for 2050 and the changes required to meet ambitious targets, allowing citizens and businesses to adapt early, tackle challenges, and seize new opportunities.

1. Introduction

According to the Danish Climate Act, Denmark must be climate-neutral by 2050 at the latest. This means that the total amount of CO_2e absorbed must equal the amount emitted. This target is equivalent to a 100 percent reduction in net greenhouse gas emissions compared to the net emissions in 1990.

The government has proposed raising the 2050 target to 110 percent and simultaneously moving the climate neutrality target forward to 2045. A reduction target of 110 percent signifies a society that goes beyond climate neutrality and absorbs more CO_2e than it emits. This is also referred to as net-negative emissions.

The target in the Danish Climate Act and the government's objectives are illustrated in Figure 1.1. At present, neither specify the path towards 2030 and 2050. Therefore, the figure assumes a linear development from 2030 onwards to 2050.

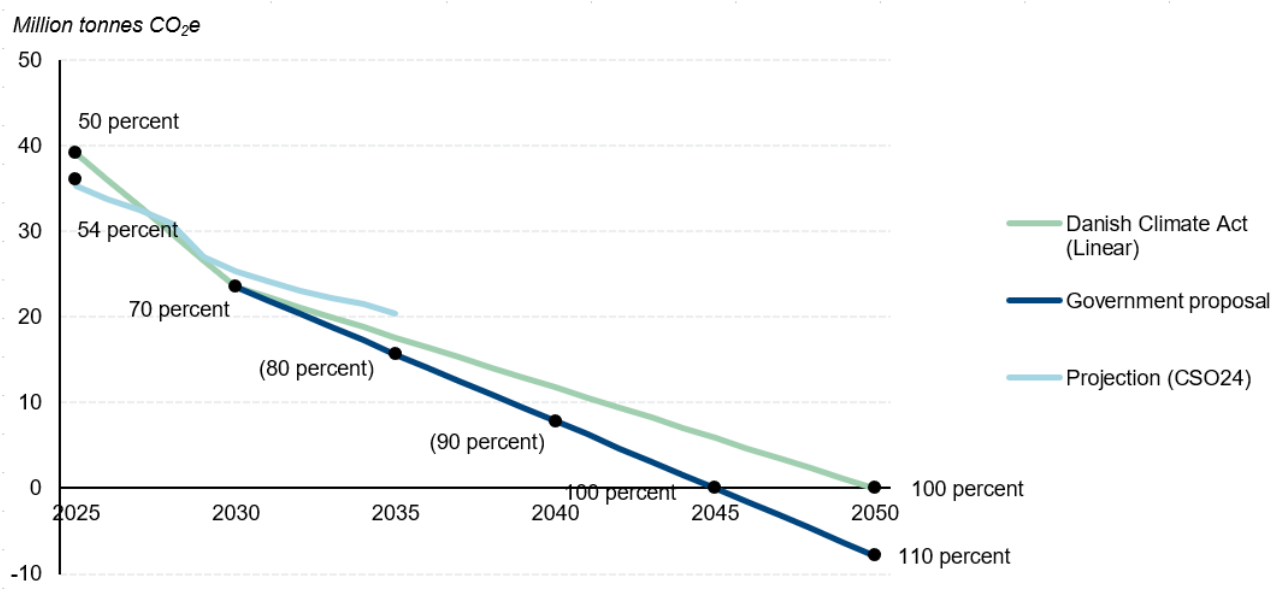

Figure 1.1 Different national reduction targets

Note 1: The figure shows emissions according to Denmark's Climate Status and Outlook 2024 (CSO24) and the linear paths to different national reduction targets. The linear paths are merely an illustration and do not reflect specific objectives.

Note 2: Total greenhouse gas emissions were 78.3 million tonnes of CO_2e in 1990.

Note 3: The effect of the "Agreement on a Green Denmark" from the Green Tripartite is not included in the figure. The government expects that the agreement will reduce emissions by 3.3 million tonnes of CO_2e by 2035, corresponding to a total reduction of 78 percent compared to 1990.

Sources: The Ministry of Climate, Energy, and Utilities[1] and the DCCC.

The Danish Context: About the Green Tripartite

In June 2024, the Danish government, along with key stakeholders in the Green Tripartite (agriculture, industry, and environmental organizations), made a political agreement on plans for a long-term transformation of Denmark's land use and agricultural production. Key goals include increasing forest cover by 40 percent, converting more than 15 percent of agricultural land into natural areas, and improving the ecological state of all 109 water bodies by 2027 through nitrogen reduction efforts. Additionally, a new fund will help finance these environmental efforts with 40 billion DKK allocated for land restructuring and conservation projects.

2. Purpose and scope of the analysis

The purpose of this analysis is to advise the Danish government and Parliament on the long-term climate target for 2050. This includes the formulation of the target, its scale, and the potential ways in which it can be achieved.

The analysis looks at both the current targets of the Danish Climate Act and the government's proposal for increased targets. The scenarios show how combinations of changed behavior and production patterns on one hand, and new technologies on the other hand, can help us achieve the target. It is a systemic analysis, with a particular focus on Denmark's use of land and other physical resources, but it also considers the exchange of resources with the outside world. The analysis highlights a future with many dilemmas and emphasizes the advantages and disadvantages of different paths.

The climate challenge and the scarcity of biogenic carbon are closely linked

The challenge of achieving the climate target in 2050 is closely linked with another challenge: the scarcity of biogenic carbon and land. Biogenic carbon is needed for food, materials, bioenergy, and negative emissions, and land is required to produce the necessary bioresources. Meanwhile, land is needed for protected nature and afforestation, among other things.

This scarcity creates competition for both biogenic carbon and land. Therefore, alongside the reduction target, it is important to consider other essential uses where biogenic carbon and land are also required. Box 1.1 explains what is meant by biogenic carbon.

The challenge of scarcity can potentially be alleviated with new technology, such as direct air capture (DAC), which can extract CO_2 directly from the atmosphere. However, DAC is still an immature technology that may prove difficult to scale and could remain very expensive in 2050. Thus, there is a significant risk in relying on a technology like DAC becoming available without having an alternative strategy.

Box 1.1 About biogenic carbon

Biogenic carbon, derived from photosynthesis, is a vital yet limited resource found in plants, biomass, and food. It is essential for food, materials, fuels, and carbon storage. Human use of biogenic carbon, which has significantly increased since the industrial revolution, impacts ecosystems and drives biodiversity loss. To manage its scarcity, bioresources should be used efficiently, following a cascade principle: first for high-value products like food, then for feed and materials, and finally for energy.

3. There are several paths to 100 and 110 percent

The analysis presents scenarios for achieving a climate target by 2050

This analysis presents stylized scenarios for how Denmark can achieve reductions of 100 and 110 percent by 2050. The scenarios are simplified examples of how Denmark might look to meet its climate targets, not an exhaustive list of future possibilities. They aim to highlight the pros and cons of each scenario, illustrate system interconnections (between the reduction target, land use, bioresource consumption, carbon storage, and food production), and provide a resource accounting framework. The results, based on models that simplify reality, carry uncertainty and should be viewed primarily as an indication of key relationships and approximate levels of emissions, consumption, and production.

Denmark can achieve about 90 percent with known transition elements

The analysis begins by examining how far Denmark can progress with known transition elements. Known transition elements are climate measures that are largely ready to be implemented or can be seen as a continuation of current trends, such as wetland restoration on carbon-rich soils and electrification.

Known transition elements can take Denmark far, but they are not sufficient to fully achieve the target by 2050. This is illustrated in Figure 1.2, which shows that Denmark achieves a reduction of approximately 90 percent by 2050, thus coming relatively close to climate neutrality.

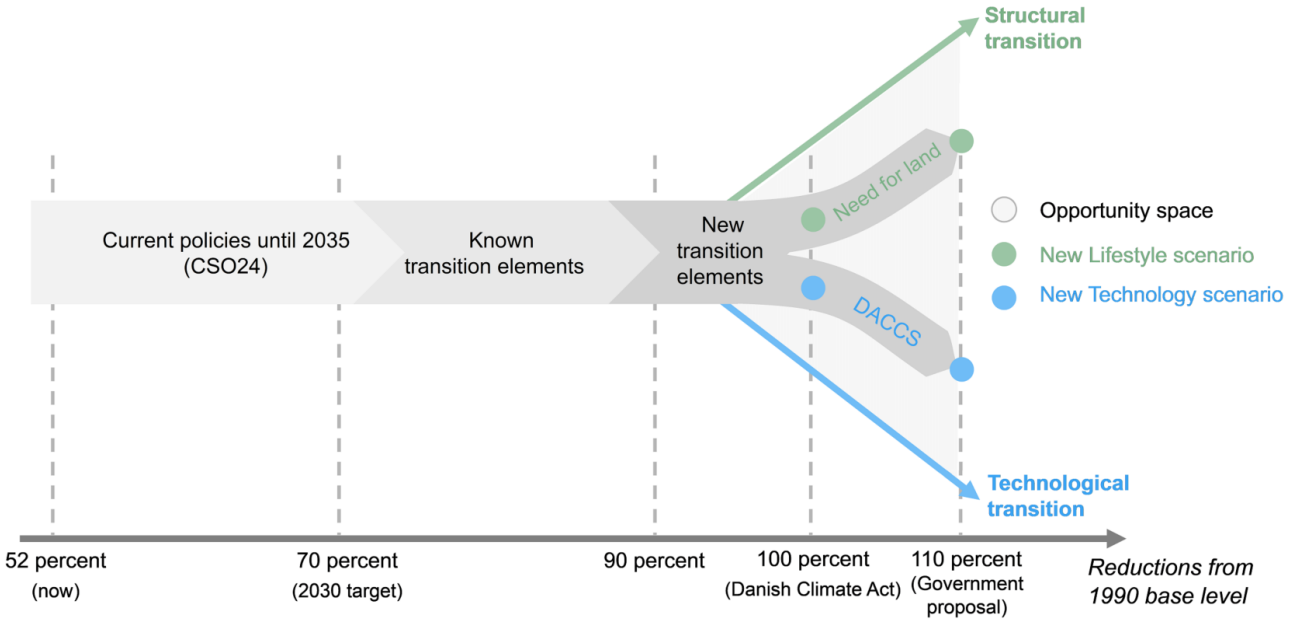

Figure 1.2 Known and new transition elements and different paths to 100 percent and 110 percent

Note: Current policy follows Denmark's Climate Status and Outlook 2024 (CSO24) and reflects expected emissions in 2035 and not in 2050.

Sources: The Ministry of Climate, Energy, and Utilities[2] and the DCCC.

Known transition elements require a political focus on implementation

With the current policies, a reduction of about 74 percent will be achieved by 2035. This reflects both the current national policies and those adopted at the EU level under the Fit for 55 package. It is uncertain how emissions are expected to develop after 2035 in the absence of new policies. However, the implementation of known transition elements will most likely require new political initiatives and a sustained climate policy effort to reach a target of 90 percent. This could involve economic incentives to phase out fossil energy and reduce agricultural emissions, along with expanding infrastructure for electricity and hydrogen transport.

There are many possible paths to 100 and 110 percent by 2050

To reach an emissions reduction of 100 or 110 percent by 2050, new transition elements are needed. New transition elements are climate measures that require technological development, involve significant behavioral changes and production shifts, or are otherwise associated with implementation challenges at this time.

Figure 1.2 illustrates the range of possibilities for new transition elements, depicted between two axes. The axes are labeled as structural transition and technological transition. Within this range, many different combinations of structural and technological transitions are possible. Along the axes, one can imagine extreme scenarios based solely on either structural transition—such as changes in consumption and/or production patterns—or the use of new technology.

The analysis looks at two paths towards the climate target

The analysis examines two different paths based on new transition elements that extend beyond known transition elements. The two paths rely on structural and technological transition, respectively, but neither are extreme. The paths are:

- **New Lifestyle:** This path is characterized by an emphasis on behavioral changes, major structural changes in sectors like agriculture, and biological CO_2 absorption, which requires land.

- **New Technology:** This path is characterized by a series of new technologies that can reduce emissions in sectors such as agriculture and deliver large negative emissions.

The two targets and the two paths toward the targets result in the four scenarios, as illustrated in Figure 1.2.

Framework conditions ensure that the climate target is achieved in an appropriate way

A territorial reduction target can be achieved in various ways, each with far-reaching consequences. It's crucial to consider how different paths to the climate targets impact other priorities which must be addressed alongside climate efforts.

In this analysis, the DCCC has selected three framework conditions that must be met alongside the climate target in all four scenarios:

- **30 percent of land for protected nature:** This condition means that Denmark can contribute an equal share to the common target in the EU's Biodiversity Strategy of 30 percent protected nature on land. This aligns with the recommendation put forward by the Danish Biodiversity Council, while the agreement from the Green Tripartite points to 20 percent, as part of the EU's recently adopted Nature Restoration Law.[3]

- **No import of bioresources for energy purposes and carbon storage:** This condition reflects the expectation that biogenic carbon will become a vital resource for countries to achieve their long-term climate targets. The aim of becoming a frontrunner, as outlined in the Danish Climate Act, is difficult to reconcile with importing bioresources when they can be produced domestically.

- **Production of green fuels for international transport:** In the scenarios presented, Denmark must produce green fuels for planes and ships that refuel in Denmark. This condition reflects Denmark's responsibility for its share of emissions from international transport, as outlined in the DCCC's analysis "Denmark's Global Climate Action" from 2023.

Achieving the climate targets involves negative emissions

In all four scenarios, significant negative emissions are needed to meet the reduction targets. This applies not only to a target of 110 percent but also to 100 percent. Negative emissions refer to methods that absorb or capture CO_2 from point sources or the atmosphere and store it. Here, the two scenarios, New Lifestyle and New Technology, differ significantly from each other.

- **New Lifestyle requires land:** In the New Lifestyle scenarios, negative emissions come from biologically-based methods, including afforestation, capture and storage

of biogenic CO_2 (BECCS), as well as pyrolysis and storage of biochar. These methods require biomass production from a significant amount of land.

- **New Technology requires DACCS:** In the New Technology scenarios, a large part of the negative emissions comes from the technology Direct Air Carbon Capture and Storage (abbreviated as DACCS). DACCS is a technology where CO_2 is captured directly from the air and then stored underground.

The scenarios have common features

New Lifestyle and New Technology share several similarities. For example, all scenarios assume a reduction in the production of animal meat and milk in Denmark, although to varying degrees and with different changes among consumers. There is also an increase in the production of biochar via pyrolysis in all scenarios. This is because pyrolysis is considered both a new technology and part of the necessary biologically-based negative emissions included in New Lifestyle, which does not use DACCS.

Figure 1.3 provides a summarized overview of the most significant transition elements.

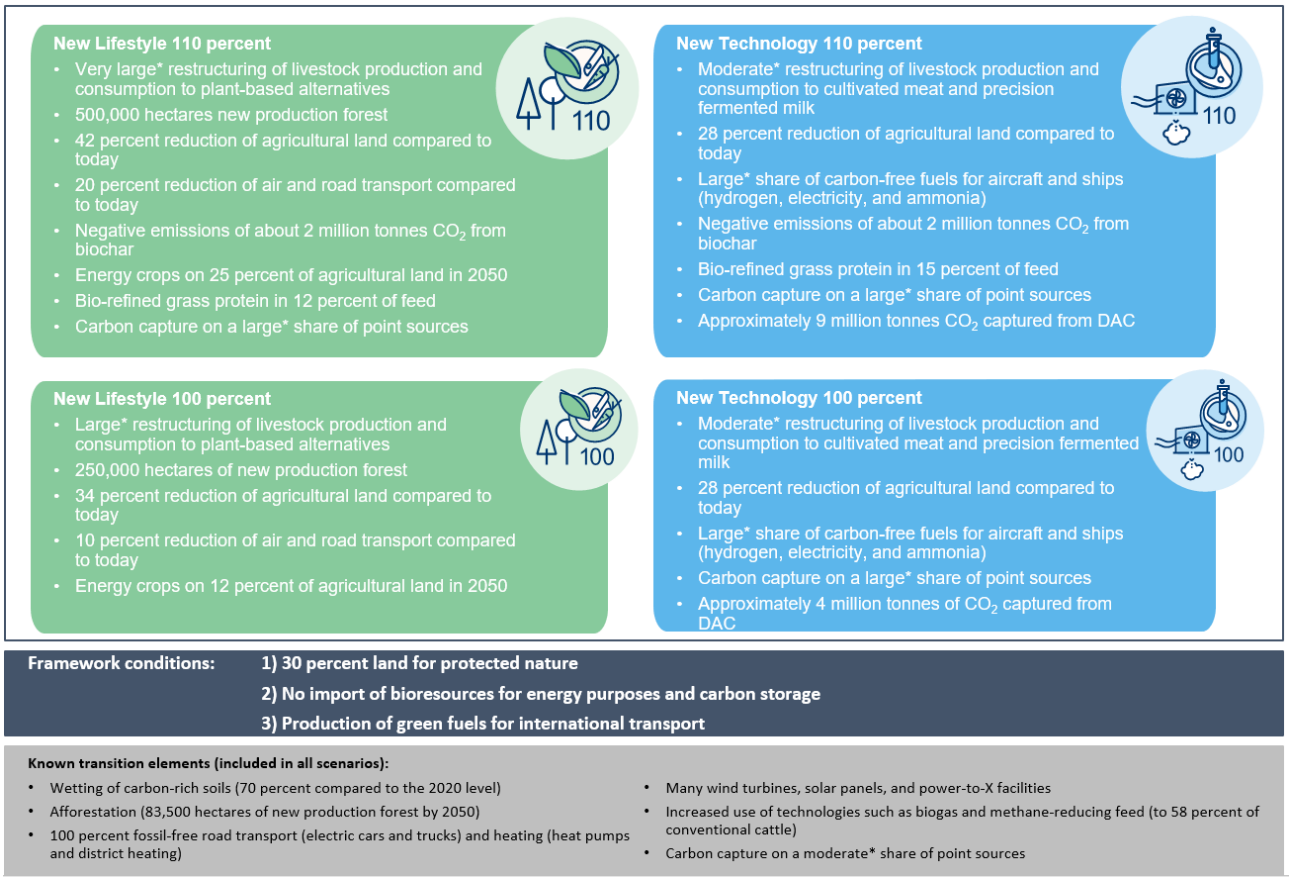

Figure 1.3 The four scenarios and the most significant transition elements

Note 1: The figure highlights the transition elements that are most significant for the reduction target and for the production and consumption of biogenic carbon.

Note 2: *Qualitative terms such as “Very Large,” “Large,” and “Moderate” etc., are used because the bullet point consists of several different transition elements.

Source: The DCCC.

There is potential to increase biomass production on land and in the sea

The scenarios aim to increase biomass production on land by incorporating several methods highlighted by the National Bioeconomy Panel and researchers at Aarhus University. These methods include switching to high-yield grasses that grow year-round, increasing straw collection, harvesting cover crops, generally increasing crop yields, using fast-growing tree species, and cultivating seaweed and mussels in the ocean.

In the long term, new technologies might enable the cultivation of biomass in less land-intensive ways. These perspectives are included to a limited extent, but they could potentially play a crucial role in achieving sufficient negative emissions if DACCS does not become a viable option.

The analysis does not account for socioeconomics

The analysis does not include economic calculations or assessments of employment effects. It also does not consider the consumption of products or raw materials produced abroad, apart from energy, feed, and food. While these factors are important for decision-making leading up to 2050, they fall outside the scope of this analysis.

4. Results from the 2050 scenarios

Agricultural emissions are hard to eliminate

Emissions from agriculture and land use account for the majority of the remaining emissions in 2050 in the four scenarios. This is shown in Figure 1.4, which displays emissions and negative emissions in 2050. The emissions primarily originate from livestock for meat and milk production, as well as from the cultivation and fertilization of fields.

Emissions from agriculture are the highest in New Technology 100, reaching almost 8 million tonnes of CO_2e in 2050. This is mainly due to the prevalence of livestock production. In the scenarios New Lifestyle 100 and New Lifestyle 110, there is a decrease in livestock production of 60 percent and 80 percent, respectively, compared to the level in 2020. This reduces emissions from agriculture to 4-5 million tonnes of CO_2e in 2050.

All four scenarios also include a small amount of remaining emissions from landfills, wastewater, and similar sources.

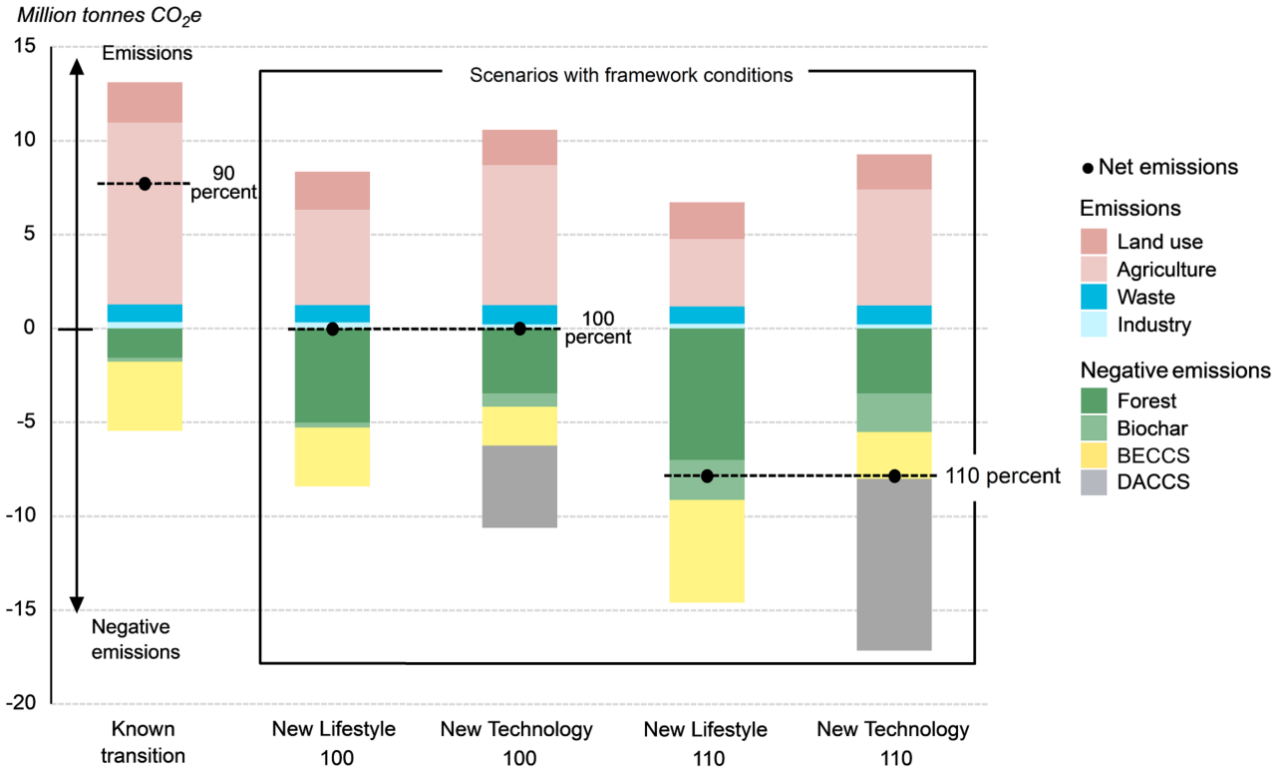

Figure 1.4 Emissions and negative emissions

Note 1: All territorial CO_2e emissions are included in the figure. Agriculture: animal digestion, manure management, fertilization of fields. Land use: LULUCF (e.g., emissions from drained carbon-rich soils) excluding forest and harvested wood products. Forest: forest and harvested wood products.

Note 2: The capture of CO_2 for fuels is not included in the figure.

Source: The DCCC.

Negative emissions will be central to climate policy

The remaining emissions from agriculture and land use, among others, must be offset with negative emissions to achieve a reduction of 100 percent. A target of 110 percent requires further negative emissions.

All four scenarios involve significant negative emissions from forests and BECCS. The New Technology scenarios also involve a large contribution from DACCS. Negative emissions from biochar from pyrolysis also features in each scenario, but it plays a relatively small role overall, especially in the scenarios for 100 percent.

The distribution between forests, BECCS, and biochar from pyrolysis could differ from what is assumed. In reality, the distribution will depend on the effective utilization of land, biomass, and biogenic carbon as a whole. Socioeconomics will also play a significant role, depending on factors such as land prices, positive side effects such as cleaner groundwater, the cost and storage efficiency of BECCS and pyrolysis, including the market price of pyrolysis products, as well as electricity and heat from cogeneration plants.

Green fuels require biogenic carbon or DAC

Biogenic carbon and CO_2 from DAC can be used both for negative emissions and for the production of green fuels. The framework condition of producing green fuels for planes and ships, therefore, significantly impacts the consumption of bioresources and the need for DAC. Without this condition, it is easier to achieve the territorial reduction target. However, the subsequent failure to address the large fuel consumption for planes and ships could result in a significant climate impact.

The scenarios feature more nature, forests, and energy crops than today

The scenarios involve a significant change in the use of Danish land. Agricultural crops for food and feed currently occupy about 60 percent of the land. In the scenarios, this changes to between 42 percent and 25 percent. This corresponds to a reduction in the land for food and feed of between 31 percent and 58 percent compared to today, as shown in Figure 1.5.

The reduction of land for food and feed is mainly due to three factors:

- 30 percent of the total land area is allocated to protected nature.
- Land is required for production forests.
- Land is required for the production of energy crops in the New Lifestyle scenarios, such as energy willow, which is used for energy and to create negative emissions.

Overall, existing agricultural land is reduced by between 28 percent and 42 percent in 2050 when the land for energy crops is counted as agricultural land.

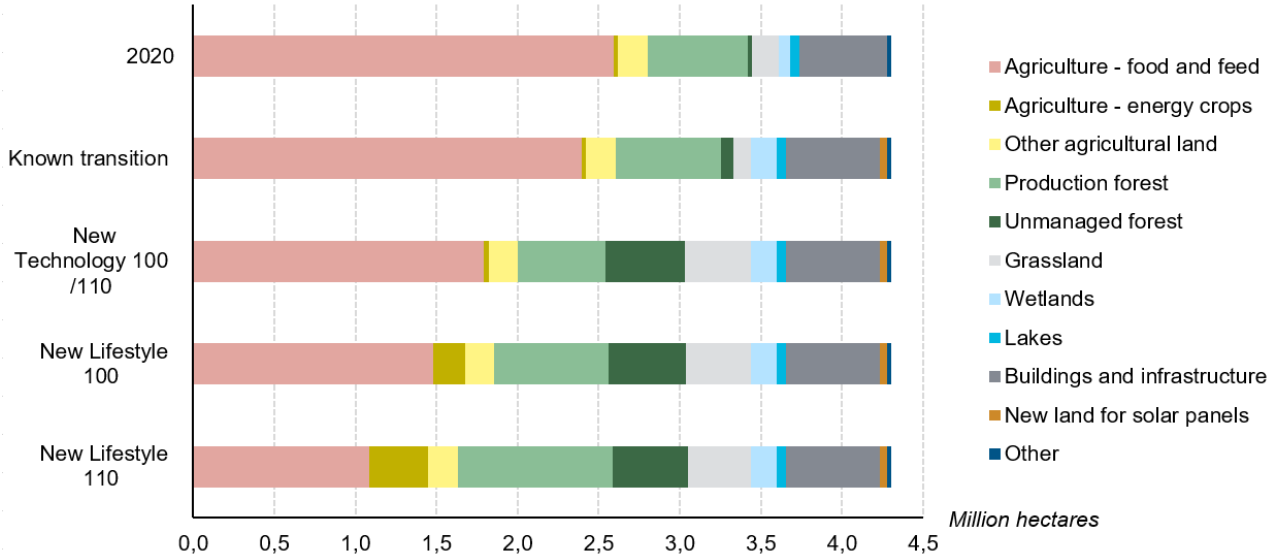

Figure 1.5 Land distribution in the analysis scenarios compared to today

Note 1: The land areas for nature in 2050 are represented in the figure by unmanaged forest, grassland, wetlands, lakes, and parts of production forest and other agricultural land. Cultivated grasslands are included in the figure under Agriculture – food and feed.

Note 2: New land for solar panels constitute the extra area (44,000 hectares) needed from today until 2050, while new wind turbines are placed in other land categories.

Source: The DCCC.

The landscape will look significantly different in 2050

The proposed changes in land use will greatly impact how the landscape appears. Many fields will be replaced by unmanaged forest, production forest, and grasslands. In New Lifestyle, energy crops are often encountered in the landscape. In this analysis, this is exemplified by willow trees, which grow fast at two to four meters per year and are harvested every one to five years. The scenarios also feature far more wind turbines and solar panels than today, but they occupy relatively little space compared to agriculture and forests. The land needed for solar panels can be seen in Figure 1.5.

Denmark can produce more food and feed in 2050

While agricultural land for food and feed is reduced in all scenarios, there is still a production surplus, which can potentially be exported. The left part of Figure 1.6 shows the surplus of both animal and plant-based food and feed in energy units. Production surplus is here defined as the difference between Danish production and Danish consumption.

Plant-based agriculture provides room for more food and more forests

All four scenarios present the possibility of a larger production surplus of food and feed than we have today. This is partly based on the assumption that the yield per hectare from Danish farmland will continue to rise through 2050. Additionally, it strongly relies on the expectation that agriculture will significantly increase its production of plant-based foods. Plant-based foods are more land-efficient than animal-based foods, and, therefore, more food can be produced on less land overall.

In the New Lifestyle scenarios, large parts of agriculture are converted to plant-based production, resulting in a greater food surplus than in New Technology. The land savings from a more plant-based production in New Lifestyle are greater than the land needed for additional production forests and energy crops.

The surplus of feed and food is slightly smaller in New Lifestyle 110 compared to New Lifestyle 100. This is because a larger portion of agricultural land is used for the production of energy crops instead of food. The energy crops are needed for negative emissions. Conversely, the surplus increases in New Technology 110 compared to New Technology 100. This is mainly due to a reduction in animal consumption and production.

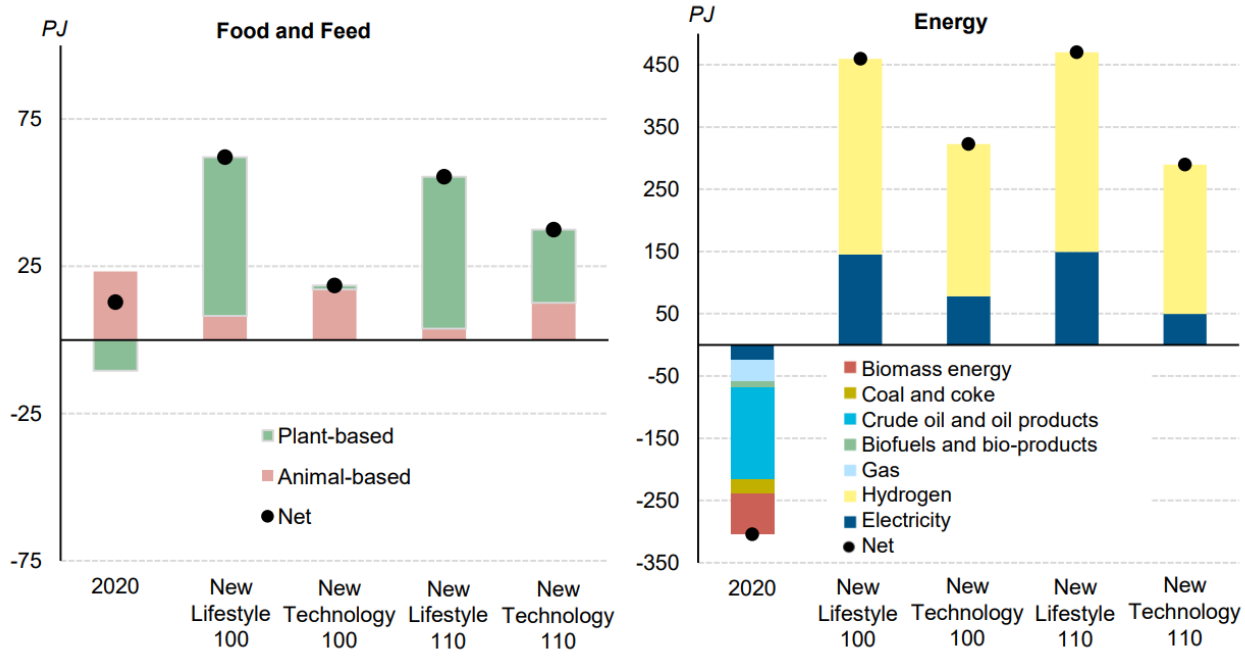

Figure 1.6 Production surplus of food and feed (left) and energy (right) in PJ

Source: The DCCC.

Denmark could have a surplus of proteins

If production and consumption of food and feed are measured in protein instead of energy, Denmark had a significant production deficit in 2020. This deficit is turned into a surplus in the 2050 scenarios. To achieve an actual and global climate effect from shifting towards more plant-based foods, global demand must follow suit. Therefore, this analysis talks about a production surplus. This surplus could potentially be exported, but the analysis has not investigated whether there are sufficient global market opportunities.

Additionally, several technological challenges persist, such as improving the digestibility of plant-based proteins. These issues must be addressed by 2050 for plant-based proteins to effectively replace animal-based ones.

There is a greater energy surplus in 2050 than today

All scenarios contain a significant production surplus of energy compared to today. In Figure 1.6, there is a particularly large surplus of both hydrogen and electricity. Since this energy is carbon-free, it cannot be used directly to alleviate the challenge of scarcity of biogenic carbon.

The analysis is based on the Danish Energy Agency's analysis assumptions for *Energinet 2023*, which reflect current political objectives towards 2050 regarding, for example, solar, wind, and power-to-X capacity. Energy from such facilities can displace fossil energy consumption abroad and help other countries achieve their climate targets.

The production surplus of electricity and hydrogen varies across the scenarios. The need for energy for domestic purposes is greatest in New Technology 110, because there is a high energy consumption for DAC and the production of green fuels.

The scenarios have different strengths and weaknesses

The two paths in the analysis, New Lifestyle and New Technology, have different strengths and weaknesses when measured against relevant societal considerations. In Table 1.1, the paths are assessed on seven considerations divided into three themes, based on the guiding principles of the Danish Climate Act and the DCCC's reflections based on discussions held in the Climate Dialogue Forum.

Table 1.1 Relative strengths of New Lifestyle and New Technology assessed on selected societal considerations

Relative strengths	New Lifestyle	New Technology
Denmark as a source of inspiration	Lower expendutres on new technology make it easier for other countries to follow Denmark's path	
Direct global effects	Greater net contribution of food and feed to foreign countries Greater net contribution of energy to foreign countries	Better opportunities for developing climate-friendly technology Lower risk of leakage
Barriers to long-term transition	Lower technological risk	Lower risk of lack of acceptance of the transition

Source: The DCCC.

There is no ideal path to achieve the climate target

New Lifestyle is characterized by a relatively limited use of new and untested technologies. Thus, this path has lower technological risk and is easier to scale to other countries. Finally, New Lifestyle provides the largest production surplus of food and feed, because a more plant-based agriculture can utilize Danish land more efficiently, and a surplus of energy in the form of electricity and hydrogen, because there is less energy consumption for transport and DAC. These surpluses can potentially be exported, thus displacing production and climate impact abroad.

Given the strong technological focus of New Technology, this pathway provides the best opportunities to develop, demonstrate, and test new technology for the benefit of other countries. Further, it is easier to gain broad acceptance for this pathway since it allows the population to largely maintain its current lifestyle and consumption patterns. However, there is a risk that the necessary technology will be very expensive and unavailable. Finally, the risk of leakage in New Technology is lower. The scenario's global climate benefits are not as dependent on foreign consumers changing their eating habits.

In summary, there is no ideal path to achieving the climate target by 2050, and political considerations and compromises are necessary.

The scenarios have high bioenergy consumption

Both New Lifestyle and New Technology have high bioenergy consumption per person, both when 100 percent and 110 percent are to be achieved. The consumption exceeds a number of research-based and analytical estimates for the sustainable global level. Therefore, neither of the two pathways have a relative strength here.

High bioenergy consumption limits the scalability of the Danish transition to other countries. If too much land is used to produce bioenergy resources, it can intensify the pressure on biodiversity, reduce the area for food production, and lead to deforestation. Other countries will therefore find it harder to look to Danish climate solutions on how high climate targets can be achieved.

5. The DCCC's recommendations

The DCCC recommends stricter Danish climate targets

The Danish government intends to increase the Danish Climate Act's 2050 target from 100 to 110 percent. The DCCC supports the direction of this ambition and therefore recommends an increase that would result in net-negative emissions from Danish territory by 2050. The world's current trajectory toward more than 2 degrees of warming, Denmark's obligations under the Paris Agreement, and the Danish Climate Act's objective regarding Denmark's role and responsibility dictate that long-term climate ambitions be increased.

Additionally, the Danish Climate Act includes political aspirations for Denmark to be a frontrunner which would require Denmark to set higher targets than most other countries. Meanwhile, with countries such as Germany and Sweden aiming for climate neutrality by 2045, this ambition is undermined. Moreover, if Denmark's 2050 target merely aligns with the broader European target, its status as a frontrunner within the EU remains questionable.

Revision of the Danish Climate Act should provide clarity on targets

Deciding on a 2050 target involves multiple societal considerations. If the government maintains a target of 110 percent, it should seek to incorporate this in the Danish Climate Act. Doing so would tackle the uncertainty induced by the current divergence between the Danish Climate Act and the government's ambitions by providing clearer guidelines for all climate stakeholders.

The climate neutrality target should be moved forward

If the 2050 target is increased in the Danish Climate Act, it may be sensible to also set a target for when Denmark's net emissions should reach zero, often referred to as climate neutrality. This should happen before 2050, for example in 2045, as the government has proposed. The net zero target is important as a reference point, for example when the 2035 target is set next year.

Since this analysis focuses on 2050, the DCCC has not explicitly assessed 2045. However, achieving 110 percent by 2050, as implied by the analysis, suggests that 100 percent could be reached by 2045.

International transport should be included in the Danish Climate Act

Denmark should actively take responsibility for its share of emissions deriving from international transport. Reducing these emissions can be supported by a national initiative, and, given the significance of the sector in overall carbon calculations, it should feature in the strategic planning toward 2050.

Therefore, the DCCC recommends that the Danish Climate Act includes another target: that fuel used by ships and planes refueling in Denmark does not burden the climate. Such a target can be formulated in different ways, for example as a separate target, a target integrated with the territorial target, or a production target for green fuels.

The way in which the climate target is achieved does matter

Establishing the 2050 target is crucial, but how it is achieved is almost equally important to consider. The DCCC recommends that Denmark's fulfillment of climate targets should be done in a way that considers that biogenic carbon is a scarce global resource. If Denmark bases its target fulfillment on increased import or reduced export of biogenic carbon, there is a risk that emissions will instead increase abroad, thereby undermining the intention of an ambitious Danish target. Therefore, the fulfillment of the territorial target in 2050 should take the following considerations into account:

- **Food and feed.** Denmark should prioritize a surplus in domestic food and feed production, both in energy and protein, to support exports. This can be achieved by shifting agriculture from animal-based to plant-based, freeing up land for other uses.

- **Bioenergy**. Denmark should avoid relying on imported biomass and biofuels for energy and should not depend on storing imported biogenic carbon to meet climate targets.

- **Land for nature**. Denmark should promptly reserve sufficient areas for nature to protect biodiversity from the pressures of increased biogenic carbon demands in agriculture and forestry.

A long-term and holistic strategy is needed

An appropriate and timely transition towards the climate target for 2050 requires a coordinated and determined approach. Planning is necessary to provide clarity for stakeholders and ensure that actions taken today fit as much as possible to the long-term perspective. By developing a long-term strategy, the government can guide society toward the 2050 climate targets. Such a strategy must account for the uncertainty that exists around technology development, costs, and behavior patterns, and it must be revised and adjusted accordingly.

The DCCC emphasizes that the long-term strategy should consider:

- **A focus on implementing already known and well-tested transition elements where reduction potential and costs are more certain.** Examples include energy efficiency improvements, the conversion of carbon-rich lowland soils, and the electrification of road transport and heating.

- **Spatial planning.** The promotion of land use that supports and coordinates several different societal considerations. While the "Agreement on a Green Denmark" has set a direction in certain areas, a comprehensive, long-term perspective is still needed (see Box 1.2). The DCCC stresses that the following three points require special attention:

    - **Designation of areas for biodiversity and protection of the water environment:** The strategy needs to designate areas to protect biodiversity and secure the water environment. Such designation and subsequent efforts can positively contribute to meeting climate targets.

    - **Direction for agriculture and food:** The long-term strategy should set a clear direction for the Danish food sector towards more climate-friendly production, focus on new food types, and more plant-based diets. Agriculture will account for the majority of emissions in 2050 and occupy significant areas. Therefore, agriculture's potentially changed role is a crucial piece in the strategic puzzle to ensure the green transition.

    - **Timely afforestation:** The long-term strategy should include concrete plans for the establishment of new forests. Afforestation can contribute significantly to achieving future climate and environmental targets. The plans should address whether the government's own target of 250,000 hectares of new forest is sufficient to meet the 2050 climate target. If afforestation is to deliver a large climate contribution in 2050, efforts to establish forests must significantly increase in pace now.

- **Fuel consumption of international transport refueled in Denmark**. The strategy should consider whether green fuels for aviation and shipping should be produced in Denmark.

- **Plans for the necessary expansion of central energy infrastructure** for electricity, hydrogen, and CO_2 to help reduce the risk of critical bottlenecks and incorrect sizing.

- **Important supporting efforts** that can contribute to and support the achievement of the 2050 climate target. The DCCC points to three efforts that are especially important in a long-term perspective:

    - **Public procurement:** The strategy should use the public sector's purchasing power to drive innovation and scale climate-friendly products, promoting their adoption and normalizing sustainable consumption.

    - **Need for research and innovation:** The strategy should identify research and innovation gaps to meet Denmark's 2050 targets, covering basic and applied research, along with development activities to translate knowledge into climate benefits.

    - **Education and labour market:** The strategy should focus on education and labour market policies so that skills and human resources match the needs of the green transition. It is crucial to prevent bottlenecks that could delay the transition and to facilitate the industry shifts that will result from the structural changes accompanying it.

Box 1.2: Nature, Agriculture, and Afforestation in the Green Tripartite Agreement

The Danish government and the Green Tripartite Agreement have set the direction for nature, agriculture, and afforestation in the coming years. Key points in relation to this analysis include:

Nature: The agreement aims to protect at least 20 percent of Denmark's land area, which is lower than the 30 percent assumed in this analysis.

Agriculture: The agreement introduces a tax on livestock emissions but does not provide sufficient incentives for the agricultural sector to shift from animal-based to plant-based production, as envisioned in the 2050 scenarios.

Afforestation: The target is to establish 250,000 hectares of new forest by 2045, covering both production and unmanaged forest. This is less than the total forest area assumed in this analysis, and faster progress is needed for forests to make a significant climate contribution by 2045 and 2050. The agreement recognizes this need.

The government should promote a public discussion of the visions for 2050

The pathway to a 100 percent or 110 percent reduction in 2050 will require changes that will affect everyone in society. This applies regardless of the specific target and whether the final part of the pathway is primarily achieved with DACCS and other technological transition elements or with a structural transition of, for example, agriculture and more climate-friendly consumption behavior.

Therefore, the DCCC recommends that the Danish government promote a public discussion of the visions for 2050 and the changes that an ambitious target requires so that citizens and businesses can adapt as early as possible, address challenges, and seize new opportunities.

6. References

[1] Denmark's Climate Status and Outlook 2024.

[2] Denmark's Climate Status and Outlook 2024.

[3] Regeringen, Landbrug & Fødevarer, Danmarks Naturfredningsforening, Fødevareforbundet NNF, Dansk Metal, Dansk Industri og Kommunernes Landsforening, *Aftale om et grønt Danmark*, 2024.