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DANISH COMMISSION ON CLIMATE CHANGE POLICY

Green energy

– the road to a Danish energy system without fossil fuels

Summary of the work, results and recommendations of the Danish Commission on Climate Change Policy

28 September 2010

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Preface

It goes without saying that I, on behalf of the entire Climate Commission, hope that this report can be directly translated into practical policy. For the energy challenges we face must be met and overcome. And efforts to meet the challenges must start now.

The Danish government established the Danish Commission on Climate Change Policy and commissioned it to develop proposals for how the government's long-term vision of relieving Denmark completely of its dependence on fossil fuels can be realised. It is a laudable vision which addresses two major challenges. Global emissions of greenhouse gases have to be reduced in the coming decades, and there is increased focus on security of energy supply as fossil fuels are becoming ever more scarce and prices will increase.

But does it really make a difference if Denmark begins work on realising this vision now? Denmark is a small country with an open economy in an ever more globalised world. Does it matter, if Denmark sets out to find its own solutions to these challenges? The answer is 'yes', it does make a difference! It is a matter of due diligence in relation to inevitable developments in the global energy

Preface

market. Denmark's standing in the international community means that Danish solutions should not only be seen in a national context, but also in the context of international developments and not least of which as a contribution towards these developments.

The work in the Danish Commission on Climate Change Policy has been exciting, and we have covered a lot of ground. How can we best replace oil, coal and gas? How do global developments affect what we can do in Denmark? How much renewable energy will be available in the future in Denmark? How do we get businesses and individuals to change behaviour? What will it all cost?

We have had inspiring debates, not least because the members of the Commission have contributed with highly professional input from each of their fields.

I would like to thank the Climate Commission's members for their hard work, their involvement, their willingness to seek compromise and, not least of which, for their humour.

I would also like to thank the hard-working secretariat, which started out as just a handful of staff but which later grew in size, as the complexity and scope of the task became more apparent.

A particularly rewarding experience has been the local workshops we have carried out with a number of municipalities and the many dialogue meetings with organisations from industry, individual businesses, non-governmental organisation, and others, from university to secondary school students, who took part in competitions to come up with the best ideas for how we can solve climate problems and save energy.

The report is now finalised. The recommendations presented are based on specialist considerations and deliberations and the Climate Commission's best advice on how Denmark can best initiate a process that will lead to a total conversion of the current energy system to one that is independent of fossil fuels. Politicians defined the task for the Climate Commission. Now, it is up to the politicians to follow up.

It goes without saying that I, on behalf of the entire Climate Commission, hope that this report can be directly translated into practical policy. For the energy challenges we face must be met and overcome. And efforts to meet the challenges must start now.

Katherine Richardson,
Chairman

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Structure of the report

This summary describes the main outcomes of the deliberations of the Danish Commission on Climate Change Policy. It includes a proposal for how Denmark can become independent of fossil fuels and, at the same time, meet the target of reducing greenhouse gases by 80%-95% compared with 1990. In addition, 40 specific recommendations for initiatives which will contribute to the realisation of the vision are presented.

The documentation section of the overall report, which is only available in Danish, presents the Climate Commission's work in more detail, as well as a description of the comprehensive analyses on which the Climate Commission has based its recommendations. Finally, the background documents, which have been prepared at the request of the Climate Commission are available (in Danish) at the Commission's website, www.klimakommissionen.dk.

The summary in a nutshell

Global climate change and the limited access to resources, especially with respect to oil, will set the agenda for climate and energy policy in the years to come. Climate change places massive demands for reductions on greenhouse gas emissions, and on our use of coal, oil and natural gas. At the same time, the price of these fuels must be expected to rise, when the remaining resources have to meet increasing demand.

We can both reduce Danish emissions of greenhouse gasses significantly, and make Denmark independent of fossil fuels. This will require a total conversion of the Danish energy system; conversion away from oil, coal and gas, which today account for more than 80% of our energy consumption, and to green energy with wind turbines and bioenergy as the most important elements.

The cost of conversion may seem surprisingly low. The low cost means that not only can we maintain our present living standards, we can also have considerable economic growth, so that energy expenditures will constitute less of our budgets in the future than today. The reason the cost is not higher is primarily because we will not have to pay for overpriced fossil fuels and CO_2 reductions, and we will be able to limit our energy consumption through efficiency improvements in all areas in the future. There are many opportunities for greater energy efficiency available already today, and new technologies will enhance our opportunities in the future.

It is difficult to make predictions about the exact design of the green energy system of the future. However, in overall terms it could look like this:

- Energy will be used far more efficiently, so that we can, for example, heat our houses using half the energy we use today, and drive our cars further on the same amount of energy

- Electricity will be at the hub of the energy system. A total of 40%-70% of energy consumption will be met by electricity, compared to 20% today

- Offshore wind turbines will be central in the coming energy system. We will have to erect many more turbines and these turbines will cover up to half of Denmark's energy consumption

- The energy system will be intelligent. The dominance of fluctuating sources (wind) in the energy system will mean that it is important that the consumption of electricity can be more flexible than today. Intelligent electricity meters, time-controlled recharging for electric cars and heat pumps in combination with heat storage systems are just some of the technologies required to exploit periods with maximal wind production. In addition, international electricity links must be expanded so that we can export and import more electricity when there is plenty of, or too little, wind

- Biomass will play an important role in the coming energy system, not least of which in the transport sector and as a backup for wind turbines

- Houses will be heated with electric heat pumps, for which wind turbines supply the energy, and with district heating. Biomass, solar heating, geothermal energy and heat pumps will, together, supply energy for district heating

- Cars of the future will be fuelled by various combinations of batteries and biofuels.

A total conversion of the Danish energy system is required. Therefore, the conversion must be gradual, but it must start now. This will make it cheaper, partly because investments can be planned in infrastructure such that existing infrastructure can be replaced as it wears out.

The Climate Commission has 40 specific recommendations for what is required in the forthcoming years to ensure that Denmark embarks upon a robust development track towards independence from oil, gas and coal. Among the pivotal recommendations is to give the public and enterprises a clear financial interest in supporting the conversion. This will mean that the market will help ensure that the best technological solutions are employed.

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Because the burning of fossil fuels is the greatest contributor to human generated greenhouse gas emissions, tackling these two challenges at the same time makes good sense.

1. Background

1.1
Two major challenges for climate and energy policy

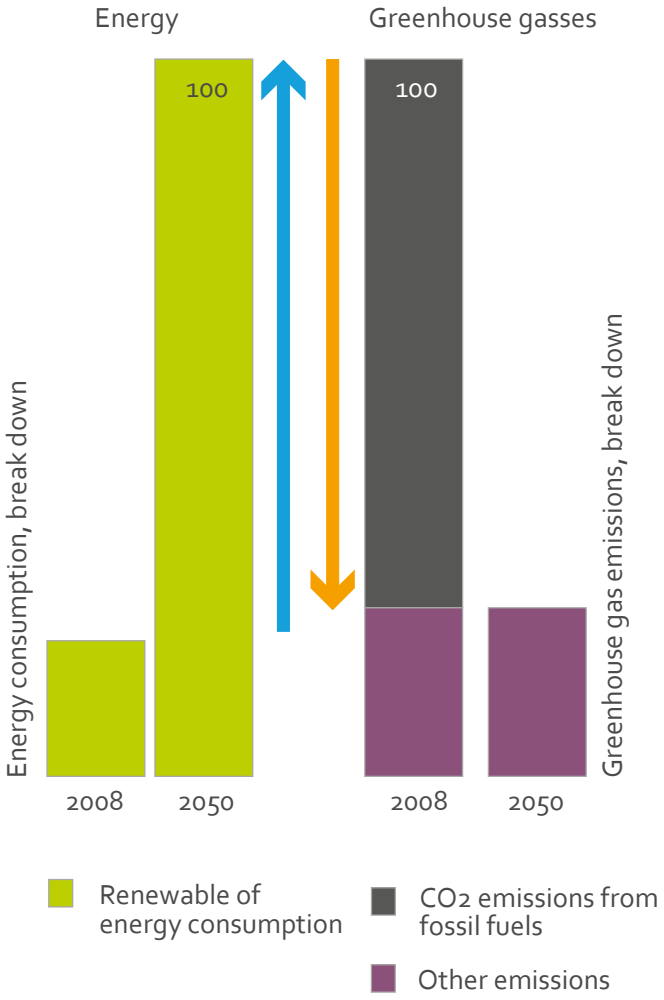
Denmark and the international community are facing two major challenges.

Firstly, the degree of human-caused global warming has to be contained. This requires a reduction in emissions of greenhouse gases.

Secondly, global growth in the decades to come will require significantly greater amounts of energy. This will push up prices of the fossil fuels that, today, supply the majority of society's demand for energy

Initially, this pressure on prices will apply particularly to the supply of oil but, at a later stage, also to natural gas. Moreover, with regard to both oil and natural gas, known reserves are concentrated in just a few regions of the globe.

Two major challenges for climate and energy policy



Today, fossil fuels (oil, coal and gas) account for around 80% of Denmark's energy consumption. It is also known that Denmark's oil and gas production from the North Sea will fall considerably in the coming years. Therefore, the political goal in Denmark is to make the overall energy system, including the transport sector, independent of fossil fuels.

Because the burning of fossil fuels is the greatest contributor to human generated greenhouse gas emissions, tackling these two challenges at the same time makes good sense. The challenges are illustrated in the figure below.

The two challenges have four consequences for climate and energy policy:

1. Emissions of greenhouse gases must be reduced significantly

There is broad consensus that we are facing human caused climate change. In their conclusions

Figure 1.1: The renewable share of energy consumption in Denmark in 2008, share of greenhouse gas emissions from fossil fuels in 2008, and the consequence of conversion to 100% renewables in 2050 for Danish greenhouse gas emissions in 2050

from the summit on 29-30 October 2009 in Brussels, the heads of state and government of the EU confirmed a goal to limit global warming to a maximum of 2°C, and that overall, greenhouse gas emissions from the developed countries, therefore, should be reduced by 80%-95% by 2050 relative to 1990.

If we are to meet this goal, a complete change in our energy system will be required. Such drastic change could have serious economic consequences if it is not carried out cost-effectively and as part of a long-term strategy.

2. Prices of fossil fuels will increase

In addition to the challenges related to climate change, the geographic location of the limited resources of oil and natural gas emphasises the importance of security of supply and security policies. Oil, gas and coal are limited resources and the size of any discoveries of fossil fuels in future decades is uncertain. The situation is especially critical for oil: production from existing fields is falling and significant investment is required in new production capacity if demand is to be met, not least of which because of the economic growth in the third world[1]. Higher production costs from ever more inaccessible fields, combined with increased demand, will push prices upwards[2]. The US government's official forecasts indicate that the price of oil may reach as much as USD 210 per barrel in 2035 (in 2008 prices)[3]. Denmark and other countries will, therefore, be confronted with a major challenge – solely on the basis of rising fossil fuel prices.

3. Greater uncertainty

As fossil fuel prices come under pressure, it is also very likely that there will be increased uncertainty in the trend in the price of oil. The balance between supply and demand of oil will be very fragile and any disruptions could lead to considerable fluctuations in the oil prices. As is the case now, oil prices in the future are also expected to have an influence on the price of natural gas.

Leading institutions, such as the International Energy Agency, IEA, and the US Energy Information Administration, suggest that the future could bring great uncertainty with respect to oil prices. In the period leading up to the summer of 2008, the price of oil increased dramatically to more than USD 147 per barrel. This came after the price had remained relatively stable around USD 20 per barrel throughout the 1990s.

Danish consumers and businesses thus risk fluctuating and uncertain energy prices in the future, which could be detrimental to economic growth and stability.

For some parts of the Danish business community, addressing the major climate and energy policy challenges could therefore serve as an important lever for green growth.

Danish independence of fossil fuels will be a way to insure the country against the domestic effects of dramatic price fluctuations and against any restrictions on consumption, such as those experienced during the oil crises in the 1970s.

4. Oil and gas will be in the hands of only a few

At the end of the day, security of supply is about whether there is access to the energy sources necessary to meet the needs of society.

The earth's fossil fuels are not equally distributed across the globe. Already today, the EU countries meet 85% of their oil consumption and 60% of their natural gas consumption through imports[4]. These figures will only increase in the future. The earth's largest known oil reserves are in the Middle East and its natural gas reserves are primarily in the Middle East and Russia. When oil and natural gas reserves are in the hands of so few countries, the risk of pressures on security of supply due to conflict and political unrest increases.

Opportunities for Danish industry

Denmark has a large number of businesses with strong competences in areas such as wind turbines, district heating, process optimisation, insulation and the manufacture of biofuels. For some parts of the Danish business community, addressing the major climate and energy policy challenges could, therefore, serve as an important

lever for green growth. This could provide valuable opportunities in the global market, where there is a growing demand for innovative solutions within green energy.

This should be considered in the context of the fact that Danish oil and natural gas deposits in the North Sea have contributed a total of DKK 224 billion to the Danish state over the past 20 years; as much as DKK 144 billion just within the past five years[5]. These revenues will fall over the coming years as deposits are exhausted.

1.2
Terms of reference and composition of the Danish Commission on Climate Change Policy

In 2008, the Danish government established the Danish Commission on Climate Change Policy. The Climate Commission was assigned the task of preparing proposals for how the government's vision of a Denmark independent of fossil fuels can be realised.

The wording of the specific task in the Commission's terms of reference is as follows:

"The Danish Commission on Climate Change Policy is to examine how Denmark can reduce and ultimately eliminate dependency on fossil fuels in the long term. The Climate Commission shall describe how to implement this long-term vision."

Terms of reference and composition of the commission policy

The Climate Commission's deliberations should take the following criteria into consideration:

1. Reducing the emission of greenhouse gases
2. Increasing energy efficiency
3. Maintaining the high security of energy supply
4. Ensuring macroeconomic cost-effectiveness by using market-based solutions
5. Continuing a high level of economic growth
6. Ensuring positive business development and promoting international competitiveness of business in Denmark
7. Ensuring environmentally sustainable development.

All seven of these criteria are to be included in the specific model for fossil fuel independence which the Climate Commission develops.

In their work on preparing their proposals, the Danish Commission on Climate Change Policy has been asked to:

- Analyse specific proposals for substantially reducing emissions of greenhouse gases
- Present proposals for a integrated energy system that ensures improved energy efficiency, reduced energy consumption, and an increasing proportion of renewable energy with continued promotion of competition in energy markets
- Assess the potential for reducing emissions of CO_2 in all relevant sectors
- Present proposals for new proactive instruments for energy and climate change policy
- Analyse the potential for reducing the emission of other greenhouse gases than CO_2.

The entire terms of reference of the Climate Commission are available on the English section of the Commission's website www.klimakommissionen.dk.

The Climate Commission was comprised of ten independent experts:

Katherine Richardson (chairperson), Professor and Vice-Dean at the University of Copenhagen

Dorthe Dahl-Jensen, Professor at the University of Copenhagen

Jørgen Elmeskov, Director of the Policy Studies Branch of the OECD Economics Department

Cathrine Hagem, Senior Researcher with Statistics Norway

Jørgen Henningsen, Previously of Director in the European Commission

John A. Korstgård, Professor and Head of Department at Aarhus University

Niels Buus Kristensen, Head of Department for DTU Transport at the Technical University of Denmark

Poul Erik Morthorst, Research Specialist at Risø DTU, the National Laboratory for Sustainable Energy at the Technical University of Denmark

Jørgen E. Olesen, Research Professor at University of Aarhus

Mette Wier, Executive Director of AKF, Danish Institute of Governmental Research

Susanne Juhl, Head of Department, from the Danish Ministry of Climate and Energy has taken part as an offical.

The Climate Commission was supported by a multi-ministerial secretariat with its base at the Ministry of Climate and Energy and with participants from the Ministry of Economic and Business Affairs, the Ministry of Finance, and the Ministry of the Environment. Other relevant ministries have been included where relevant. The Climate Commission has also made use of external consultancy assistance.

1.3 The framework for the Climate Commission's work

Within the boundaries of its terms of reference, the Danish Commission on Climate Change Policy has defined two framework conditions for its work:

1. An 80%-95% reduction in greenhouse gas emissions

The terms of reference state that the Climate Commission's work should reflect the EU's ambition at that time of a 60%-80% reduction in total European greenhouse gas emissions by 2050. As mentioned above, the EU's ambition has since been stepped up to an 80%-95% reduction for the developed countries. On this basis, the Climate Commission has chosen to examine whether and how Denmark can reduce its greenhouse gas emissions by more than 80% before 2050.

It is also likely that a future EU target will include international mechanisms for trading in rights to greenhouse gas emissions, as is the case today. In its calculations, the Climate Commission also applies a price for greenhouse gas emissions.

However, the specific design of any international mechanisms in 2050 is not known today. The Climate Commission has, therefore, focused on describing how emissions emanating from Denmark, itself, can be reduced by 80%-95% by 2050.

2. Definition of independence

The Danish government's platform from November 2007, *Mulighedernes Samfund* (a society of opportunities), specifies that the Climate Commission is to come up with proposals for how Denmark can be fully relieved of its dependence on fossil fuels. The Climate Commission has chosen to define independence from fossil fuels as follows:

No fossil energy is used/consumed in Denmark, and the average annual domestic production of electricity based on renewables must, as a minimum, be equal to Danish consumption.

In 2008, a total of 80% of Danish energy consumption came from fossil fuels. The Climate Commission's task is, thus, to find a way to reduce the 80% to 0%.

The energy system today is integrated across national borders, and will be so to an even greater extent in the future. Trade in energy provides bet-

It is realistic to assume that the transition to an energy system independent of fossil fuels can be achieved by 2050.

ter and more cost-effective solutions for energy supply. However, it also means that we use energy from countries that decide their own energy mix. The Climate Commission's definition of independence implies that Denmark phases out its use of fossil fuels but does not exclude the possibility that Denmark trades electricity with countries, which base their electricity production on fossil fuels.

However, the Climate Commission's definition of independence excludes the possibility of continuing to consume oil in the transport sector and compensating for this by excess production and subsequent export of renewable energy.

1.4
Conditions governing the Climate Commission's work

Furthermore, the Climate Commission has placed emphasis on the following nine key conditions and principles, and these have directed the Climate Commission's recommendations:

1. The year 2050 is a realistic target year
2. Society must be able to continue to develop
3. A flexible energy system must be able to incorporate new technologies
4. Fixed, stable and long-term framework conditions are essential
5. Conversion must be initiated now.
6. Danish climate and energy policy must be considered in an international perspective
7. The transition to a new energy system must be socio-economically optimised
8. The energy system must be considered as a single whole
9. Biomass presents both opportunities and challenges.

The principles are described in more detail in the following:

1. The year 2050 is a realistic target year

It is a political responsibility to decide the deadline for when Denmark should be independent of fossil fuels. However, on the basis of the EU target of an 80%-95% reduction in greenhouse gas emissions from developed countries by 2050, the Climate Commission has used the year 2050 as the end year for the target of independence from fossil fuels.

It is realistic to assume that the transition to an energy system independent of fossil fuels can be achieved by 2050. Most of the necessary technology is already known today, and the present energy system (the capital stock) will, in any case, have been replaced by 2050.

A large proportion of the necessary changes are also achievable before 2050. The analyses by the Climate Commission indicate that a 100% conversion to renew-

A conversion of this magnitude cannot be implemented in a short time.

able energy in the electricity and heating sector is technically possible by as early as 2030. On the other hand, it is not deemed realistic to speed up phase out of fossil fuels in the transport sector. The Climate Commission has also calculated the economic costs associated with a 2030 deadline for parts of the energy system.

2. Society must be able to continue to develop

In principle, conversion away from fossil fuels could already be realised in the very near future. However, this would require the introduction of drastic sanctions and would mean that society would grind to a halt. The Climate Commission has, therefore, concentrated on a gradual transition to an energy system without fossil fuels.

Transport, heating, commerce, and industry, as well as everything else in society depend on having access to energy. The Climate Commission has, therefore, concentrated on proposals that can ensure and underpin continued growth in Danish society, both during and after the conversion to fossil fuel independence. Danish families must have well-functioning homes, have their transport needs met, and have plentiful job opportunities. Conversion of the Danish energy system must support this development; not prevent it.

3. A flexible energy system that can incorporate new technologies

The Climate Commission has analysed future development opportunities for a fossil fuel-free energy system in 2050. However, the Climate Commission's guiding principle has been that it cannot, and should not, identify exactly what such an energy system will look like in 2050 or identify which technologies and solutions are best.

It is important that we are able to take advantage of new and unexpected technological breakthroughs. A number of the technologies existing today are not yet mature, and there is no guarantee they ever will be. Furthermore, new technologies will emerge in the future that are entirely unknown to us today. The Climate Commission stresses the importance of ensuring that the different policies and initiatives are designed in a way that accommodates all technologies, so that market forces can be allowed to determine the best socio-economic mix of technologies in Denmark's future energy system.

4. Fixed, stable and long-term framework conditions are essential

Investment in the necessary conversion of the energy system and infrastructure must be planned over the long term. Many energy infrastructures have long life spans and the cheapest way to realise the conversion of the energy system is in connection with natural replacement or renovation of the existing infrastructure.

It is important to have the system as a whole in mind when transitioning to a new energy system. The entire energy system must be integrated. Otherwise, there is no guarantee that energy will be available where and when it is needed.

Stability in the form of a fixed and long-term framework for energy policy will also promote an investment by individuals and businesses in conversion and the development of new technology.

It is also important that the political framework is established with at focus on coherence of the entire energy system, as a whole.

5. Conversion must be initiated now

The Climate Commission emphasises that a comprehensive conversion of the entire way that we produce, distribute and use energy must be initiated now. A conversion of this magnitude cannot be implemented in a short time.

Although there is uncertainty as to future technological solutions and, therefore, with respect to how the energy system will look in the long term, there are a number of initiatives that can be implemented now which will be beneficial and contribute to the conversion of the energy system, irrespective of what the future brings.

It is important that actions in the short term are also viewed from the long-term perspective, so we avoid making inappropriate investments that do not underpin the desired development. This also supports the argument that conversion should be initiated now, so that future investments are focused on the long-term goal.

A clear signal now will help prevent bad investments in the future and will instil a sense of confidence in industry and the public. Moving away from dependence on fossil fuels will also reduce the vulnerability of the Danish economy to changes in fossil fuel prices from day one.

6. Danish climate and energy policy must be considered in an international perspective

The future Danish energy sector cannot be seen in isolation. Denmark is, and will continue to be, an open economy in a mutually dependent relationship with its surroundings in a globalised world. Energy is a commodity which is traded extensively across Danish borders. Danish energy policy can, therefore, not be considered a purely national matter. The energy policy of the EU is undergoing rapid change, and actors in the energy market are also operating across national borders.

Global efforts and the framework that will be created for future international climate and energy policy will, therefore, also impact on Denmark's ambition of becoming independent of fossil fuels. They will affect the type of energy relevant investment and research which is carried out, and they will affect the price linked to continued emissions of greenhouse gases.

7. The transition to a new energy system must be socio-economically optimised

The transition to independence must include consideration of the economic implications for society. A fundamental principle for the Climate Commission's work has, therefore, been that its recommendations should identify the optimal route to independence in a socio-economic context. In other words, the transition must take place as inexpensively possible.

Providing a detailed description of an energy system in 2050 is impossible. However, the Climate Commission has worked with selected future scenarios in order to come up with recommendations that are resilient under different possible development scenarios for international climate policy and for the price of selected energy sources.

Establishing the framework for future development is vital. Economic incentives play a central role in the Climate Commission's recommendations, because, if implemented correctly, they leave it to the players in the market to find the best and most effective solutions. Due to a number of market imperfections, however, it will be necessary to include other instruments as well.

8. The energy system must be considered as a single whole

It is important to have the system as a whole in mind when transitioning to a new energy system. The entire energy system must be integrated. Otherwise, there is no guarantee that energy will be available where and when it is needed. Since the conversion to non-fossil fuels is expected to entail a considerably increase in electrification largely based on wind, which is a fluctuating energy source, it will become even more important than today to focus on the system in its entirety, as electricity is more difficult to store than fossil fuels.

9. Biomass presents both opportunities and challenges

Biomass is an obvious alternative to fossil fuels. Unlike fossil fuels, biomass is a renewable resource. However, there are limits to how much biomass can be produced, both in Denmark and in the world. Even if most of Danish farmland was converted to production of biofuels, it would be far from sufficient to meet the future energy demand in Denmark. An energy system based extensively on biomass, would become dependent both on considerable imports and on trends in the price of biomass.

The Climate Commission has therefore made analyses based on two different scenarios: A scenario where the consumption of biomass is limited to a level corresponding to Denmark's own production with unchanged food production, and a scenario with unlimited import of biomass. The Climate Commission's recommendations are robust under both scenarios.

The Danish economy will continue to grow up to 2050. More goods will need to be transported, we will be travelling and consuming more. We may, also, be living in larger houses with correspondingly higher heating needs. Conversion to a system without fossil fuels is possible while families and enterprises continue to experience increased growth and welfare.

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2. An energy system without fossil fuels

Denmark can meet the target of becoming independent of fossil fuels by 2050. However, this requires an energy system which is dramatically different from today.

The Danish economy will continue to grow up to 2050. More goods will need to be transported, we will be travelling and consuming more. We may, also, be living in larger houses with correspondingly higher heating needs. Conversion to a system without fossil fuels is possible while families and enterprises continue to experience increased growth and welfare.

However, there is a price to pay in the form of the substantial investment necessary to build an energy system based solely on renewable energy. This price should be considered in the context of the cost of continued use of fossil fuels, and in the context of the benefits of helping to achieve reductions in greenhouse gas emissions.

Higher prices of energy and the demand for reductions in greenhouse gas emissions mean that Denmark's energy system, in any event, will have to adapt in the years to come.

Exactly what our energy system will look like in 2050 will depend on, for example, future technological break-throughs, energy prices, and political decisions. Nevertheless, it is very likely that the target can be reached, because with current technologies and solutions it is already possible to come a long way towards meeting the target. That being said, there is the reservation that further technological development is needed, especially in the transport sector, if the ambition to become independent of fossil fuels is to be realised.

The ambitious target can be reached through a strategy with two key elements:

1. Energy must be used far more efficiently. Improvements in energy efficiency must reduce total energy consumption by up to 25%. This is possible through technological development and intelligent energy consumption. Improvements in energy efficiency are necessary in order to limit energy consumption and ensure a more cost-effective shift away from fossil fuels
2. Future energy must be based on renewable energy. To a great extent, the energy system must be converted to a system based on electricity, which is primarily generated by offshore wind turbines. Additional energy will come from biomass, which can be produced by Danish agriculture and forestry, as well as from other types of renewable energy such as geothermal energy and solar heating.

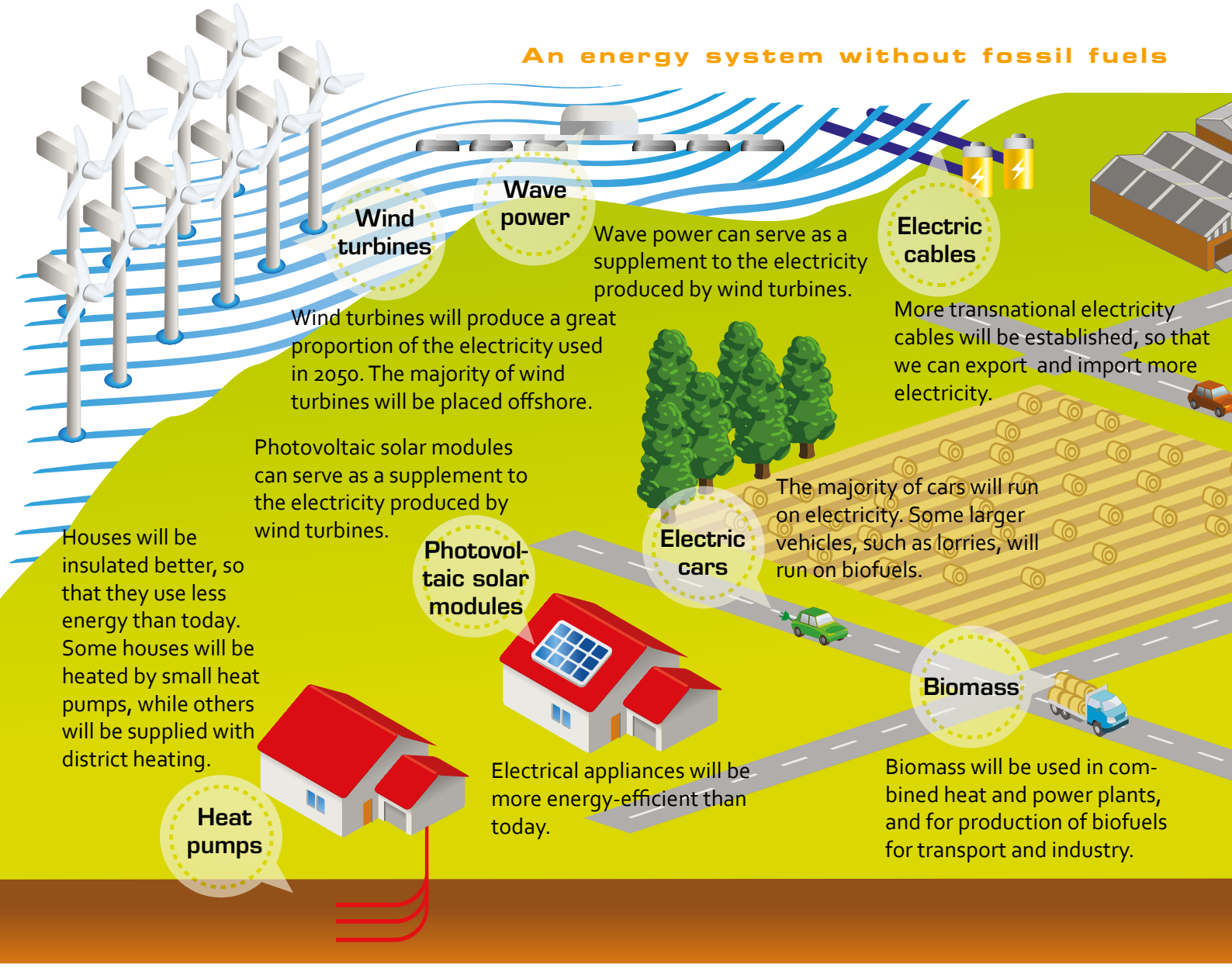
Key to the Climate Commission's recommendations are better efficiency in energy consumption as well as conversion of the energy supply, if the two objectives on reduction in greenhouse gases and independence from fossil fuels are to be met.

Balancing efficiency and establishment of new energy sources should, in principle, take place so that overall costs are minimised. If it is cheaper to use energy more efficiently rather than erect a new wind turbine, then the first solution should be chosen. On the other hand, more wind turbines are better if further energy-efficiency improvements will be more expensive than the costs of erecting new wind turbines.

However, it is also essential to see the energy system as a single entity. The system must ensure

that the energy demanded is available at all times. On the one hand, this requires that energy is led to the consumers who need it, when they need it, and in the quantity and type they need it. On the other hand, it requires that energy consumption to some extent is adapted in relation to the fluctuations in energy production, which will be unavoidable due to the increased production by renewable energy.

An energy system without fossil fuels



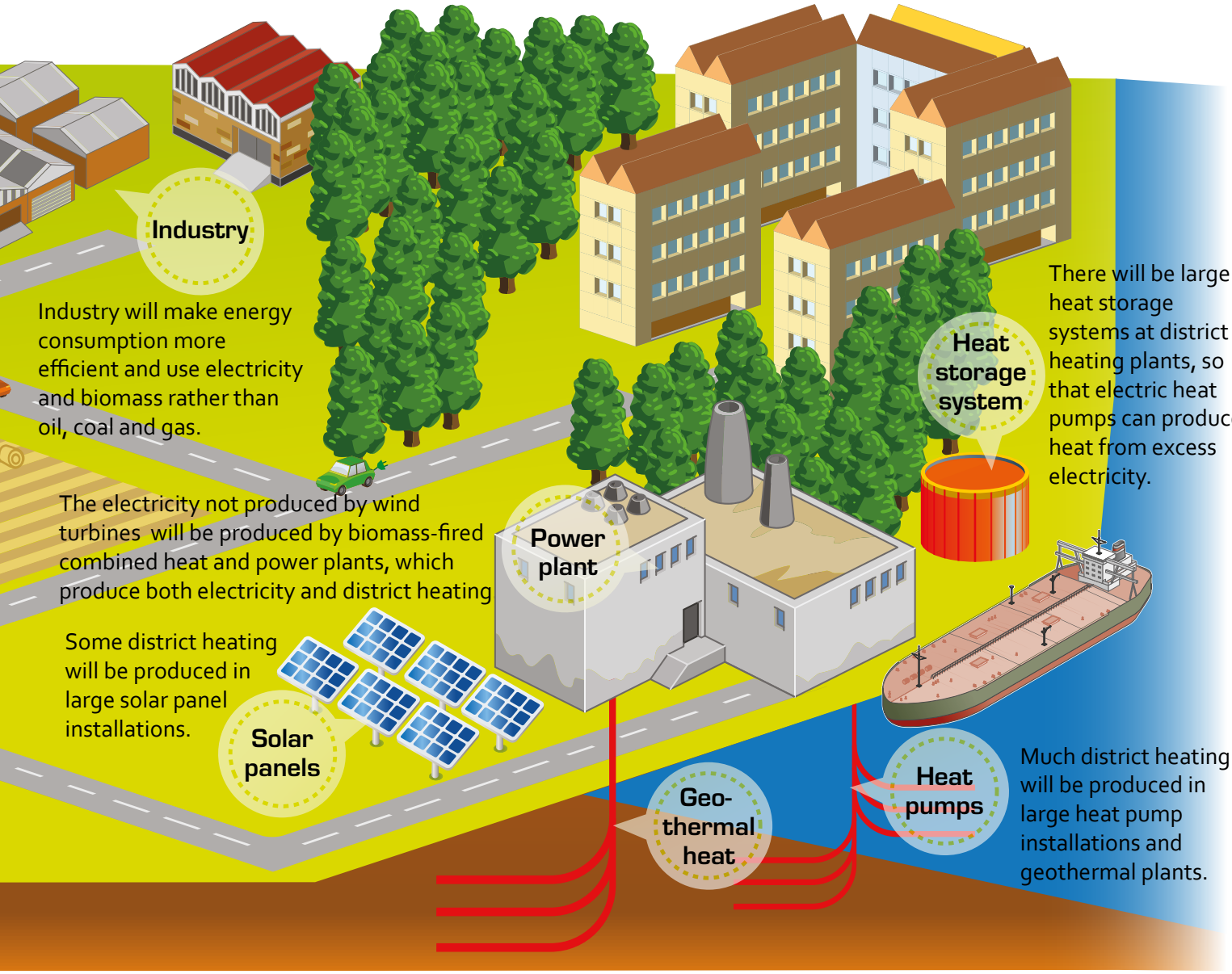


Figure 2.1: The energy system in 2050 without use of fossil fuels.

How we become independent of fossil fuels

It is not possible to predict precisely how the energy system of the future will develop. However, there are some aspects in 2050 that are consistent:

More efficient use of energy

- Energy consumption in homes will be more efficient. Better insulation and efficient energy systems can reduce energy consumption for heating an average house by 60%, and cut average energy consumption by any electric appliance, from lamps to washing machines to one half
- Passenger transport and freight will more energy-efficient. In 2050 energy use can be reduced by 60-70% primarily through the introduction of electic vehicles
- Energy efficiency in industry and agriculture can be doubled. By using half the energy for production of the same amount of goods.

New energy systems with biofuels and electricity from renewable energy

- The energy system will be converted to electricity and will be based on intelligent consumption in private homes, in institutions and in businesses
- Much more of the energy we use every day will come from electricity. Today, around 20% of the energy we use comes from electricity. In the future, this figure will rise to at least 40% and up to 70%, if electric cars gain ground
- Offshore wind turbines will be a central source of electricity and wind power will increase many-fold compared with today, so that there is from about 10,000 MW to 18,500 MW of wind power in 2050. This corresponds to 60%-80% of electricity consumption compared with just 20% today

- Biomass will play an important role in the energy system as a whole, not least in the transport sector and as a backup for the fluctuating production from wind turbines As much as 30% of our energy can come from biomass and waste incineration, and as much as 70%, depending on how biomass prices develop

- We will heat our houses with electric heat pumps, with energy from wind turbines and with district heating. Biomass, solar heating, geothermal energy and heat pumps will together supply energy for district heating

- In the long run, the transport sector will be converted to electricity and biofuels

- With the right technological development, more and new renewable energy technologies can also come into play.

A society independent of fossil fuels is illustrated in the figure above and described in more detail in the box below. The following sections describe the energy system in more detail.

The Climate Commission concludes that the transition to a fossil fuel-free energy system could reduce Denmark's greenhouse gas emissions by around 75% compared with emissions in 1990. Achieving an 80% reduction or more, would require enhanced efforts to curb other sources of greenhouse gas emissions. Of these other sources, agriculture is the greatest emitter.

2.1
Energy efficiency will make establishing a green energy system cheaper

The energy services[6] that we enjoy today, can be enjoyed using considerably less energy. More efficient use of energy does not mean that we have to suffer deprivation, even if consumption falls. There must be enough energy to meet the increasing demand for energy that will occur naturally in the future. Fortunately, technology provides many opportunities for utilising energy in a more efficient manner without loss of welfare.

Succeeding in reducing the energy consumption of end users up to 2050 will be a huge, but surmountable challenge. At the same time, overall economic activity is expected to double.

High costs without efficiency improvements

Efficient use of energy is an important part of realising the target. This applies to current consumption of fossil fuels, as well as future consumption of renewable energy.

Lower consumption will increase the resilience and stability of the energy system and make it less vulnerable to rising energy prices and limited resources. At the same time, the need to increase the capacity to produce and supply more energy is reduced.

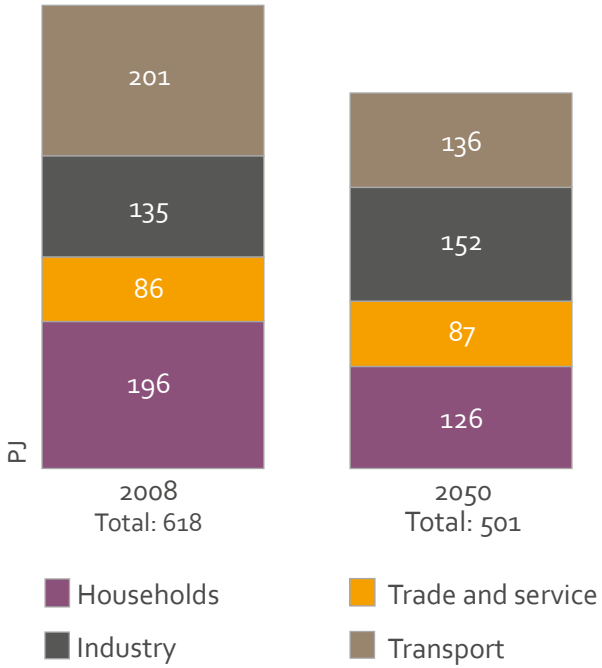


Figure 2.2: Energy consumption in PJ by the end users, today (2008) and in 2050.

The Climate Commission's, as well as a number of international[7] and Danish analyses[8] have shown that efficiency improvements of end consumption are more cost-effective compared with new expansions at the supply side.

Large potential in new technology

Even with the technologies known today, great opportunities exist to reduce energy consumption through improvements in energy-efficiency and, in many cases, there is money to be saved in making these improvements. For example, there are already considerable opportunities for efficiency improvements in connection with heating buildings, use of electrical appliances, and in energy consumption for industrial processes.

Although energy-efficient solutions are often more expensive in initial costs, in many cases the reduced energy costs balance out the extra initial costs. This is particularly true in the case of investments that have to be made in any event in order to replace or purchase new equipment, or in connection with renovation of buildings[9]. Technologies can be improved and made cheaper through research, development and demonstration. However, there is no excuse for not implementing already profitable improvements in energy efficiency immediately.

Electric cars more efficient

For several reasons, transport requires special attention. The most obvious alternatives to oil today in transport are conversion to biofuels or use of electricity. Production and use of biofuels are linked to considerable energy conversion losses and widespread use of biofuels would, therefore, require significant amounts of biomass, which is likely to be a scarce resource in the future. Through the use of electricity, opportunities for efficiency improvements are considerable. This is because petrol and diesel motors have a very low efficiency rate, as the majority of the energy led into the car disappears as heat. In contrast, electric motors have a high efficiency rate.

Therefore, conversion to electric vehicles, in itself, will mean a significant reduction in energy consumption, as an electric car is more efficient than a petrol car. Thus, use of electric vehicles will reduce the need to expand the energy supply. However, electric vehicles and their batteries, in particular, still lack some development before they can serve as a valid replacement for petrol and diesel cars.

2.2
A green energy system

Today, 80% of Danish energy supply is based on the combustion of fossil fuels. This percentage is so high that it is not possible to merely replace fossil fuels with other combustables – i.e. biomasse – without Danish energy supply becoming dependent on imports.

The Climate Commission's analyses indicate that a much larger proportion of energy will in the future be provided through the electricity system, if conversion to a green energy system is to take place as efficiently as possible.

The renewable energy source most available in Denmark is wind power, which supplies energy in the form of electricity. This should be considered in the context that, at present, wind power seems likely to become the cheapest form of renewable energy. This is partly because biomass resources are limited which means that prices will increase, if the rest of the world also makes a paradigm shift towards the use of biomass. Electricity can also be utilised in many different types of energy consumption and it often gives more efficient energy recovery than other types of energy.

The estimate made by the Danish Commission on Climate Change Policy of future available renewable energy resources in Denmark shows that the technical renewable energy potential is more than adequate to deal with the expected energy consumption. These resources include wind power (onshore and offshore), biomass (including waste and biogas), solar energy, geothermal energy, wave power, etc. It should be stressed that far from all the potential will be financially viable to exploit.

Therefore, conversion to electric vehicles, in itself, will mean a significant reduction in energy consumption, as an electric car is more efficient than a petrol car. Thus, use of electric vehicles will reduce the need to expand the energy supply.

Table 2.1: Potential renewable energy from Danish sources, in PJ

	Current production	Total resource	How much of consumption in 2050 can the energy resource technically cover?
Wind	26	1.220	> 250%
Wave power	0	40	< 10%
Solar electricity and heating	1	250	< 50%
Biofuels and waste	89	250*	< 50%
Total renewables**	123	1.760	> 300%

* Incl. 20 PJ fossil fuel waste

** Heat from geothermal installations and heat pumps is not included in the estimate, as the potential is hard to determine

Energy consumption doesn't change with the wind

An energy system based on wind turbines will have extremely fluctuating energy production, depending on when and how hard the wind blows. In other words, there will be periods with a lot of energy available and other periods with less energy. The system must always be able to deal with peak-load periods, when a large number of consumers and businesses use electricity at the same time. The Climate Commission believes that several different approaches can be combined to ensure a match between energy supply and demand in the energy system by 2050:

- Firstly, the Danish energy system should be linked more closely to neighbouring countries through expansion of electricity links, so that fluctuations in wind power can be integrated more closely with, for example, output from the large Swedish and Norwegian hydropower plants

- Secondly, wind power should be supplemented with other forms of renewable energy when there is no wind – in particular. power plants based on the combustion of biomass, biogas and waste. The system should, therefore, be flexible

- Thirdly, electricity consumption should be made more flexible, so that fluctuations in electricity production can be optimally exploited. Wherever possible, electricity should be used when it is generated.

The ultimate combination of energy sources will, amongst other things, depend on how other countries' energy systems develop. If the rest of the world also pursues an ambitious climate policy, it is likely that growth in demand for biomass will put pressure on resources and prices.

Security of supply considerations imply that a significant production capacity for energy must be maintained in Denmark. Security of supply demands that an electricity system based on renewable energy gives the same high security of supply as today.

Costs of ensuring that demand can be met, even during peak periods and in low wind conditions, have, therefore, been included in the calculations carried out by the Climate Commission.

With this background, the most important aspects in the picture of the energy system of the future in 2050 are the following seven elements:

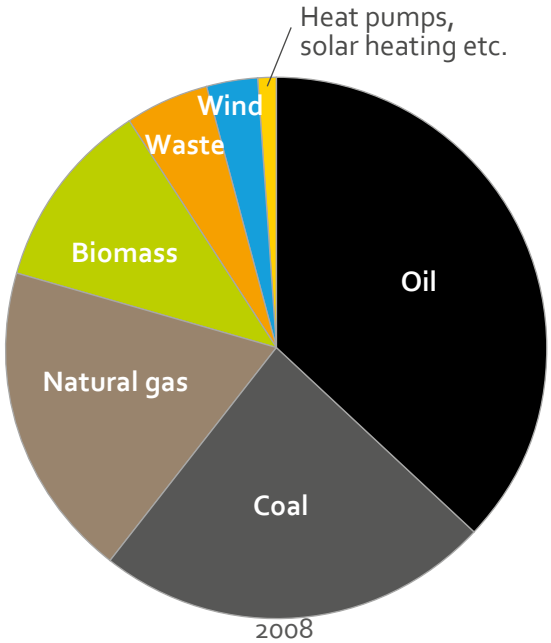
Production of renewable energy

1. Many-fold increase in wind-power capacity.
2. Biomass will play a pivotal role.
3. Other renewable energy sources will serve as a supplement.

New intelligent energy system

4. Intelligent electricity consumption will ensure incorporation of renewable energy.
5. The northern European electricity market. will be further integrated.
6. The transport sector will be converted to electricity and bioenergy.
7. Small-scale heating with electric heat pumps will be more widespread.

Figure 2.3: Energy sources in 2008 and possible breakdown of energy sources in 2050[10].



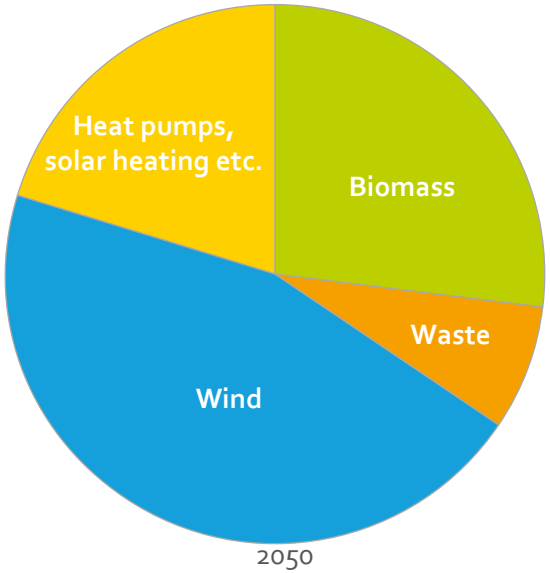


Figure 2.3 illustrates the possible break-down of renewable energy sources in 2050, assuming that the rest of the world follows an ambitious climate policy. This means that a high price is put on emissions of greenhouse gases, and that biomass will become a resource in great demand. The result will be a significant expansion of offshore wind farms and considerable improvements in energy efficiency. The Climate Commission's analyses show that less ambitious climate efforts by the rest of the world will result in a similar picture, but with more, less expensive biomass.

The seven important elements are described in more detail in the following section:

2.2.1 Production of renewable energy

1. Wind power will double from the current level to more than 10,000 MW

Expansion with wind turbines, especially offshore, is one of the most important initiatives in realising fossil fuel independence. Calculations show that there is a need for at least 10,000 MW, and up to 18,500 MW wind power in 2050. In comparison, at the end of 2008 about 3150 MW had been installed.

2. Biomass will play a pivotal role

In addition to electricity production from wind turbines, energy will in the future be produced from biomass and waste.

A number of power plants can already use biomass. Biomass also has the advantage that it can be stored. This makes biomass a valuable energy source which is likely to be increasingly utilised, especially in the transport sector and as reserve capacity for more variable sources, i.e. wind, which do not have the same storage possibilities as biomass.

3. Geothermal heating, photovoltaic solar modules and wave power as supplements

Energy should come from the renewable energy sources which, most energy-efficiently and cost-effectively, can supply it. By 2050, this may mean that other sources than wind and biomass may come into play.

For example, a number of district heating towns are situated in areas with geothermal heat and, here, geothermal heating could be exploited either directly for district heating production or in combination with heat pumps which can raise the temperature of the geothermal heat to an appropriate level.

Photovoltaic solar modules and wave power may also be technologies which come into use, although they are currently not competitive in terms of price.

2.2.2. New intelligent energy system

It is extremely challenging to establish temporal coherence between electricity production and electricity consumption. This requires an intelligent electricity system; a so-called 'smart grid'[11], with continuous adjustment to balance consumption and production.

4. Smart grid and intelligent electricity consumption

Incorporating increased fluctuations in electricity production due to an increased importance of wind power in the production system can be facilitated through promoting electricity consumption which can temporally adapt to electricity production. Especially on the longer term, when the capacity of the existing power plants in the electricity system drops and the proportion of electricity consumption from wind power increases, will flexible consumption become very significant for the operation of the system.

New technologies can ensure that electricity is used at times of large production. These must be employed through a nationwide smart grid. In particular, the Danish Commission on Climate Change Policy can see three types of electricity consumption which will grow in the future and which could potentially be crucial for system operation. These are:

- Heat pumps for district heating production and for individual heating
- Flexible electricity consumption by industries
- Electric vehicles

Depending on technological development, on the longer term, the level of use of electric vehicles is likely to be significant for the operation of the electricity system. On the other hand, the spread of heat pumps could well accelerate as early as in the next few years. Heat pumps can supply about 3 kWh heat for each kWh electricity they use. Heat pumps connected to the district heating system can benefit from a large store of heat and can, thus, be used to shift electricity consumption on a 24-hour/weekly basis.

In addition to the areas described above, it seems likely that, on the long term, there will be considerable potential in increasing the flexibility in electricity consumption by industry and households.

5. Integration of the northern European electricity market

Expansion of wind power will help even out the overall imbalance between consumption and production of energy in northern Europe, rather than increasing it - also if expansion takes place in Denmark. This applies if the northern European electricity market is considered as a whole. Norwegian hydropower resources act as an effective store of renewable energy for fluctuating wind power. In periods, especially in the winter, hydropower production falls and the increased wind power in these periods can partly counteract this drop.

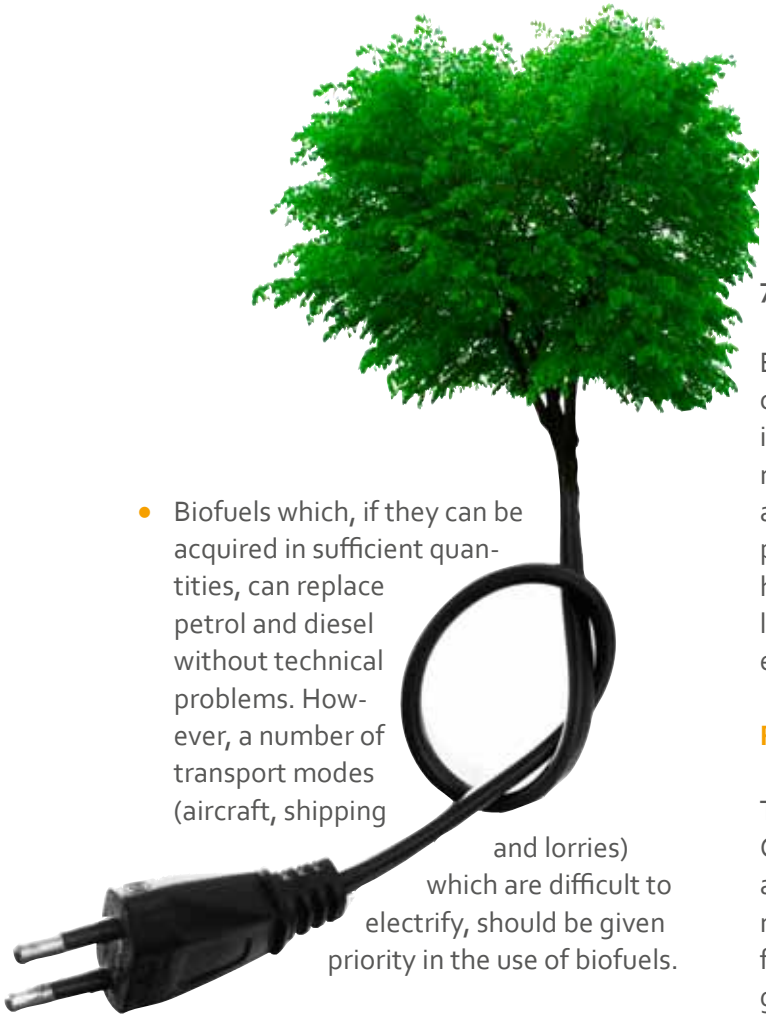
It is important, therefore, that the Nordic and northern European electricity markets are integrated further through expansion of international electricity links. Stronger links with hydropower-based systems in the Nordic countries and with areas where wind conditions are not the same as in Denmark, will make it easier to integrate large amounts of wind power into the system. At the same time, they will ensure that electricity can be imported from Denmark's neighbouring countries when production from wind power is not sufficient.

6. The transport sector is converted to electricity and bioenergy

The transport sector is a particular challenge. The vision of a future without fossil fuels requires a complete conversion of energy supply for the transport sector and Denmark is entirely dependent on technological developments abroad and on the development of international standards to meet this goal. Therefore, it is difficult to carry out large national conversion in the short term.

At present, there seem to be two main routes for conversion of the transport sector:

- Electric power, which has a great potential for exploiting wind-based electricity production, and where energy storage in the vehicle can be in batteries or in chemical form (usually as hydrogen with conversion to electricity through a fuel cell). In addition to just electric cars, plug-in hybrid cars will have a potential in a transition period, or permanently, if the internal combustion engine runs on biofuel.



- Biofuels which, if they can be acquired in sufficient quantities, can replace petrol and diesel without technical problems. However, a number of transport modes (aircraft, shipping and lorries) which are difficult to electrify, should be given priority in the use of biofuels.

In a longer transition period, there will not necessarily be a clear answer to which technology can replace petrol and diesel in the transport sector. Technological and price developments will, ultimately, determine the precise composition in 2050.

7. Small-scale heating with electric heat pumps

Buildings situated outside district heating areas can benefit from heating using electric heat pumps instead of the current oil and natural gas. Furthermore, large electric heat pumps can be installed at a number of district heating plants. Small heat pumps can exploit the geothermal heat, while large heat pumps can better exploit heat from the sea, lakes or waste heat. Heat pumps can help make electricity consumption more flexible.

Potential for CCS[12]

The CCS technology is primarily intended to collect CO2from coal-fired and gas-fired power plants, and coal and gas are not part of the Climate Commission's vision of a Denmark independent of fossil fuels. CCS can potentially contribute to greenhouse gas reductions, although utilisation in Denmark will require that the technology becomes more competitive, and that new power plants are built or the lifetime of existing coal-fired plants is extended. As a technology, CCS also has a potential for use in certain production processes. At biomass-fired installations, CCS can also be a possible supplement to endeavours to reduce emissions of greenhouse gases.

No special advantage in using nuclear power in Denmark

The Danish Commission on Climate Change Policy has no wish to make recommendations which limit the use of potentially important technologies. On the contrary, the Commission wants to keep as many doors open as possible so that the future energy system can be adapted to developments in technology and resources. The Climate Commission has. Therefore, also considered whether nuclear power has a role in a future Danish energy system independent of fossil fuels. The Climate Commission has reached the conclusion, however, that there is no obvious advantage in investing in nuclear power rather than renewable energy in Denmark. This is partly because there is no indication that nuclear power will be economically competitive, for example, compared with offshore wind turbines, especially if costs of storage of waste products and decommissioning are included. Nuclear power is not well suited for a system with other fluctuating energy supplies, as is expected in an energy system with a large proportion of wind energy. Finally, the Climate Commission has

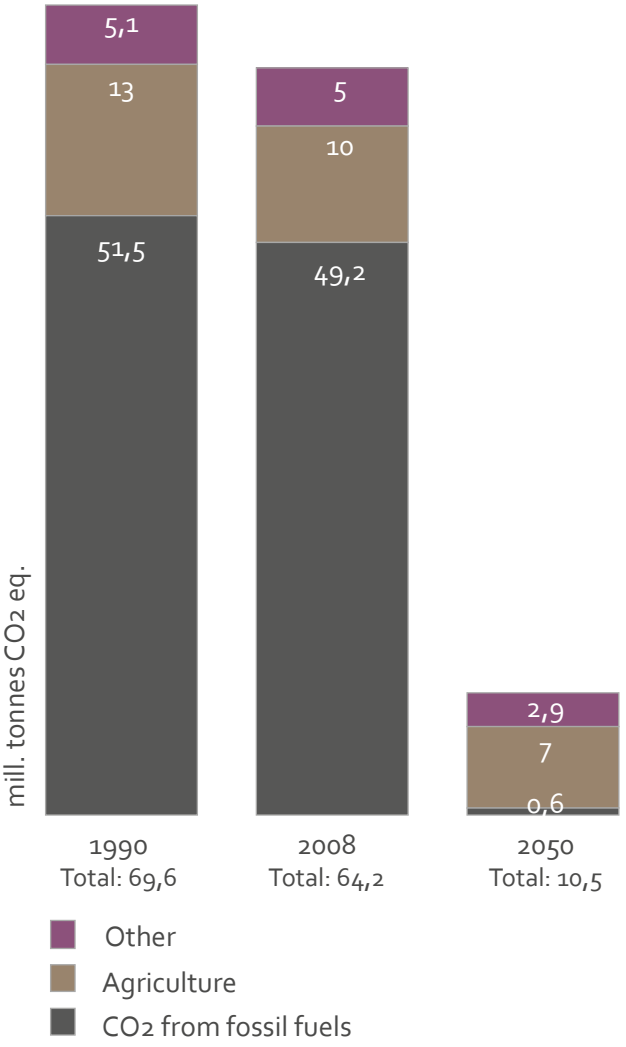


Figure 2.4. Danish greenhouse gas emissions in 1990, 2008 and without fossil fuels etc, in 2050[13].

noted that Denmark has not maintained professional competencies within nuclear power and this will mean that investment in nuclear power would require imports of technology and know-how and would not build on existing competencies in the Danish business community.

2.3
Limiting greenhouse gases from other sources than energy

Even 100% conversion to renewable energy would 'only' reduce emissions of greenhouse gases by about 75% in 2050 compared with 1990. Reductions in emissions of greenhouse gases from other sources than energy consumption are therefore necessary if, on its own soil, Denmark is to meet the EU target of limiting climate emissions by 80-95%.

As the figure 2.4 shows, agriculture is the second-largest contributor to emissions of greenhouse gases today, after emissions from the use of fossil fuels.

The Climate Commission has also examined the opportunities for reducing greenhouse gas emissions which do not explicitly come from use of fossil fuels. Analyses show some potential for reductions in these areas. This potential has been included for the year 2050 in the figure.

As mentioned above, agriculture is the second-largest emitter of greenhouse gasses, so if Denmark intends to live up to an 80%-95% reduction in greenhouse gas emissions by just reducing domestic emissions, it is vital to focus on a development in agriculture which considerably curbs emissions from production, itself.

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An energy system independent of fossil fuels is possible, but the huge reorganisation and conversion will not come on its own. Therefore it is vital that a number of new initiatives are taken now to ensure that the vision is made concrete now and that conversion can commence in the near future.

3. Recommendations from the Danish Commission on Climate Change Policy

Realising the long-term goal of Denmark becoming independent of fossil fuels and of reducing greenhouse gas emissions by 80%-95% requires establishment of the overall framework for such a development. An energy system independent of fossil fuels is possible but the huge reorganisation and conversion of the energy system will not come on its own. Therefore, it is vital that a number of new initiatives are taken now to ensure that the vision becomes established and that conversion can commence in the near future.

The new initiatives must reflect that, at present, it is not reasonable or possible to establish a detailed plan for conversion up to 2050. Therefore, the Climate Commission identifies only initiatives for development over the next 10-15 years. In designing its recommendations, it has been crucial for the Climate Commission that the recommendations should only promote **robust** initiatives, i.e.:

- Initiatives which are appropriate to implement with current knowledge. Therefore, emphasis is on utilising economic instruments, including taxes, which are deemed to be the most cost-effective

- Initiatives which are not dependent on one single future development but which are relevant for different future technologies and development routes so that the Danish energy system is not locked into a single scenario

- Initiatives which ensure that the necessary decisions are taken in good time so that they do not become unnecessarily expensive at a later date

- Initiatives must all be designed to promote cost-effective actions.

On this basis, the Climate Commission presents here a total of 40 specific recommendations for initiatives and decisions, all of which have been designed in the expectation of implementation over the next few years in order to ensure progress towards achieving the long-term goal in 2050.

The recommendations have been divided into seven overall groups.

- 14 cross-sectoral recommendations on overall legislation, taxes and research

- 7 recommendations to ensure that Denmark uses energy as efficiently as possible and that both consumers and the business community make the necessary changes in their patterns of energy use

- 8 recommendations on establishing an intelligent energy system

- 3 recommendations on converting the transport sector to electricity and biofuels

- 4 recommendations on EU and other international initiatives

- 4 recommendations on reductions in non-energy-related greenhouse gases.

The wording of the specific recommendations focuses on presenting the principles, overall guidelines and considerations. The Climate Commission has not clarified all the details for the specific

design and implementation of the various recommendations. This will have to be done in connection with specific implementation.

The recommendations from the Climate Commission comprise a consolidated whole and if some of the recommendations are not realised, other, new initiatives will be necessary.

3.1
Cross-sectoral recommendations

Conversion to a society based on green energy requires the involvement of all of society. It is about ensuring that conversion is cost-effective. Finally, it is about securing the necessary knowledge and technological development during the process of conversion.

3.1.1.
Overall framework - national and municipal levels

Realisation of the vision of Denmark becoming independent of fossil fuels and achieving significant reductions in greenhouse gas emissions is a long-term challenge which requires that there is certainty regarding the long-term goals and frameworks and that all parts of society contribute.

It is vital that there is regular follow-up of efforts through status reports and milestones and that, on the basis of these follow-up evaluations, efforts are adjusted as necessary.

The vision is one of many which make up the building blocks of the Denmark of the future. In a political process involving many different interests, it is important that this vision is incorporated in future political action and initiatives across sectors. This applies to everything from construction decisions to transport to urban development etc.

On this basis, the Climate Commission recommends:

1 recommendation
That an overall statutory framework be established for the vision of Denmark becoming independent of fossil fuels and achieving significant reductions in greenhouse gas emissions. This implies:

- That the government annually assesses developments in emissions of greenhouse gases, energy consumption, energy efficiency improvements and the introduction of renewable energy with a view to adapting instruments, and that analyses of how this vision can be realised are updated regularly
- That, at regular intervals, for example every five years, instruments are developed and adapted for the next five-ten years in relation to progress towards the final goal of realising the vision.

2 recommendation
That the government establishes long-term framework conditions, including expected taxes. The framework conditions should provide all players with a basis for planning and implementing relevant initiatives.

3 recommendation
That, on the basis of the national vision of fossil fuel independence, municipalities implement strategic energy planning, which includes planning of future types of supply. At the same time, municipalities should incorporate the vision in their spatial planning, including land-use planning. Planning should be coordinated across municipal borders.

3.1.2. Economic incentives to secure cost-effective decision-making

The use of economic instruments will be crucial in reaching the goal of fossil fuel independence cost-effectively. A uniform tax across uses will ensure consolidated cost-effective efforts. This means that, as a point of departure, an initiative will not be implemented if an alternative initiative solves the same problem but more cheaply. For example, most energy efficiency improvements will be done by the enterprises providing the best pay-back.

The use of economic instruments will be crucial in reaching the goal of fossil fuel independence cost-effectively.

It should be noted, however, that there are market imperfections in the individual sectors or types of energy. This makes it appropriate, in a number of areas, to supplement economic instruments with other initiatives, e.g. regulation or information and campaigns.

The Climate Commission recommends that a tax be phased in on fossil fuels, as a fundamental instrument to realising the long-term goal of fossil fuel independence. Phasing in this tax should be commenced now and the tax increased gradually over time so that, together with other instruments, it can secure gradual phasing out of fossil fuels.

Gradual phasing in of a tax on fossil fuels will mean taking into consideration the investments that have already been made in installations and equipment. For example, it would be advisable that Danes gradually convert to renewable-energy-based technologies when their oil-fired furnaces wear out. However, it is not advisable to scrap all oil-fired furnaces from one day to the next.

By applying a tax rate which gradually increases up to a level of DKK 20 per GJ[14] in 2020, even on the short term the tax on fossil fuels will have a significant effect, especially in promoting more efficient energy consumption by the business community, phasing out coal-fired power plants and converting small individual oil-fired furnaces to heat pumps.

A further important consideration is that the tax should be large enough to provide a clear signal to consumers. It is important that both households and enterprises understand that, on the long term, the cost of fossil energy sources will continue to rise so that they see that investments in energy efficiency improvements can pay. A clear signal with respect to the tax will, therefore, have a positive effect in itself.

For businesses exposed to competition from abroad, a tax of DKK 20/GJ in 2020 could be a serious challenge, if, on the shorter term, the business has difficulty in making energy consumption more efficient or in using renewable energy.

However, it is deemed that a gradually increasing tax on fossil fuels to a level of this size could be managed by the business community in general without generating serious consequences for competitiveness. Even though energy taxes increase, by

far the majority of businesses' energy costs will still comprise only a relatively small proportion of total costs.

The announcement of and, thus, the knowledge of a future tax on fossil fuels which increases gradually will, in itself, increase the effect of a given tax measure and will reduce the costs of conversion considerably, also for businesses exposed to competition.

It will be possible to protect the business community from costs by a partial re-injection of the revenues back to businesses which are especially exposed to competition. If this route is chosen, it should be based on analyses of he particular enterprise's exposure to competition, as well as the additional costs for society of such a re-injection. It is important not to exempt these businesses from the tax itself, as the incentive for energy efficiency improvements and conversion to renewable energy would disappear.

The tax on fossil fuels could lead to considerable displacement of domestic coal-based electricity production which is in very direct competition with electricity production at power plants in other countries in the northern European electricity market. Whether this should lead to a compensation scheme for electricity production at the existing power plants up to 2020 (when many of the plants will be ready for scrapping in any case) must be weighed against the costs of deviating from the cost-effective tax system.

In the transport area, a committee has been set up under the Danish Ministry of Taxation to assess the possibilities to restructure the vehicle taxation system to take into account the environment, congestion and revenues. In light of the fact that oil consumption for transport purposes comprises a large and increasing proportion of total fossil energy consumption, it would be appropriate that the goal of fossil fuel independence be specifically incorporated in the work of this committee. Introduction of road pricing can potentially alleviate the problems of increased cross-border trade, which will follow from a unilateral Danish tax increase on petrol and diesel (i.e. the tax on fossil fuels).

On this basis, the Climate Commission recommends:

4 recommendation
That a new tax be introduced on fossil fuels which, as a point of departure, includes all use of fossil fuels and at the same tax rate for all uses. The tax should comprise the bearing instrument to promote energy efficiency and conversion to renewable energy in both the business community and in households.

5 recommendation
That a clear message is sent on a gradually increasing tax up to a level which, together with other instruments, secures fossil fuel independence by 2050.

6 recommendation
That the tax be phased in gradually from a relatively low level, for example, DKK 5/GJ in 2011 to DKK 20/GJ in 2020 and around DKK 50/GJ in 2030 (at fixed prices). The specific rate of increase for the tax should be assessed at suitable intervals in the light of developments in energy consumption, prices, technologies, etc.

7 recommendation
That electricity production from existing power plants be covered by a temporary compensation scheme, if it is deemed to be desirable to prevent the temporary increase in net imports of electricity which may be caused by the tax. This should be weighed against the increasing socio-economic costs of differentiating the tax.

8 recommendation
That a thorough analysis be carried out of whether the current tax and subsidies system represents the best balance of fiscal, distribution, energy policy, and other considerations, including whether the system conflicts with cost-effective conversion to an energy system independent of fossil fuels. In this connection there should be special focus on whether it is appropriate to continue

- The current tax-exemption for biomass for heating purposes
- The current tax exemptions in the energy area for businesses.

9 recommendation
That there be consideration of, in the long term, introducing a general energy tax for biomass, if it is politically deemed that increased use of biomass could lead to an unwanted dependence on imported biomass.

10 recommendation
That the overall new car-tax system be set up so that it underpins the long-term conversion to a fossil fuel independent society (see the recommendations under transport). Cross-border trade issues from a gradual increase in tax on petrol and diesel should be considered in the context of the possibilities for restructuring to road pricing.

11 recommendation
That the CO_2 tax be adjusted regularly so that it corresponds to the expected price of CO_2 on the EU ETS market, so that a cost-effective effort is achieved across ETS sectors and non-ETS sectors.

3.1.3. Research, development and demonstration

Development of new technologies and solutions is a vital factor in cost-effective conversion to green energy. They should help promote energy efficiency and increased utilisation of renewable energy sources.

Danish research, development and demonstration should concentrate on areas which are central for achieving the goal and in which Denmark already has strong competencies. At the same time, a research base should be maintained in order to translate new knowledge regarding the conversion of the energy system into practice under Denmark conditions. Therefore, any earmarking of resources to the area should be relatively broad and with problem or challenge orientation so that focus is on selected areas of interest, while retaining flexibility in execution.

Public research, development and demonstration efforts require a long-term overall financial framework and secure, stable appropriations from year to year. The framework should match the level of ambition in the objectives. Robust investment is required if Denmark is to reach the goal in 2050. At the same time, the framework should reflect that there should be special focus on demonstration of the technologies and solutions developed.

The Climate Commission has, for example, identified a need for demonstration projects relating to installation designs which combine heat pumps,

About 40% of the energy consumption in Denmark is currently related to buildings.

solar panels and heat storage for district heating production as well as for the application of biogas/natural gas or other alternative fuels for vehicles with high fuel consumption and limited infrastructure requirements.

On this basis, the Climate Commission recommends:

12 recommendation
That continuity in research, development and demonstration appropriations be secured by setting the level for a number of years, e.g. 5-10 years, and that the total appropriations for energy-related research, development and demonstration be retained at, at least, the 2010 level.

13 recommendation
That the strategic research, development and demonstration council and programme committees for the energy area develop a common strategy across the relevant programmes which underpins the development of an energy system independent of fossil fuels. Regular joint evaluations and reporting of implementation of the strategy should be carried out.

14 recommendation
That the strategy should include acknowledgment of the fact that the demonstration phase has special significance for the development necessary in the areas dealt with in the Climate Commission's other recommendations regarding energy efficiency, electricity and heat supply, and transport.

3.2
Consumption of energy – efficiency and conversion

Over the past 30 years, Denmark has implemented significant energy efficiency improvements and, today, the country is relatively energy efficient. However, there are significant opportunities for implementing additional cost-effective initiatives with existing technology. With focused research and development efforts, these opportunities can be increased and associated costs can be reduced.

Energy efficiency means that society's increasing demand for energy services can be satisfied with lower energy consumption. A cost-effective realisation of the vision assumes that a significant part of these opportunities are realised.

The great challenge in energy efficiency is, therefore, how the major technical possibilities for increasing energy efficiency can be realised in the best and cheapest possible way. There are a number of barriers preventing initiatives from being realised, even though they are apparently economically attractive to consumers and enterprises. Past efforts to promote energy efficiency have consisted of a combination of economic incentives, normative approaches (regulation) and information.

The proposed tax on fossil fuels will, particularly in the long term, bring increased incentives to make energy use more efficient. However, within the different areas, there is a need for more and intensified initiatives, which specifically contribute to overcoming the various barriers and market imperfections that prevent private consumers and businesses from making the most efficient decisions. This may, for example, be lack of knowledge about the opportunities that exist today.

Non-economic barriers and market imperfections

In practice, there are a number of non-economic barriers and market imperfections linked, e.g., to lack of knowledge. This means that costs and opportunities for efficiency improvements do not necessarily fully reflect investment and energy consumption by households and businesses. This includes potential energy-efficiency improvements which would be financially advantageous but which, because of the barriers, are unlikely to be implemented.

Economic instruments, including a tax on fossil fuels will, amongst other things, create incentives to improve energy efficiency and they will contribute to reaping energy-efficient potentials. However, there is also a need for instruments which directly address the barriers to realising improvements in energy efficiency and, at the same time, help the economic instruments achieve their full and intended effect.

3.2.1.
Energy efficiency of buildings and electricity consumption

About 40% of the energy consumption in Denmark is currently related to buildings. There are significant and inexpensive possibilities for reducing this consumption. Thus, this is an obvious area of special interest, and it applies particularly to existing buildings which, on average, use 2.5-times more energy for heating than new buildings[15].

For new buildings, the Climate Commission finds that there is currently no need for further requirements in relation to the politically agreed changes in the building regulations which increase energy requirements by at least 75% no later than 2020. What is important is that the more strict regulations are implemented and that compliance with these is checked. With respect to new buildings, there is however, a need for continued development and testing of new solutions and the development of the necessary expertise and experience in the construction industry. This can be done by the construction of demonstration buildings that meet stricter requirements than in the building regulations.

There are generally greater opportunities to reduce energy consumption in existing than in new buildings. In many cases, such efficiency initiatives can be profitable if energy improvements are implemented in connection with renovation and replacements carried out for other reasons.

Due to the longevity of buildings, it is necessary to act now. Buildings and building components are typically only renovated and replaced every 30-50 years. Therefore, it will be more expensive if action is not taken now.

Introducing the suggested tax on fossil fuels, will provide increased incentives to realise energy savings in buildings and will make more projects cost-effective. However, new initiatives are required to help overcome the barriers that prevent the necessary energy renovations from being completed to the extent required. These include the need to make determined efforts to overcome the barriers to investing in building improvements and efforts to support the professional assistance in this connection.

Typical for this area is that both builders and building owners possess only modest knowledge concerning energy efficiency and they are uncertain about possible solutions and effects. This is why it

is so important to continue the current information efforts.

There is also a large potential for improvements in energy efficiency in Danish energy consumption; from lighting to domestic appliances to various consumer electronics. These largely include products produced for a global market. Therefore, promotion of energy efficiency will be most effective through international initiatives.

The key instrument for promoting development and use is to stipulate ambitious and dynamic efficiency requirements at the EU level within the framework of the Ecodesign Directive and the common European energy labelling scheme. Recommendations from the Climate Commission for this area are described in section 3.4 on international initiatives. In addition, it is important that, for example, the Danish Centre for Energy Savings continues to carry out campaigns to enhance information and make it easy for consumers to choose efficient products.

On this basis, the Climate Commission recommends:

15 recommendation

That an "energy savings account" be introduced for all buildings, i.e. a payment into an energy savings account which, in combination with energy labelling and a certified consultancy scheme, will strengthen building owners' incentives to make energy improvements to buildings. Such a scheme must contain the following elements:

- Each year building owners must pay an amount into an energy savings account linked to the specific building. The scheme will apply to all buildings; private as well as public

- The annual payment into the account is determined per square metre of heated area on the basis of the energy standard of the building, which is determined on the basis of the building's rating on the A-G scale under the energy labelling scheme. Buildings with top rating will not have to pay

- The account may be spent on certified consultancy in connection with energy renovation, and subsequently as a contribution to implementing the renovations

- After the energy improvements, the building is once again classified on the A-G scale as the basis for the future reduced payment into the energy savings account.

16 recommendation
That, in cooperation with the construction industry, a certification scheme for builders be introduced with a view to competency development, greater visibility and credibility of the builders and tradesmen specialising in energy renovation and installation.

The suggested tax on fossil fuels will provide an important incentive to promote improvements in energy efficiency and a move away from fossil fuels.

3.2.2. Energy efficiency improvements in the business community

Today industry accounts for about 23% of energy consumption; most of which is used for processing purposes. Private trade and service account for about 13% of energy consumption, which is primarily used for heating and electricity consumption in buildings, see above. The potential for energy efficiency improvement is great. A new study shows a potential for cost-effective improvements in energy efficiency over the next 10-15 years of about 25%[16], and in the long term the potential will be even greater.

However, significant barriers prevent this potential from being exploited. Only few private enterprises are so energy intensive that energy consumption and efficiency potential are considered as important, strategic focus areas. For the majority of enterprises, energy and CO_2 costs rarely make up for more than 1%-2% of the production value. This leads to limited interest in and knowledge about efficiency options. Studies show that, in general, requirements are a maximum repayment period of 2-5 years for efficiency projects. As the average life span of production equipment is significantly longer, requirements for rapid pay-back rates mean

that there is a significant socio-economic efficiency potential in production enterprises.

The suggested tax on fossil fuels will provide an important incentive to promote improvements in energy efficiency and a move away from fossil fuels. However, there is a need for supplementary initiatives which can help improve awareness of and knowledge about energy consumption and opportunities for efficiency improvements.

Businesses within private trade and service are often relatively small, and energy costs represent a very small part of the enterprises' total costs. Introducing the tax on fossil fuels and payments to the energy savings account will increase awareness of energy costs. However, there is a need for easily accessible information about opportunities for efficiency improvements, including on how much energy is typically used by similar enterprises.

In Denmark, about 700 enterprises are covered by the requirement to prepare annual green accounts. The requirement for green accounts is currently a brief, qualitative description of the most important resources and environmental conditions at the enterprise. It is necessary to expand the requirement for green accounts, so they contain knowledge about the enterprises' consumption of fossil fuels and greenhouse gas emissions, which will promote enterprises' incentives to make energy-efficiency improvements.

On this basis, the Climate Commission recommends for trade and service enterprises:

17 recommendation
That the Danish Energy Agency establish a benchmarking of energy consumption within relevant sub-sectors. This should be done on the basis of the reporting by supply companies of energy consumption in buildings to the Danish Building and Housing Register. In a relevant way, benchmarking should compare electricity consumption and energy consumption in different sub-sectors (e.g. supermarkets, office buildings, etc.).

In *industry*, energy is used for many different purposes and processes. Often, there will be low costs associated with new investment in the right energy-friendly installation but very high costs, if otherwise functional production equipment suddenly needs is to be modernised.

In order to promote energy-efficiency in industry, the Climate Commission recommends:

18 recommendation
That requirements for energy-efficiency improvements are made in line with other requirements in connection with environmental approval of large enterprises. As part of this, requirements should be made on using the best available technologies (BAT) in connection with new installations.

19 recommendation
That requirements for the content of green accounts should be expanded, so in future they include statements of developments in consumption of fossil fuels and greenhouse gas emissions.

3.2.3. Improvements in energy efficiency in the public sector

Public-sector energy consumption constitutes 4% of total energy consumption. Both a tax on fossil fuels and the establishment of energy savings accounts for all buildings will have a full impact on all types of public institution. However, it is necessary to launch further initiatives to promote energy efficiency. This is because there is a need for better coordination of long-term investment decisions and operating costs in the public sector, as well as a need for increased awareness and improvements in the information base on energy consumption and cost-effective efficiency opportunities in all parts of the sector.

On this basis, the Climate Commission recommends:

20 recommendation
That government institutions:

- Realise all cost-effective energy-efficiency projects by 2020. There should be annual reporting of the energy consumption of each ministry and energy consumption per square metre must be benchmarked.
- Buy energy-efficient products and services. To enable this, National Procurement Ltd. Denmark (SKI) should impose requirements on energy-efficiency in their procurement agreements.

21 recommendation
That municipalities and regional authorities:

- Calculate and publish their annual energy consumption per square metre of heated area on the basis of information from the Danish Building and Housing Register (BBR). The Danish Energy Agency should regularly prepare a benchmarking that compares energy consumption (per square metre of heated area) in the various municipalities and regions for comparable institutions.

- Make a long-term plan to reduce energy consumption and to convert away from fossil fuels. The plan should ensure that all cost-effective energy-efficiency projects are realised and it should be reviewed every five years on the basis of new energy labelling, etc.

3.3
An intelligent energy system

The energy system consists of various individual technologies on which there is usually much focus; wind, biomass, solar, etc. These are important technologies but the challenge of the future energy system is to merge the different technologies into one coherent energy system, which at any time can provide the energy demanded by Danes without using fossil fuels, and at reasonable prices.

The previous section on energy efficiency improvements of energy consumption deals with the demand side of the energy system. This section deals with conversions in the supply side, i.e. energy production, as well as the coherence in the system.

There is a need for massive conversions to make energy production independent of fossil fuels. This applies in relation to electricity production, heat production, energy use by industry, etc.

As described in chapter 2, electricity is likely to become the dominant energy carrier in the future energy system. Biomass will be an important secondary energy source; particularly in those places where the use of electricity is very expensive or perhaps not even possible. This applies, for instance, to electricity production in power plants, when there is no wind, in parts of process energy consumption and as biofuels in parts of the transport sector.

Electricity consumption will grow dramatically. In addition to electricity consumption for various appliances etc., in the future, large amounts of electricity will be used for production of district heating via heat pumps, for heat pumps in individual buildings to replace oil-fired boilers and natural gas-fired boilers, for processing purposes in industry and for transport. A very large part of electricity production is likely to come from wind turbines. Therefore, there is a need for large expansion, primarily of offshore wind turbines. There is a similar need for expansion and development of the entire electricity grid.

It is extremely challenging to establish temporal coherence between electricity production and electricity consumption in such an energy system. This requires an intelligent system with regular adaptation of consumption as well as production. Electricity consumption must be flexible, without causing inconvenience for users. It is also important to be able to import and export electricity and to expand energy storage.

Wind turbine production varies with wind speed and there will be periods in which too much electricity is produced and other periods in which too little is produced. There will, therefore, be a need for reserve and peak-load capacity which can

produce electricity in wind-calm periods, and for strong links abroad so that surplus electricity can be exported and electricity can be imported during periods of electricity shortages. Hydropower storage in Norway and Sweden represents efficient electricity storage, and this must be fully utilised. Therefore, it is necessary to further develop the northern European electricity market, for example by expanding transmission lines to neighbouring countries.

However, there is also a need to make electricity consumption more flexible, if such a system is to be able to meet energy needs at all times without large investment costs in grid and production capacity.

Adjustment of electricity consumption must be achieved through:

- Flexible use of heat pumps and heat storage systems in the district heating supply
- Flexibility in individual heat production with heat pumps
- Increased flexibility in electricity consumption in industry, households, trade and service

- Flexible recharging of electric cars
- Expansion of the transmission grid and distribution grid as well as installation of intelligent electricity meters.

Conversion to green energy requires investments in many places in society. To ensure sufficient capacity to produce renewable energy, support for investment is necessary. To safeguard against investing in too much capacity, it is preferable that consumers pay the costs through the price of electricity. This ensures a greater incentive for continuing improvements in energy efficiency than if consumers paid indirectly through higher taxes. The supplementary costs may be in line with the principles of the current PSO scheme[17] and/or through a supplement to the distribution tariffs.

This is an entirely new system with a number of challenges to overcome in order for the system to be cost-effective and to provide a high security of supply. It takes time to establish the individual elements, and it is necessary to gain experience, not least in the relationship between these elements. Therefore, now is the time to launch efforts to make the energy system integrated, intelligent and flexible.

On this basis, the Climate Commission recommends:

22 recommendation
That, in collaboration with the national TSO, Energinet.dk, and the electricity grid companies a specific plan for developing an intelligent energy system be drawn up. On the basis of the vision of a Denmark independent of fossil fuels in 2050, the plan must focus especially on efforts up to 2025.

3.3.1. Multiplying wind turbine capacity

Expansion of wind turbines – particularly offshore – will provide one of the most important sources of renewable energy. Calculations show that there is a need for between 10,000 MW and 18,500 MW wind power in 2050. In comparison, at the end of 2008 about 3,150 MW had been installed. If existing tenders and plans for expansion onshore are included, this number is expected to increase to around 4,000 MW in 2012.

The need for wind-power expansion must be assessed in the light of the fact that converting the entire electricity supply up to 2050 is a conversion of historic dimension,and which entails considerable technological and planning requirements. Con-

version should, therefore, take place gradually over several decades in order to achieve the necessary experience and build the required competences. Depending on future developments, the Climate Commission deems that between 100 MW and 300 MW wind power will have to be erected annually in the period 2015-2025. An appropriate size for the expansion could be 200 MW wind power per year in the period 2015-2025.

The scope of the expansion must be evaluated regularly, as a part of the overall evaluation to be carried out every five years.

Considerable expansion of wind turbines requires establishing the right framework for this expansion. At present, expansion in Denmark is characterised by short-term planning and inflexible conditions. The market for expansion of offshore wind turbines is to an increasing extent becoming international. Lack of interest and, thus, less competition to build offshore wind farms in Denmark could lead to significantly higher prices for electricity consumers. If a long-term framework is established, this could lead to better opportunities to plan investments and, therefore, to reduce costs, which, in turn, could help bring down prices of new offshore wind farms.

On this basis, the Climate Commission recommends:

23 recommendation
That an expansion strategy be adopted and implemented, with long-term rolling planning of offshore wind turbine expansion, including an infrastructure plan. This strategy should be based on an average annual expansion of around 200 MW capacity in the period 2015-2025.

24 recommendation
That it be investigated how a tendering procedure can be established which ensures cost-effective offshore wind turbine expansion in relation to the actual costs as well as the international market situation. As a step towards achieving this, the various methods (call for tenders, open door procedures, etc.) should be analysed in more detail.

25 recommendation
That the necessary support for renewable energy technologies, to ensure the expansion of wind turbines and other electricity generation based on renewable energy, be paid by electricity consumers via a supplement to the electricity price, in line with the principles in the current PSO (Public Service Obligation) scheme.

3.3.2
District heating expansion and production

District heating today accounts for around 50% of the overall heat supply in Denmark. Also in future, district heating will play a key role in heat supply. However conversion away from fossil fuels is needed. This conversion is tied up closely with conversion of electricity production. The district heating sector must change from being a flexible electricity producer, based on combined heat and power, to being a flexible electricity buyer in the future. Whereas today heat is being produced primarily together with electricity at combined heat and power plants, in the future heat will to a greater extent be produced by electric heat pumps connected to the district heating system. In this manner, district heating will serve as energy storage for wind-power production. In this context, new installation concepts need to be tested, including combinations of heat pumps, solar panels and heat storage for district heating production.

Conversion of district heating production to a system based extensively on electric heat pumps requires establishment of the right incentives. This should be seen in the context of the review of the energy tax system mentioned in recommendation 8, including a possible tax on biomass for heat production. The tax on electricity must be designed so that it promotes efficient heat production with highly efficient heat pumps. The tax should be imposed on the electricity consumed, not on the heat production.

Conversion of district heating production will also be a part of overall municipal energy planning, cf. recommendation 3.

On this basis, the Climate Commission recommends:

26 recommendation
That heat pumps in district heating supply be promoted and that an appropriate interplay with wind power and combined heat and power production be ensured. This should be ensured through an appropriate incentives structure, including that the tax is imposed on the electricity used for the heat pumps.

3.3.3
Individual heat supply

Phasing out fossil fuels involves converting oil and gas heating in individual buildings to some other

form of heating up to 2050. To some extent this will be to district heating, but it will also include extensive utilisation of heat pumps.

Conversion of individual oil-fired furnaces to heat pumps is one of the socio-economically cheapest initiatives as these types of heating cost more or less the same. Already today, in many cases, conversion from individual oil-fired furnaces to heat pumps is financially advantageous for users, and the tax on fossil fuels will strengthen incentives. Lack of information, and unwillingness to believe that the price of oil will increase, can, however, make some people invest in new oil-fired furnaces. As new oil-fired furnaces have a long lifetime, it is inappropriate to install new oil-fired furnaces after a given date.

Conversion of natural-gas furnaces to heat pumps is also among the socio-economically cheapest initiatives. In individual natural-gas areas in Denmark, some consumers may be required to connect to the natural-gas grid, and if these consumers are to use heat pumps, they will have to be relieved of this requirement.

Since biofuels are not subject to taxation, conversion to biomass rather than heat pumps may be more attractive from the perspective of the individual consumer's financial situation. It may be relevant to introduce a tax on biomass or subsidies to heat pumps, in order to ensure that socio-economically attractive heat pumps can compete with individual biomass installations, also in terms of private finances. The subsidies could possibly be financed through the grid tariff, or the electricity tax could be reduced, which will ensure full or part equality with biomass, which is exempt from taxes. This will promote increased use of individual heat pumps. Consideration of these points should be included in the analysis of the current tax system, see recommendation 8.

Installing individual heat pump systems in larger buildings (apartment blocks, schools etc.) will probably be more expensive and complex than for small buildings. Therefore, in areas with district heating, it will be beneficial to connect these buildings to the district heating grid.

Conversion to heat pumps for households should be carried out in parallel with expansion of wind turbine capacity as heat pump installations provide good opportunities for adaptation to fluctuating electricity generation.

On this basis, the Climate Commission recommends:

27 recommendation
That, in order to promote phasing out of oil for individual heating, new oil furnaces may not be installed after 2015.

28 recommendation
That it be ensured that individual heat pumps are competitive compared with biomass installations, and that individual heat pumps are prepared for flexible electricity consumption, meaning that the required electronic control system and storage capacity are available.

3.3.4 Flexible electricity consumption in other sectors

In addition to district heating and individual heating, there is a need to increase flexibility in electricity consumption by industry and households. More flexible electricity consumption should be promoted through a combination of metering by the hour, and price incentives through tariffs and taxes. Furthermore, electrical appliances in the future could have built-in intelligence and remote control systems.

In the longer term, the transport sector has great potential for flexible electricity consumption.

Therefore, it is important to ensure that the spread of electric cars supports this, see the section on transport.

On this basis, the Climate Commission recommends:

29 recommendation
That possibilities and incentives for flexible electricity consumption by industry, households and transport be established through,

- Regular follow-up on the spread of intelligent electricity meters in order to ensure that these meet the requirements of an intelligent electricity system
- Analysis of the future potential for flexible electricity consumption in industry and in households, including the incentives structures best suited to underpin flexible consumption
- Promotion of electric cars that are ready for flexible electricity consumption, in other words cars with the necessary electronic control system.

3.4
Transport based on electricity and biofuels

The transport area is one of the areas which weighs heavily, accounting for 26% of total energy consumption in 2008. Oil consumption by transport accounted for 65% of total oil consumption. At the same time, the transport area is one of the most complex challenges in realising the vision of Denmark becoming independent of fossil fuels and reducing greenhouse gas emissions markedly by 2050.

Achieving the vision will involve a revolution in energy supply in the transport sector, requiring that new technologies gain a foothold in the market and gradually replace existing petrol and diesel vehicles.

As mentioned already, there seems to be two possible main routes for this conversion:

- Electric power, which has a great potential for exploiting wind-based electricity production, and where energy storage in the vehicle can be in batteries or in chemical form (usually as hydrogen with conversion to electricity through a fuel cell). In addition to plain electric cars, plug-in hybrid cars will have potential in a transition period.

- Biofuels which, if they can be acquired in sufficient quantities, can replace petrol and diesel without technical problems. A number of transport modes (aircraft, shipping and lorries) which are difficult to electrify, should be given priority in the use of biofuels.

Several problems are associated with biofuels, primarily climate impact and scarcity, and these make it problematic, at present, to base a future strategy for the transport sector on biomass alone. Use of second generation biofuels is being promoted through the target of 10% renewables in the transport sector by 2020, in which second generation biofuels count double, cf. the EU Directive on the obligation of Member States to use energy from renewable energy sources.

The most important barriers to extensive electrification of road transport are:

- That battery technology has not been developed sufficiently enough for electric cars to be competitive compared with conventional cars. Batteries are too expensive and do not have enough capacity for driving long distances between recharging/battery replacement.
- That electrification of passenger cars is delayed or stagnates because of the "chicken and egg" issue: No electric cars without recharging stations and vice versa.

Making people change from private to public transportation or cycling/walking can only to a limited extent contribute to reducing overall energy consumption. Studies show that even an extensive transferral from transport by car to transport by bicycle, will only reduce energy consumption by 2%-2.5%. Furthermore, even a doubling in public passenger transport (trains and buses) will only reduce car numbers by around 15%, which will be more than set off by the expected growth in car numbers over the next ten years.

In the short term, improvements in the fuel efficiency of vehicles are deemed to be the socio-economically cheapest way of curbing the transport sector's use of fossil fuels. In the long term, electric cars have a considerable potential for not only bringing down carbon emissions and use of fossil fuels through wind-based electricity, but also for reducing total energy consumption, because of the higher energy efficiency of electric cars. Of course, plug-in hybrid cars have the same properties when running on electricity. In the long term, they will probably be more expensive than purely electric

cars, although in the short term they have the advantage that they are less dependent on a fully developed recharging infrastructure.

The agreed restructuring of car taxes must ensure, as a minimum, the same degree of incentive to choose energy-efficient cars as in the current differentiation of car registration tax etc. The tax on fossil fuels should also cover petrol and diesel for transport, see recommendation 4. However, cross-border trading issues could speak in favour of not realising this until the introduction of green road pricing.

Demonstration projects can provide experience from full-scale use of electric cars and plug-in hybrid cars. Demonstration projects and trials can also help develop frameworks for how vehicles with high annual fuel consumption and limited infrastructure requirements can be converted to biogas/natural gas. Similarly, trials with alternative fuels should be carried out, if relevant.

On this basis, the Climate Commission recommends:

30 recommendation

That the phase-in tax break in the current tax exemption for electric cars be continued after 2015 in order to establish a clear framework for manufacturers over a longer period. The specific details should be considered in the context of the restructuring of car taxes in general, and

- The tax relief must promote electric cars in quantities allowing for a full-scale test of the cars and the associated infrastructure. Due to fiscal and socio-economic considerations, the relief should be limited to the order of 100,000 cars up to 2020, corresponding to around 4% of cars on Danish roads.
- The tax relief can be designed as a tax relief per kWh of installed battery capacity, with a gradual reduction if electric cars eventually become more competitive.
- The tax relief should also include plug-in hybrid cars with immediate effect. Subsequently, it can be extended to other alternative fuels.

31 recommendation
That an overall plan be prepared for expanding the car-recharging infrastructure, to cost-effectively underpin gradual full-scale introduction of electric cars, including through more public recharging stations, rapid recharging as well as battery-change stations. The plan must relate to possible consequences for the expansion of the general electricity supply infrastructure.

32 recommendation
That, amongst other things, experience with and frameworks for how vehicles with high annual fuel consumption and limited infrastructure requirements can be converted to biogas/natural gas, be established, e.g. through supporting demonstration projects. Other alternative fuels can also be covered by the scheme.

3.5
International, including the EU

There is considerable energy consumption by 'portable' appliances and products used by households, the public sector and the business community. These products can be made significantly more efficient at a very low cost, if international requirements are imposed on manufacturers. It is vital that active efforts be made by the Danish government to influence EU regulation so that requirements are ambitious and dynamic and so that they are implemented as quickly as possible.

In a number of areas, efforts to reduce consumption of fossil fuels and greenhouse gas emissions are most effective and cheapest through internationally coordinated initiatives and, in some areas, Denmark only has limited possibilities to influence developments alone. These include setting standards for sustainable production of bioenergy and biofuels, which are typically traded across national borders.

With the future large expansion of wind turbines, it will be essential for Denmark to have a well-functioning international electricity market which will minimise the risk of Denmark ending up selling excess electricity production cheaply and buying electricity expensively. An extensive expansion of the international electricity transmission grid would help reduce this risk.

On this basis, the Climate Commission recommends:

33 recommendation
That the Danish government in the context of the EU works for continued energy efficiency improvements in products and appliances within the framework of the Ecodesign Directive. This work should include:

- That new types of appliances with high energy consumption be monitored at EU level with a view to earlier dialogue with manufacturers on improving energy efficiency, and possible establishment of efficiency requirements.
- That the efficiency requirements be extended to more of the most important products and appliances used in the trade and service sectors.
- That when setting efficiency requirements for products with high electricity consumption, additional requirements be included on built-in intelligence in order to improve their ability to function in a flexible electricity system.

34 recommendation
That in order to improve the energy efficiency and reduce CO_2 emissions of means of transport:

- The EU aim at further tightening the standards for CO_2 emissions and energy efficiency from 2020.
- The ICAO aim at increasing the energy efficiency of aircraft and at setting standards for alternative fuels.
- The IMO continue to work on energy efficiency improvements in shipping.

35 recommendation
That sustainability criteria be drawn up for all bioenergy used in the EU.

36 recommendation
That Denmark actively support current international initiatives for expansion of international electricity transmission grids, including offshore grids for connecting offshore wind farms. It is central that efforts be coordinated across country borders, so that cost-effective expansion is ensured.

3.6
Reducing greenhouse gas emissions in other sectors than energy

The Climate Commission's analyses show that phasing out fossil fuels in 2050 will only reduce total greenhouse gas emissions by around 75% compared with 1990. Reductions in emissions coming from other sources than burning fossil fuels are a prerequisite, if greenhouse gas emissions are to be reduced by 80-95% relative to 1990.

Other emissions come from several sources, of which agriculture accounts for around half. Other sources include emissions from industrial processes and so-called industrial gases; the offshore sector; CO_2 from incinerating plastic waste; methane and nitrous oxide from effluent and landfilled waste.

Only a limited part of these emissions is covered by climate regulation today: CO_2 emissions from cement production and emissions from the offshore sector are covered by the EU Emission Trading System, while emissions from incinerating plastic waste and methane emissions from gas motors are subject to CO_2 tax. In addition to this, certain uses of the industrial gases (HFC, PFC and SF6) are also subject to taxes. This ensures pricing of about 30% of emissions from the group of other sources.

Industrial gases are also subject to a number of other restrictions. In total, only just under a third of the emissions from the group of other sources are directly subject to climate regulation. In addition to this, is the fact that some of agriculture's emissions of nitrous oxide are limited indirectly through restrictions on use of nitrogen on agricultural land. However, the majority of the non-regulated emissions are not easily measured, which complicates establishing efficient regulatory mechanisms.

Emissions of greenhouse gases from agriculture are expected to fall up to 2050. This is particularly due to expectations for continued significant production efficiency improvements, which will lead to increasing productivity in both arable and livestock farms. However, intensive cultivation of low-lying agricultural land leads to large emissions of CO_2 and nitrous oxide, which could be considerably reduced by returning these areas to nature and/or bioenergy cultivation. At the same time, there are opportunities to produce bioenergy on some of the other environmentally sensitive areas and, by cultivating perennial energy crops, this production will lead to carbon storage in the soil and significant reductions in nitrous oxide emissions. In livestock production, there are possibilities for a number of technologies which reduce emissions of methane and nitrous oxide from management and storage

of manure. Any further cost-effective reductions in emissions from agriculture will require creating new knowledge and developing new technological and biotechnological solutions.

On this basis, the Climate Commission recommends:

37 recommendation
That a detailed analysis be initiated of whether emissions of greenhouse gases outside of the energy sector can be priced to a greater extent than at present. For example, this could be by including emissions in an emissions trading system, or by imposing taxes.

38 recommendation
That reductions of greenhouse gas emissions from stables and manure systems be included as a specific objective in application for environmental approval in connection with extension and conversion of livestock farms.

39 recommendation
That instruments be initiated to ensure that emissions from cultivation and drainage of low-lying land are stopped, for example through a tax corresponding to the associated greenhouse gas emissions.

40 recommendation
That agriculture-related research and development include methods and technologies to reduce emissions of nitrous oxide from utilisation of manure and methane emissions from livestock.

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The Climate Commission's calculations, which, amongst other things, look at various possible price developments for biomass and energy, show that the additional cost of converting to a society without fossil fuels is affordable in overall terms.

4. Effects of conversion to fossil fuel independence

4.1 Economic consequences

Complete conversion of society to green energy will entail a number of economic advantages as well as disadvantages. Substantial investment in energy-efficiency improvements and in a new supply system is required and will lead to large savings in annual fuel expenditure. Both the investments and the savings are uncertain. Therefore, great uncertainty is linked to the total costs, not least when considering the effects from a perspective of 2050.

The Climate Commission's calculations, which, amongst other things, consider at various possible price developments for biomass and energy, show that the additional cost of converting to a society without fossil fuels is affordable in overall terms. However, this is subject to the considerable uncertainty linked to an estimate of societal costs. Thus, conversion is not synonymous with great loss of welfare. This is partly a result of the strong upward

trend in energy prices which will, in any event, occur in the period up to 2050.

The long-term additional costs, measured in terms of loss of welfare, of realising an ambition of becoming fossil fuel independent, are assessed in overall terms to be in the order of 0.5% of Denmark's GDP in 2050, when including the derived effects on the Danish economy. This is an expression of the additional costs which are imposed on society in the scenario of the future without fossil fuels, relative to the reference scenario with continued use of fossil fuels (see box). The additional costs are to be understood in the context of the fact that considerable economic growth is assumed, which means GDP will more than double by 2050.

By far the majority of the additional costs are linked to conversion of the transport sector.

If the rest of the world implements an ambitious climate policy, this would be expected to lead to relatively lower oil and gas prices than in the case of an unambitious policy, because demand will fall. On the other hand, it must be expected that the price of CO_2 allowances and biomass will be higher if the rest of the world sets ambitious climate targets and, therefore, demands more biomass. In both scenarios, energy prices, including the price of CO_2, are therefore expected to be considerably higher in 2050 than they are today. This means the overall socio-economic effect in Denmark will not vary substantially between the two scenaria.

Box 4.1: Assumptions behind the calculation of costs

Development:

In order to be able to assess the additional costs of reaching the goal of fossil fuel independence, it is necessary to define a reference.

The reference scenario is a hypothetical scenario describing how developments could turn out, if the goal to assess costs against had not been set. The choice of reference, thus, helps to determine the calculation of additional costs. Such a scenario is obviously difficult to define 40 years ahead but the main idea of the Commission's reference scenario is that it represents a projection of the historical trends.

The reference scenario is compared to a future scenario. The ***future scenario*** of the Climate Commission means a scenario running from today to 2050, which includes initiatives that realise the objective of fossil fuel independence.

Two parallel future and reference scenaria have been compared. One where the rest of the world carries out an ambitious climate policy, and one with unambitious international framework conditions. Each future scenario has, therefore, a comparable reference scenario with the same assumptions about the rest of the world.

Economic growth:

The Danish Commission on Climate Change Policy has used the Danish Ministry of Finance's long-term economic forecast, which from 2008-2050 shows an average annual growth of 1.72% in GDP, which means that GDP will more than double up to 2050. The assumption for economic growth is relatively optimistic and therefore implies relatively strong growth in demand for energy services in both the reference scenario and the future scenario.

Fuel and CO_2 prices in 2050:

	Scenario with ambitious framework conditions	Scenario with unambitious framework conditions
Gas oil (DKK/GJ)	110	164
Natural gas (DKK/GJ)	62	84
Coal (DKK/GJ)	13	24
Bioenergy (wood chips) (DKK/GJ	123	66
CO_2 (DKK/tonne)	1.150	380

It may seem surprising that total phase out of the use of oil, gas and coal will not involve large costs for society in the long term. However, the reason is bound up with several central conditions, which are also important in the overall strategy:

- The conversion will take place gradually over a long period of time, so that account can be taken of fully exploiting the existing capital stock. On the other hand, it is also essential that conversion be initiated now, due to the magnitude of the required conversion of our energy system.

- Increased global demand for energy will make the alternative to green energy still more expensive. The price of oil, gas and coal will increase up to 2050 as the world's energy needs increase significantly. At the same time, technological development will gradually make green energy more competitive.

- Climate targets will cost if we do not convert. If, and when, Denmark is to live up to international targets, e.g. for a reduction of greenhouse gases by 80%-95%, the costs will be considerable, if a phase-out of fossil fuels has not been carried out. This will mean that Denmark will have to buy allowances and credits from other countries to realise the target.

As mentioned above, the calculations of socio-economic effects involve a great deal of uncertainty, and there are a number of effects which it has not been possible to put a figure on in such a long-term calculation. However, the uncertainty works both ways. The various technologies and systems can become more expensive than assumed up to 2050, or they can become cheaper. The same applies to the price of energy and the price of CO_2 allowances. Amongst other things, price development will depend on what other countries do up to 2050. Under the various changes to preconditions upon which the Climate Commission has made its calculations, there are only minor overall economic effects of conversion. The various uncertainties and effects point in opposing directions and there is no reason to doubt the fundamental conclusion that costs are limited.

In general, the calculations do not include costs of the instruments necessary to realise a future without fossil fuels. This is due to the fact that it is impossible to identify today the exact instruments

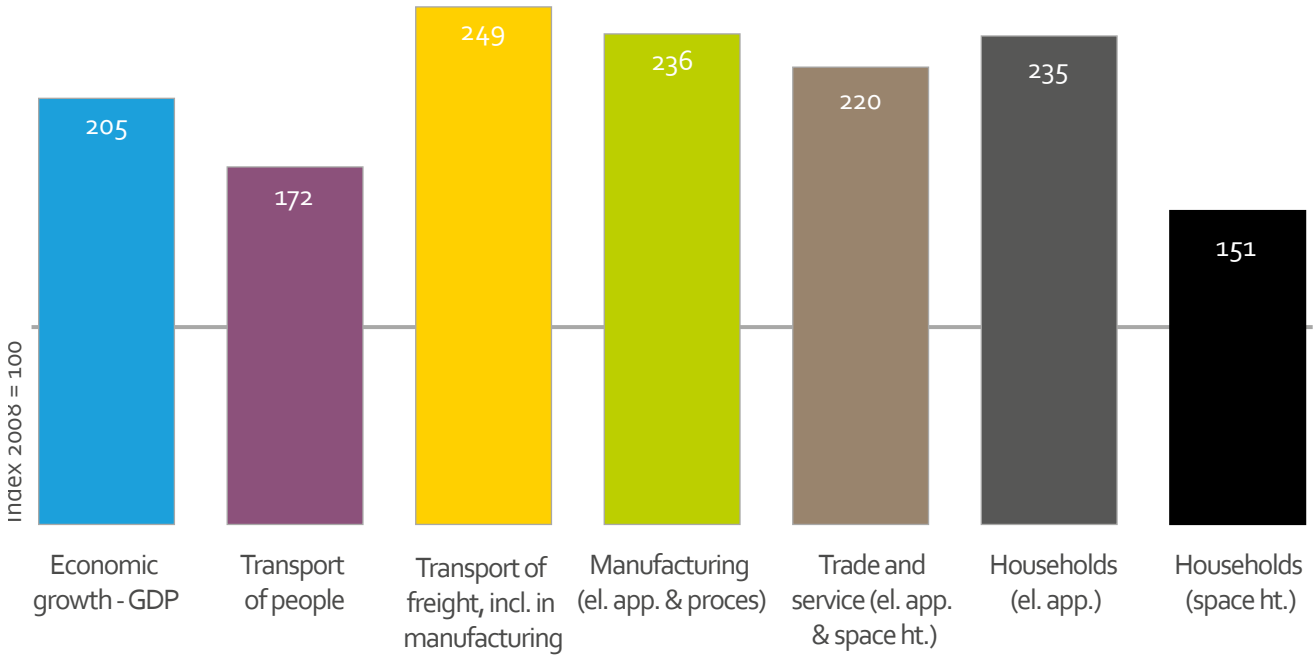

Figure 4.1: Growth in energy services and GDP relative to 2008 (2008 = 100)

that will have to be used, for example in the year 2048. Furthermore, uncertainty about technological development is simply too great to include in the model.

The economic development will involve increased demand for energy services, as can be seen in figure 4.1. It is assumed that industrial production (measured as production value) is about 2.3-times greater in 2050 than today, that the heated area increases by about 50%, and that passenger transport increases by about 75% compared to current levels. Growth in energy services reflects the fact that in 2050 Danish society is expected to be much wealthier than it is today.

The considerable improvements in energy efficiency mean that growth in demand for energy services

is compensated for by lower consumption of energy. In the scenario of the future with an ambitious world, energy consumption by the different sectors will fall by 2050 by about 20% compared with 2008, where in the corresponding reference scenario it increases by about 10%. Conversion of a large amount of passenger transport to electric cars will contribute significantly to this efficiency improvement, as electric motors are considerably more energy-efficient than internal combustion motors.

Over time, energy costs are expected to account for a falling share of GDP, despite rising energy prices and rising needs for energy services. This is due to the fact that there will be many efficiency improvements and continued growth throughout the economy.

4.2
Increased investment but lower fuel costs

A complete conversion of the Danish energy system will require substantial investment. This applies both to the overall infrastructure and the many new energy technologies from heat pumps to electric cars and energy-efficient equipment. Increasing energy prices will, in themselves, make it attractive to move costs of producing energy services from energy to capital stock and, in a fossil fuel-independent future, investment costs for energy technology will dominate, while running costs of energy will be limited.

The largest investments are expected to be:

- Conversion to electric cars in the transport area
- Expansion of offshore wind turbines
- Heat pumps for both individual heating solutions and district heating
- Energy renovation of buildings
- Expansion of the electricity infrastructure.

While investments in energy supply will be made by energy companies, which will have their investments written off through consumer payments for electricity and district heating, a large number of the investments necessary in buildings and in the transport sector will have to be met by individual households which, in return, will reap lower annual fuel costs. The same applies for investments by the business community in energy-efficient equipment etc.

Increased investments are compensated for by lower expenditure on fossil fuels and CO_2 reductions, which are expected to increase significantly in price in the future.

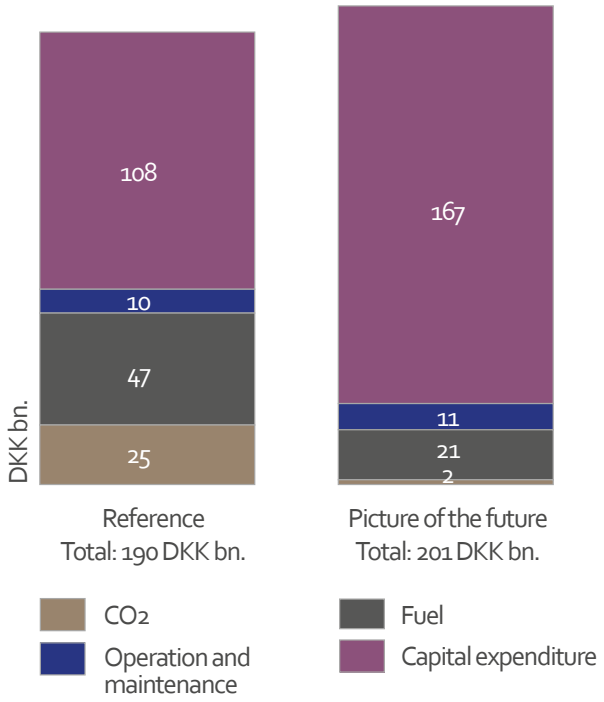

Figure 4.2: Societal costs of the energy system and energy efficiency improvements in 2050 (ambitious scenario of the future)

In a society based on fossil fuels, the price of future energy services will, therefore, be vulnerable to fluctuations in the price of oil, gas and coal. In a future without dependence on fossil fuels, on the other hand, the price of energy services will more

depend on capital costs, including interest rates, how successful research and innovation are in developing cheaper and better technologies, and the price of biomass.

4.3
Business economic effects

Converting to green energy will have various business economic effects. The most important effects include expenditure on energy consumption and investment needs, as well as the opportunity to exploit new technology.

For businesses as a whole, costs of energy amount to around 4% of production value. Therefore, energy costs for, by far, the majority of businesses are relatively limited but for some individual businesses, energy costs are significantly greater.

With these modest energy costs, most sectors will not experience any significant immediate impacts on their competitiveness as a result of converting the energy system. And with a long-term stable development towards a society independent of fossil fuels, any costs there may be will probably be reflected in pay levels so, at national level, there will not be any distortion of overall competitiveness. Of course, this does not exclude the possibility that individual sectors will see more dramatic effects.

As mentioned, the price of energy is expected to rise, but this will also be the case in a scenario where fossil fuels are still being used. At the same time, improvements in energy efficiency will reduce energy consumption. Overall, it is expected that energy expenses will represent a declining percentage of corporate costs up to 2050.

Denmark currently has a number of strongholds within green technology but a number of other countries are also investing heavily in this area. Investment in conversion of the Danish energy system to green energy will help the Danish business community to retain and develop strongholds which will be in great demand globally.

4.4
Costs for Danes

In a future independent of fossil fuels, the energy costs of private households will primarily be linked to electricity consumption, heating consumption, and - in situations where the electric car does not

become the dominant solution - to biofuels. We will see a significant technological development up to 2050 that will make the energy consumption far more efficient, but the price consumers will have to pay for a unit of energy is expected to increase. This will also apply in the transition phase, partly as a result of increases prices of fossil fuels and CO_2 emissions.

Recommendations from the Climate Commission will directly impact the energy prices consumers have to pay in two areas: partly the tax on fossil fuels and the user-financed support for renewable energy, which will mean increases in the price of electricity. The increase in the price of electricity for consumers will, however, be counteracted in part by a drop in the market price due to expansion of offshore wind turbines etc.

During the conversion period, the tax on fossil fuels will involve increasing prices of electricity, heat and transport fuels etc., but the direct costs for private households will be gradually compensated for by energy efficiency improvements and conversion to renewable energy.

In 2020, the proposed tax rate of DKK 20 per GJ will mean a price increase of DKK 0.82 per litre of petrol[18], for example, and about DKK 0.90 per litre of heating oil. Subsidising the recommended expansion of wind power is deemed to imply an increase in the price of electricity paid by consumers of about DKK 0.06 per kWh in 2020. In comparison, prices were just over DKK 10 per litre petrol in 2008, just over DKK 9 per litre heating oil, and the price of electricity was just over DKK 2 per kWh.

In the long term in 2050, conversion to green energy is likely to mean that electricity will cost around DKK 0.1 per kWh[19] more than it would otherwise. This assumes that, as at present, subsidies for renewable energy in the electricity sector are financed by electricity consumers. The increase in the price of electricity should be considered in the context of the fact that the price (in the reference scenario) is likely to increase to about DKK 2.5 per kWh in 2050.

As energy-related expenditure accounts for a greater proportion of the overall budget for low-income families, increased expenditure on energy will inpact these families harder, all else being equal.

The following box shows the financial consequences for an example family. It should be stressed that

Example of the financial consequences for a family in 2020 and in 2050

As an illustration, the energy expenditure for an example family has been calculated. The example family lives in a 150 m² house, which is today heated by natural gas. The house has average insulation, the family has an electricity consumption of 4,000 kWh/year, and a car with an annual mileage of 18,000 km. and average petrol consumption of 16 km/l.

In 2008, the family's natural gas bill was DKK 15,650 and the electricity bill was DKK 18,100. Furthermore, the family spent almost DKK 12,000 on petrol, in addition to DKK 31,000 on depreciation, tax, running expenses and maintenance for the car. Total: DKK 66,750

In 2020, the tax on fossil fuels will affect the price the family pays for natural gas and petrol. Moreover, the price of electricity will have increased due to the fact that costs of subsidies to expand wind power will be imposed on electricity consumers. It is assumed that the family has not invested in a new heating system, better insulation or a new car. Their energy consumption is therefore the same as in 2008.

The price increases applicable to the tax on fossil fuels and expansion of wind power cost the family an extra almost DKK 1,900 for natural gas, almost DKK 200 for electricity and around DKK 900 for petrol[1]. The majority of the extra costs for the family arise from the tax on fossil fuels and will, therefore, go to the state coffers.

Up to 2050, the family changes the natural-gas installation to a heat pump, they insulate their house and replace their car with an electric car. Despite more appliances in their house, electricity consumption remains almost constant (4,300 kWh/year).

In 2050, the family, therefore pays around DKK 7,200 for electricity consumption by the heat pump and around DKK 11,600 for other electricity consumption. The family also spends around DKK 5,400 for electricity for their electric car.

In total, in 2050 the family meet their demand for energy services with a lower annual energy bill. However, initiatives for energy-efficiency improvement and conversion mean increasing investment costs. When these are included as an annualised cost with an interest rate of 5%, expenditure increases to a level comparable with 2008.

With extra investment in the heat pump and extra insulation, the total heating costs are around DKK 12,200, costs of electrical appliances are around DKK 11,600, while the electric car, including depreciation, car tax, running costs and maintenance costs the family DKK 43,300 per year. Total: DKK 67.100 kr.[2]

The costs of electrical appliances are somewhat higher than in 2008, although far from corresponding to the much greater use assumed from 2008-2050. The family's heating costs fall, while transport costs only increase moderately. The very modest additional transport costs should be seen in the context that, with the calculation assumptions applied, the state covers some of the costs via reduced energy taxes corresponding to around DKK 3,000 and that the family's mileage is assumed to remain the same.

1) Calculations for 2020 only include the effect of the proposed instruments. Tax increases from the Spring Package 2.0 have not been included, neither have price changes due to developments in the framework conditions up to 2020.

2) Calculations for 2050 include electricity tax increases from the Spring Package 2.0. Registration tax for the electric car is assumed to be the same as the 2008 car tax.

this type of calculation must be based on a large number of assumptions and, therefore, should not be perceived as a complete picture, nor as an average; it is merely an example.

4.5
Effect on public finances

Achieving the objective of fossil fuel independence is expected to result in public revenue losses with the current tax regulations. This is reflected in the energy taxes, where today renewable energy is exempt from energy tax except for use of biofuel for transport. Conversion will mean loss of revenues from the use of fossil fuels but, on the other hand, it will mean some increase in revenues from expected increased electricity consumption and increased consumption of biofuels. Furthermore, the conversion will potentially influence revenues from car registration taxes etc.

In relation to GDP, public revenues from energy taxes up to 2050 will be reduced to about half, i.e. about 1.1%-1.2% of GDP in 2050. An important part of this reduction in revenues will also take place without the conversion to fossil fuel independence. This is because energy consumption is expected to become more efficient in line with, e.g. technological developments. GDP up to 2050 is, thus, expected to grow faster than energy consumption. In terms of current prices, revenues from energy taxes will be almost unchanged in 2050 compared to today.

If the Climate Commission's recommendations are followed that the CO_2 tax be regularly adjusted to correspond with the international CO_2 price and that a tax on fossil fuels be implemented, the public purse will not be burdened up to 2050.

Even conversion to fossil fuel independence will mean losses in revenues from energy taxes in 2050 which, at current prices, will amount to about DKK 10 bn., corresponding to 0.3% of GDP in 2050. In addition to this come potential impacts of revenues from car taxes, as well as costs linked to energy consumption in public buildings etc, just as subsidies for renewable energy are assumed to be paid by users. Up to 2050, however, it is expected that the tax system will develop in any case and it should be noted that the basic tax base, i.e. transport and heating consumption, etc., will still be present. There will, therefore, be good opportunities to achieve unchanged revenue levels in 2050.

4.6
Effects on the environment and health

The Danish Commission on Climate Change Policy has not analysed the effects of a conversion to green energy on the environment, health and other areas, but notes that, in addition to reductions in CO_2 emissions, there will generally be a number of positive effects on the environment from the lower energy consumption and from conversion of energy supply to increased use of renewable energy.

In the transport sector, transition to electric cars will lead to less air and noise pollution which, in particularly densely built-up areas, can have a significant derived effect in improved health and reduced health costs.

In existing buildings, reductions in energy consumption through better insulation, better windows and ventilation with heat recovery will give a better indoor climate with resulting positive effects on health.

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Analyses by the Climate Commission show that conversion of the energy system to being 100% independent of fossil fuels by 2050 is a realistic objective.

5. The way forward

The world is facing two great climate and energy policy challenges: increasingly scarce fossil fuels and the need to reduce emissions of greenhouse gases to alleviate climate change. Converting the Danish energy system to being completely independent of fossil fuels addresses both of these challenges in that just under 80% of Danish greenhouse gas emissions originate from the burning of fossil fuels.

Analyses by the Climate Commission show that conversion of the energy system to being 100% independent of fossil fuels by 2050 is a realistic objective. Socio-economic costs for such a conversion will not be high.

Sooner or later, limited access to fossil fuels will force Denmark to break its dependence upon them. In this context, it is important to note that, in its economic analyses, the Climate Commission has not attempted to value the security of supply that

will be achieved if society becomes independent of fossil fuels. A social development which is no longer dependent on access to imported fossil fuels can, therefore, be considered an additional benefit obtained from an energy system independent of fossil fuels.

If Denmark is looking to break its dependence on fossil fuels before the mid 21st century, the Climate Commission's analyses show that the conversion must start now. Conversion of the energy system to being independent of fossil fuels should be made a national goal. A long-term and stable framework for the conversion process is essential and considerable infrastructure investments in renewable energy are required. A clear goal and a stable framework will mobilise the resources for such investments and all players in society from the government to regions, municipalities, business and the individual citizen will have to contribute to reaching the goal.

The Climate Commission hopes that this report, "Green energy – the road to a Danish energy system without fossil fuels", will be regarded as a solid professional foundation which can support the coming societal debate, and political decisions, on when and how Denmark is to become independent of fossil fuels.

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Annotation

1. IEA, World Energy Outlook 2008.

2. IEA, World Energy Outlook 2009.

3. U.S. Energy Information Administration / International Energy Outlook 2010.

4. BP Statistical Review of World Energy 2010.

5. Danish Energy Agency, 2010.

6. Energy services are defined as the objective of a given type of energy consumption, including consumption of energy to heat buildings, to run electrical appliances, for industrial processes, for propulsion of vehicles, etc.

7. The IEA's "Energy Technology Perspective 2008 figure ES1, page 39, and McKinsey's cost curve (The McKinsey Quarterly, February 2007).

8. The background documentation for the Danish energy policy agreement entered into in February 2008.

9. A number of Danish studies also show that the potential for energy-efficiency improvement is great. For an overview, see "Forsyningssikkerhedsstrategien 2010" (security of supply strategy 2010, only available in Danish).

10. The same method of calculation as in the Danish Energy Statistics will be used.

11. A smart grid is a generic term for a number of elements, which together can create an intelligent electricity system. The electricity grid, communications, IT systems, markets for electricity trading, electricity meters, cut-off possibilities, control and regulation, are all elements in the smart grid concept. A smart grid is therefore not the same as a physical grid.

12. Carbon Capture and Storage (CCS) involves separation and collection of carbon dioxide when burning fuels, then compressing and storing it.

13. Emissions from fossil fuels in 2050 include emissions from the offshore sector and CO_2 from plastics in waste. Emissions from other sources in 2050 include methane and nitrous oxide from burning, emissions of the industrial gases PFC, HFC, SF6, CO_2 from industrial processes, solvents, methane and nitrous oxide from agriculture, methane and nitrous oxide from waste and effluent.

14. 1 GJ corresponds to the energy content in 28 litres of oil.

15. For a new building erected according to the Danish BR2010 requirements.

16. See "Energibesparelser i erhvervslivet" (energy savings in industry) from February 2010 by Dansk Energianalyse A/S and Viegand & Maagøe Aps.

17. PSO is short for "Public Service Obligations". The majority of the PSO payment currently charged to electricity consumers is used to support renewable electricity production.

18. All prices are incl. Danish VAT and in current prices.

19. On the basis of the future scenario with an ambitious world.

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" Green energy – the road to a Danish energy system without fossil fuels",
published by the Danish Commission on Climate Change Policy.

Photo credits: Hans Christian Katberg Olrik Thoft, City of Copenhagen, Colourbox,
Keen Press, and the Danish Energy Agency
Layout and illustrations: Solid Media Solutions
Translation: GlobalDenmark Translations A/S
ISBN www 978-87-7844-880-4
Also available in a printed version ISBN: 978-87-7844-881-1