Future Climate
Engineering Solutions

The IDA Climate Plan 2050

MAIN REPORT

IDA
STRENGTH THROUGH KNOWLEDGE

Cover: Rune.Anders.Lars

Printed: IDA's Print Centre

ISBN: EAN 978-87-87254-27-4

Issued by The Danish Society of Engineers, IDA

August 2009

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The IDA Climate Plan 2050 is the Danish contribution to the international Future Climate project.

A renewable future

The world is standing at a crossroads: we can choose to continue emitting increasing quantities of greenhouse gases, with major climate changes as a consequence, or we can choose to take up the challenge and work for a renewable future. At IDA and in the international engineering project, Future Climate – Engineering Solution, we choose the challenge. We believe in a renewable future where consideration for the globe's climate goes hand in hand with growth and abundance.

Creating a renewable future requires knowledge and action. The IDA Climate Plan 2050, which is based on the expert knowledge and insight of engineers and other specialist groups, shows that Denmark can reduce its greenhouse gas emissions by 90 % by 2050. Denmark must achieve reductions of this magnitude in order to show real co-responsibility towards an increase in mean global temperature of no more than 2 degrees Celsius. The IDA Climate Plan 2050 draws attention to the technologies that are to be developed and the means that are to be implemented in order to be able to meet the 2-degree target.

Not only is it beneficial to the climate to implement, but it will also pay for itself in terms of security policy, commercially and economically: Denmark will be able to avoid becoming dependent on oil and gas imports from the Middle East and Russia. It will be possible to multiply the export of Danish energy technologies, and The IDA Climate Plan 2050 is a particularly good socioeconomic operation.

Avoiding climate changes is something we cannot do, however. Now is the time for us to consider the measures that will be initiated and prioritised when the climate changes affect us.

IDA recommends that the government and all Parliamentary parties work towards implementing the incentives and means that are described in The IDA Climate Plan 2050. We also call upon all parties to work towards achieving as ambitious a climate agreement as possible under the auspices of the UN. Ultimately, the political will and society's ability to act that are the crucial factors for a renewable future.

The IDA Climate Plan 2050 is also based on the IDA Energy Plan 2030 and the IDA Green Future sustainability report, and based on contributions and inputs from hundreds of engineers and other specialists. More than 15 conferences and seminars have been held in connection with the work, and IDA's specialist companies have constituted the backbone of this work.

I would like to extend a big thank you to all those who have made specialist contributions towards and offered work capacity for The IDA Climate Plan 2050. The plan represents an impressive breadth of expertise, and I hope it can constitute a valuable contribution to the discussion on how we are going to solve one of the biggest challenges of the 21st Century.

Lars Bytoft

President

The Danish Society of Engineers, IDA

Indholdsfortegnelse

Many good forces behind the IDA Climate Plan 2050

The IDA Climate Plan 2050 builds on IDA Energy Plan 2030 and the IDA sustainability report "Green Future – Steps towards a Sustainable Development", and the overall work is based on the work of six theme groups that originate from IDA's specialist companies. During the process, a number of seminars, conferences and workshops have been held at which individual sectors, technologies, etc. have been presented and discussed. The results of the individual themes have been processed by the project's coordination group that has collated the many threads and has drawn up The IDA Climate Plan 2050 in cooperation with IDA's administration.

The coordination group for the Climate Plan 2050

Hans Jørgen Brodersen (the Society for Technology Analysis and Assessment, STAV), Kurt Emil Eriksen (IDA-BYG, the Society for Construction and Installation Techniques), Lars Bennedsen (IDA Environment), Ane Mollerup (the Society for Risk Assessment, RISK), Michael Søgaard Jørgensen (the Society for Green Technology, SGT), Jakob Christensen (the Society for Rail Transport, JETRA) and Leif Amby (the Mors-Thy Department). IDA Energy, the Danish Maritime Society, the Society for Planning, Roads & Traffic, The E-Group, IDA Process, IDA Production and Logistics and the Danish Society for Materials Testing and Research (DSM), Energy Technical Group, IDA North have also participated in the work.

A special thank you must go to Ida Fabricius (DTU), Hans Otto Kristensen (DTU), Nanna Høgh Nielsen (PH-Consult), Jens Jørgen Linde (PH-Consult), Ole Fritz Adeler (Krüger), Lars Klinge (Comxnet), Thea Drachen, Søren Gabriel (Orbicon), Per Alex Sørensen (Planenergi A/S), Per Nielsen (EMD), Nicolai Kipp (Energinet.dk), Jens Peter Kofoed (AAU), Peter Ahm (PA energy), Flemming Vejby Kristensen (Energimidt), John Bøgild Hansen (Haldor Topsoe), Mogens Mogensen (Risø/DTU), Anders Dyrelund (Rambøll), Mogens Nielsen (Danish District Heating Association), Jan Don Høgh (Københavns Energi), Jesper Magtengaard (Dong Energy), Jan Erik Nielsen (PlanEnergi), Jonas Mills (Danish Construction), Helge Bach Christensen (IDA Energy), Jacob Sørensen, Eskil Thuesen, Ingeborg Callesen (The Society for Green Technology), Anette Christiansen (The Agricultural Council of Denmark), Torben Chrintz (NIRAS), Thorfinn Deleuran (the Society for Green Technology), Rikke Fog-Mills (DTU), Philip Giødesen Lund (DTU), Irene Nicolajsen (The Agricultural Council of Denmark), Michael Tersbøl (The Danish Association for Organic Agriculture), Kaj Jørgensen (Risø/DTU), Peter Buchwald (DSB), Henrik Kragerup (NNE Pharmaplan), Gorm Simonsen, Peter Brønd (IDA Production and Logistics), Bente Hessellund Andersen (NOAH), Thomas Færgeman (Concito), Gilli Trond (Bitland Enterprise) and Jens Astrup Madsen (The Agricultural Council of Denmark). None of these people are held responsible for the content and conclusions of the reports, howeve

Climate Plan 2050 was first presented at a conference on the 11th May 2009, after which there was a 10 day hearing period where all interested parties could submit their comments to the coordination group. The group discussed the 17 hearing statements received and these statements were considered in different ways in the report.

The energy system calculations were undertaken by Assistent professor, PhD Brian Vad Mathiesen, Aalborg University, Professor Henrik Lund, Aalborg University and Senior Researcher Kenneth Karlsson, DTU/Risø.

The overall responsibility for the Future Climate – Engineering Solutions project has been placed in the hands of IDA's Steering Group for Environment, Energy and Climate, consisting of Helle Herk-Hansen, Charles Nielsen, Vilhjálmur Nielsen and the undersigned.

I would like to take this opportunity to thank everyone for their invaluable contributions and inputs. Without you there would be no Climate Plan 2050.

Have a good read!

Søren Skibstrup Eriksen

Chairman of IDA's Steering Group for Environment, Energy and Climate

Introduction

The IDA Climate Plan 2050 is a holistic message on the way in which the Danish climate gas emissions can be reduced by 90 % by 2050 while also improving Denmark's self-sufficiency, economy and developing Danish trade and industry.

The report also contains a number of recommendations on Danish climate policy. The recommendations are key to ensuring that Denmark's greenhouse gas emissions are reduced to a sustainable level and to enabling Denmark to counteract as efficiently and economically as possible the climate changes that have already become a reality.

The report is divided into six chapters that deal with the following sector areas: energy systems and energy production, agriculture, trade and industry, construction, transport and climate adaptation. The individual chapters describe opportunities and challenges by reducing greenhouse gas emissions in the related sectors, the Climate Plan's sector-specific targets and present arguments for these, as well as describing the concrete measures that are necessary to realise the plan.

The report is accompanied by a background report containing analyses of technical energy systems and socioeconomic impact analyses. The material also includes a professional report describing the energy-saving potential in industry, and the overall materials finally include 4 professional memoranda and an IDA analysis. Together, the reports and memoranda constitute The IDA Climate Plan 2050.

2-degree target

The IDA Climate Plan 2050 is a part of the Future Climate – Engineering Solutions project in which 13 engineering organisations worldwide are working together to offer national solutions for the way in which greenhouse gas emissions can be reduced so that the global mean temperature rises by no more than 2 degrees Celsius.

IPCC's Fourth Assessment Report from 2007 shows that if the temperature rises by no more than 2-2.4 degrees Celsius, the total concentration of greenhouse gases in the atmosphere will be kept between 445 and 490 ppm (CO_2 equivalents). As the concentration of greenhouse gases in the atmosphere reached 445 ppm (CO_2 equivalents) already in 2005, IPCC has estimated that greenhouse gas emissions must culminate as soon as possible and no later than 2015, and that greenhouse gas emissions must be reduced by 50-85 % by 2050 compared with the year 2000.

At IDA, we take it for granted that we, the inhabitants of the well-to-do OECD countries, cannot in the long-run sustain greater greenhouse gas emissions per inhabitant than inhabitants of other parts of the world. Since Denmark's greenhouse gas emissions are approximately double those of the average world citizen, this means that we as a country must undertake a substantial reduction commitment. The IDA Climate Plan 2050 has therefore aimed to show that it is technologically and economically possible to reduce greenhouse gases emissions in Denmark by 90 %. This corresponds to each Dane contributing no more than around 1.3 tonnes CO_2 equivalents by 2050.

Such a drastic reduction in the emission of climate gases will be of substantial significance to the way in which we organise Danish society and in particular the Danish energy system. This objective cannot therefore stand alone, and the following objectives have constituted the framework for the development of The IDA Climate Plan 2050:

- To reduce greenhouse gas emissions by 90 % by 2050.
- To maintain Denmark's energy self-sufficiency.
- To develop Denmark's commercial position in the climate and energy field.
- To develop the Danish economy and affluence.

A 40 year perspective

IDA's Climate Plan 2050 works with a perspective of 40 years. Working on scenarios with such a long-term perspective involves a range of uncertainties that must be considered.

One central area in the climate plan concerns the maturity and development of technologies. Based on the knowledge of technical possibilities, actual production plans and the costs of development, experts have given professional advice on how a great extent of different technologies can be expected to contribute to reducing greenhouse gases. For time perspectives of 10 to 15 years, this evaluation is performed on a relatively well-known basis, however for longer time perspectives there is the potential for quite major changes. For example, many energy systems have lifetimes that are considerably shorter than 40 years and in addition innovative breakthroughs within materials and CCS technologies will have an impact on actual development.

With regards to the 40-year time perspective, this room for change means that there is the potential for great changes if we are prepared for them. On the other hand, it should be noted that IDA's Climate Plan 2050 is the engineers' best proposal (with our current knowledge) of Denmark's climate future, a future in which workplaces, energy savings and reductions in greenhouse gas emissions work together in the most socially optimal way. An important goal in the work has therefore been to demonstrate that there is a technological and financial way forward that is different to the one that Denmark is currently following.

IDA's Climate Plan 2050 works with scenarios for the years 2015, 2030 and 2050. The scenarios are compared with the reference from the Danish Energy Agency. The most significant difference between the reference years and IDA's Climate Plan 2050 are the major constructions costs in the climate plan compared with the reference's major fuel costs. The comparison is therefore sensitive to both changes in fuel prices and changes in interest and investment requirements. A sensitivity analysis is therefore performed in which the construction system costs have been raised by 50 percent as well as a calculation with a socio-economic real interest rate of 6 percent rather than 3 percent. The results of the sensitivity analyses are evident from the Background Report to IDA's Climate Plan 2050, from which it can be seen that IDA 2015 and IDA 2030 have the lowest socio-economic costs under these conditions. It should however be noted that this applies to the entire package. In the event that the interest rate or investment scope is changed, several of the individual measures will be socio-economically negative.

A national plan seen in an international perspective

IDA's Climate Plan 2050 has a national basis both in the work to establish future energy scenarios and where means are proposed. This is due to several factors.

In relation to the work on scenarios for the future of Denmark's energy and emission, it must be emphasized that although the analyses occur within a closed energy system without trade, this does not mean electricity will not be traded in the future. This has only been performed with a view to the fact that the energy systems in the climate plan are not obliged to export or close down wind turbines etc. in certain situations. Any changes in the capacity of electricity trading will not be crucial to the comparison. The major significant difference between the reference years and IDA's Climate Plan 2050 is characterized by the fact the climate plan contains major construction costs, whilst the reference has major fuel costs. The comparison is therefore particularly sensitive to both changes in fuel prices and changes in interest and investment requirements.

There are also other areas in the climate plan that have a significant international dimension, for example biomass. A 100 percent renewable energy system has been constructed in IDA's Climate Plan that can potentially be maintained on national biomass resources. There is no goal in the climate plan to prevent a trade in biomass. However on a national basis, IDA's Climate Plan gives the opportunity for Denmark to be independent from importing biomass when we have insufficient fossil resources remaining in the North Sea.

EU regulation plays a significant role in all the sectors that are covered by the climate plan: agriculture, transport, energy etc. Nevertheless, analysis and recommendations relating to EU regulation and support schemes are not included in IDA's Climate Plan 2050. This does not suggest that they are not relevant but is an expression of limitations when working on the climate plan.

Summary

The IDA Climate Plan 2050 describes the way in which Denmark can reduce its greenhouse gas emissions by 90 %, including energysupply, agriculture and industry in the first half of the 21st Century. IDA's Climate Plan 2050 is a scenario in which Denmark takes a marked step away from fossil fuel based energy to 100 percent renewable energy. This requires a range of changes not only in the energy system but also in buildings, in transport routes, eating habits and within research and development and not least within industry. The plan is a simultaneous description of the way in which investments in technology and infrastructure can develop Denmark into a modern society based on renewable energy sources and efficient utilisation of all available resources. A society in which growth in trade and welfare can take place by interacting with a sustainable environment.

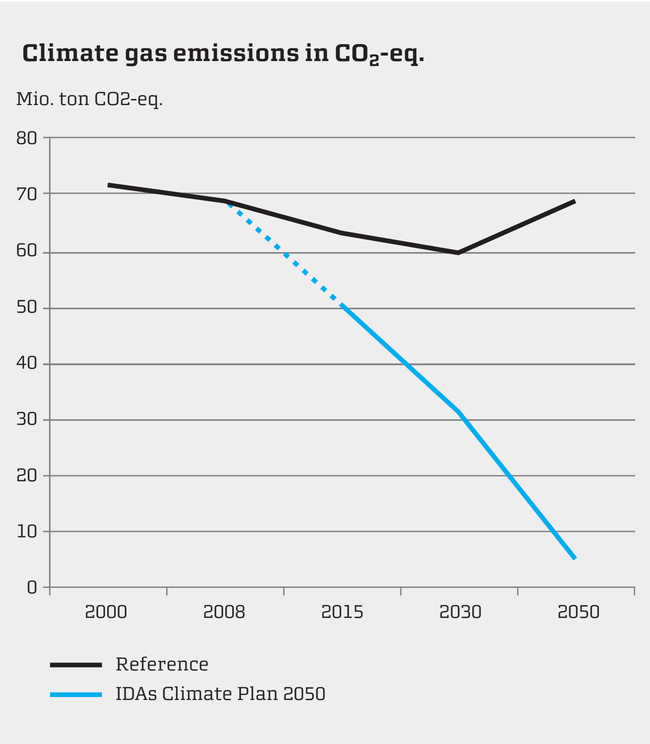


Figure 1: Denmark's greenhouse gas emissions – The Danish Energy Agency's reference and The IDA Climate Plan 2050

Over the past 20 years, Denmark has experienced relatively stable greenhouse gas emissions. The IDA Climate Plan 2050 wants to speed up the Danish reductions (➜ see figure 1). This is absolutely necessary if we want to take a fair share of the reductions that need to take place on a global scale. There are also major economic, security policy and commercial advantages to be gained from implementing The IDA Climate Plan 2050.

Socioeconomic calculations show that a reorganisation of the energy supply will lead to savings of DKK 9 billion as early as 2015 (➜ see figure 2). The savings will rise up until 2050 so that they amount to DKK 25 billion per year. It must be emphasised that there is considerable uncertainty surrounding the calculations for both 2030 and 2050.

In commercial terms, major advantages will be gained from implementing The IDA Climate Plan 2050. Efficient and renewable energy technologies are Denmark's fastest growing export goods, and the realisation of The IDA Climate Plan 2050 and its associated recommendations may create potential for an increase in the export of energy technologies.

INVESTMENTS IN A SUSTAINABLE FUTURE

The IDA Climate Plan 2050 is based on a strategy whereby Denmark makes ambitious investments in developing the Danish energy and infrastructure, and in the longer term enjoys the benefits of the investment. The starting point is that it will become more and more expensive to reduce greenhouse gas emissions for each year that passes before Denmark seriously begins its investments and introduces the necessary measures. Postponing the necessary reorganisation will at the same time reduce Denmark's opportunities as a commercially pioneering country.

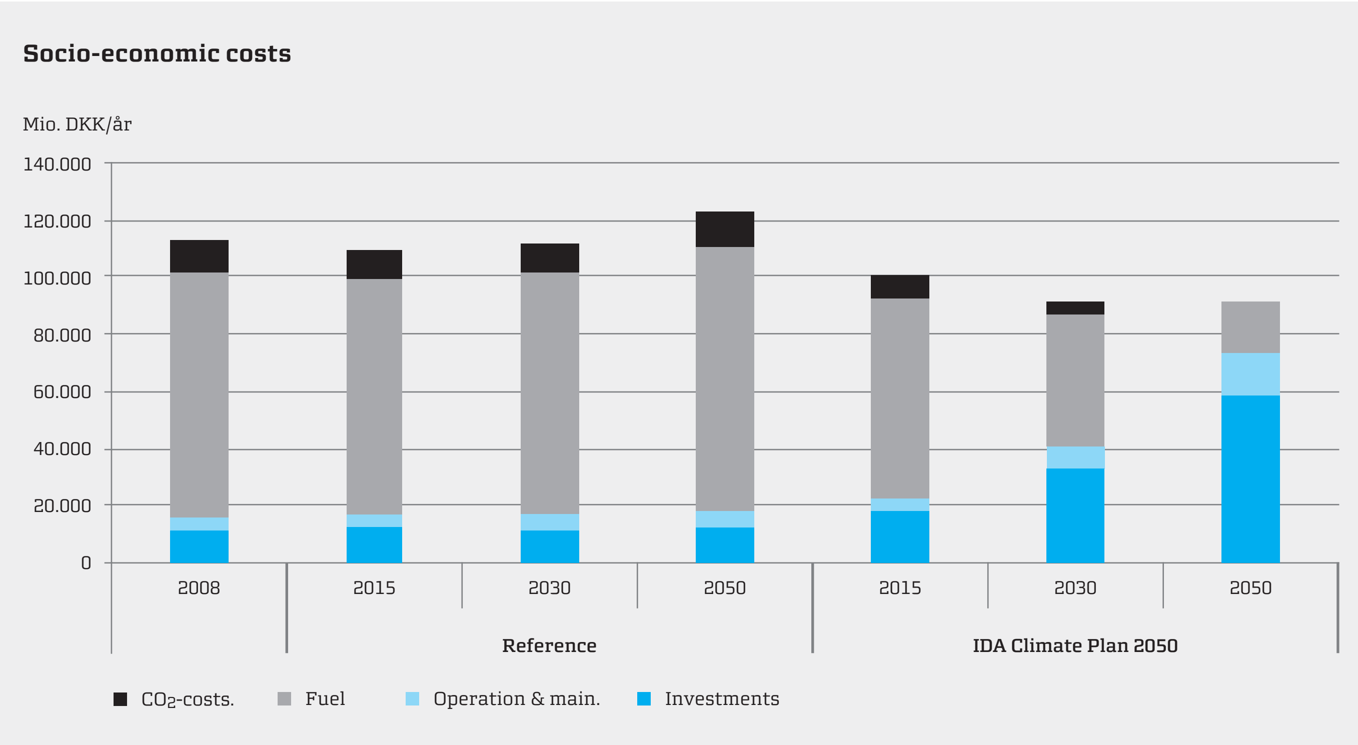


Figure 2: Socioeconomic expenses for the Danish Energy Agency's projections and for The IDA Climate Plan 2050

IDA's Climate Plan 2050 sets the scene for a range of major investments within all sectors. The socio-economic calculations that are performed in connection with the climate plan indicate that it will be worthwhile for Denmark to invest in such investments. However this type of calculations naturally includes a range of uncertainties relating to energy prices, general economic development etc.

A 100 % RENEWABLE ENERGY SYSTEM

Wind turbines and biomass constitute the backbone of The IDA Climate Plan 2050 that is based solely upon renewable energy. In 2050, Danish greenhouse gas emissions will originate largely from agricultural production and the emissions that are linked with the Danish people's food consumption.

In The IDA Climate Plan 2050, 60-65 % of the electricity production is based on wind power. The majority of the combined heat and power production is based on biomass and waste and thus constitutes the stabilising element of an otherwise fluctuating energy production. The remaining electricity and combined heat and power production are based on solar cells, wave power, geothermics and solar heat.

Such a comprehensive development of renewable energy sources requires the initiation of a number of consecutive initiatives. It will be necessary to increase research and development within the critical technologies. It is particularly important to also provide necessary opportunities to test and demonstrate the technologies and to establish innovation markets and feed-in tariffs that can support a market characteristic following the new technologies. In the windmill area, it is also important to draw up a long-term development plan for off-shore and on-shore wind turbines as soon as possible.

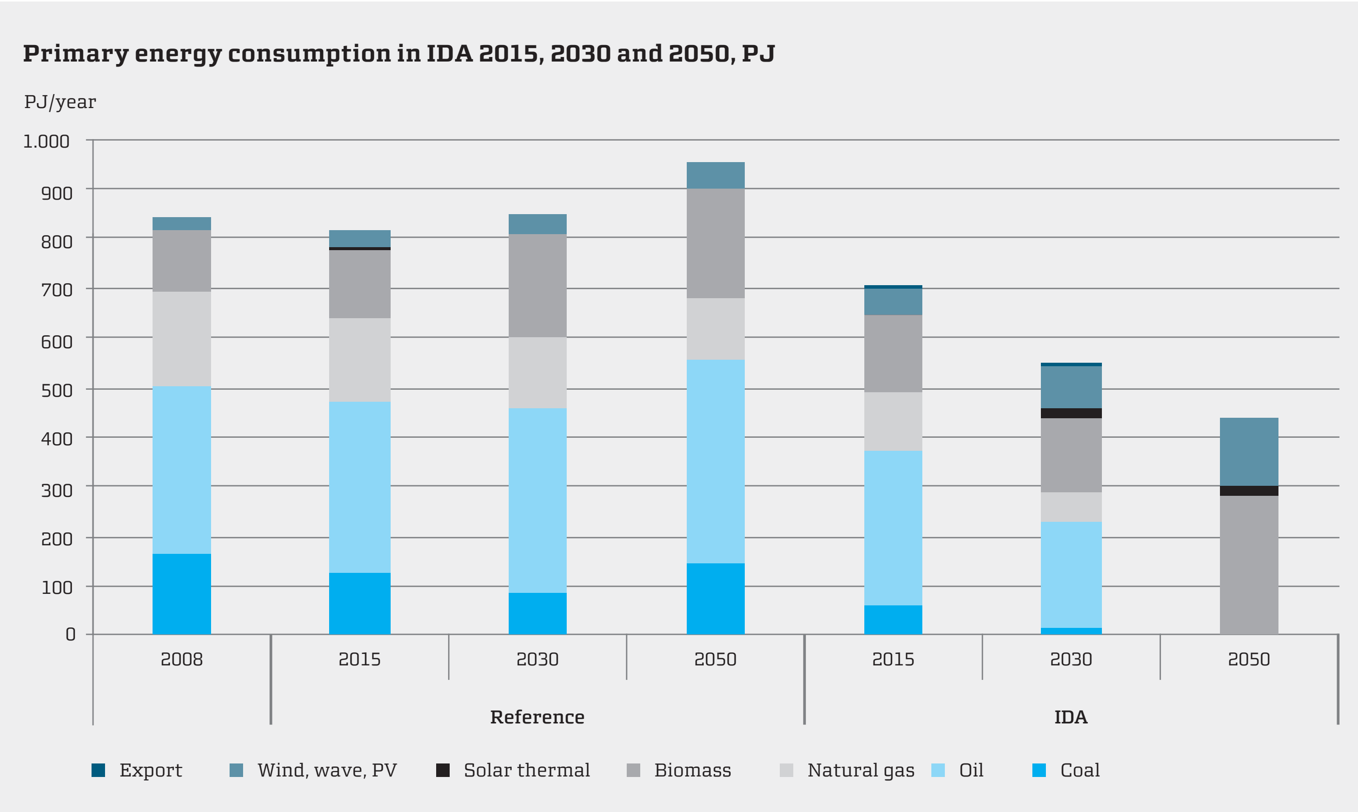


Figure 3: The energy composition in the Danish Energy Agency's projections and in The IDA Climate Plan 2050 respectively

AN EFFICIENT AND FLEXIBLE ENERGY SYSTEM

The many renewable energy sources set substantial requirements for a flexible and efficient energy system whereby the energy consumption can vary and can change smoothly between electricity and heat production. Key factors of the plan are fuel cell-based combined heat and power plants, heat pumps and batteries in electric cars that support the storage of energy and alternating electricity and heat production. After 2030 there will also be a need for electrolysis plants. New research, development and demonstration projects within these technologies and the interplay between them will be crucial to the development of the system.

In order to ensure flexible energy consumption, simultaneous development of communication and reconciliation systems should take place, enabling the energy consumers to gain access to constantly varying electricity and heating prices. This will be the first step towards all consumer products and energy meters being fitted with inbuilt units that can be set to automatically turn on and off according to the price level.

Continued development and expansion of district heating are absolutely crucial to the ability to increase the efficiency of the energy system. The plan looks at 70 % of all houses being covered by district heating and a reorganisation of district heating that is run at a low temperature. A condition for this is that both national and local strategic heating plans are developed.

ENERGY SAVINGS AND EFFICIENCY IMPROVEMENTS ARE KEY

The IDA Climate Plan 2050 emphasises cost-effective solutions, which mean that energy streamlining and more efficient utilisation of nature's resources constitute a cornerstone of the plan. All in all, the plan looks at the Danish energy consumption being reduced to 707 PJ by 2015, to around 556 PJ by 2030 and to around 442 PJ by 2050.

Trade and industry currently represent approximately 1/3 of Denmark's total energy consumption, and this is where the most profitable energy savings are to be found. The plan looks at implementing all energy-saving schemes in trade and industry with a repayment period up to 7,5 years. This means that trade and industry's energy consumption can be reduced by more than Ð by 2015, something that is linked with substantial business and socioeconomic gains.

The technologies to implement the energy saving measures are currently in place. The challenge is to speed up industry. IDA recommends that an energy-saving fund be used to offer advice and significant grants for investments in energy-optimised process technology. Public requirements will also be necessary, stating that businesses must optimise their energy consumption by using the latest technology in both operations and new plants.

HOMES WITH A MINIMUM ENERGY CONSUMPTION AND RENEWABLE ENERGY SUPPLY

The IDA Climate Plan 2050 also looks at the energy consumption in buildings and homes being markedly reduced in the forthcoming years, and at making the mass housing CO_2 neutral through a combination of energy savings, the integration of renewable energy and the development of district heating based on renewable energy. The energy consumption in buildings and homes currently constitutes more than 40 % of the total Danish energy consumption.

Denmark currently has the world's most stringent energy requirements for buildings, but it will still be necessary to sharpen those requirements. The first houses that do not use energy have already been erected, and it is recommended that requirements be introduced at this early stage into the building regulations stating that houses erected after 2020 must be erected in accordance with the Zero Emission Housing standard.

However, the greatest savings potential is in the existing mass housing, and even by 2050, the majority of the mass housing will consist of homes that were erected before 2009. The Climate Plan looks at a substantial reduction in energy consumption through continuous renovation up to 2020 and at bringing 75 % of the poorest insulated structures up to the current building regulation requirements. In 2030 the energy consumption in buildings will be halved compared to the present level due to futher reductions.

Many energy savings are privately financially profitable and in order to support renovation of private buildings it will be necessary to prepare a long-term plan for increasing energy efficiency and for state funds to be earmarked that will speed up energy savings in private residences and in non-profit residential buildings. It is essential to discuss which financial initiatives will be implemented and to consider whether funds from the National Building Fund should be used within the non-profit sector.

It is at the same time necessary to fortify research and development in new energy saving materials and to further improve directions and guidelines for workmen and private persons, and to establish overall better information in the field.

In combination with more leading edge buildings, these initiatives can simultaneously give Danish engineers, architects, construction businesses and energy technologies good opportunities to come to the forefront of the international construction materials market.

REDUCTIONS IN TRANSPORTATION EMISSIONS WILL NOT HAPPEN OF THEIR OWN ACCORD

Significant reduction in transportation emissions vil demand, that electricity becomes the general energy source for transportation. In practice this means more rail and electric cars.

Transportation is the sector in which the least is currently being done to reduce greenhouse gas emissions. Transportation represents around one quarter of the Danish greenhouse gas emissions and, at a time when emission reductions are absolutely necessary to keep Denmark on the trail of a non-fossil-based economy, the emissions from transportation are still on the increase.

A significant reduction in transportation climate emissions therefore means that all known tools and technologies must be brought into play. This includes reducing the climate emissions from individual forms of transport, changing the transportation work over to the forms of transport that have the least impact on the climate, and planning and urban densification that can reduce the transportation work as such.

For example, the Climate Plan looks at a comprehensive replacement of the Danish vehicle fleet with electric cars up towards 2050. This should be done in parallel with developments in the electricity sector with the expansion of wind turbines.

The Climate Plan 2050 sets the stage for a significant expansion of the rail network, electrification of this and a changeover to private and goods transportation largely by rail. This requires significant investments in the railways as well as a number of initiatives that make the rail both temporal and economically competitive.

CLIMATE-OPTIMISED PRODUCTION AND CONSUMPTION OF FOODS AND BIOMASS

There are good opportunities to reduce the impact on the climate from Danish production and consumption of foods. Climate Plan 2050 looks at reducing CO_2 emissions from agriculture and food production by 9,5 mil. tons by 2050 through climate optimisation of agricultural production, a change in dietary habits with a trend towards lower consumption of dairy and meat products and greater consumption of vegetables and fish, and halving the food waste in households. In addition to this comes a further reduction as a consequence of energy savings in line with other production sectors.

The plan also discusses the idea of agriculture being able to supply steadily increasing quantities of biomass for energy production, among other things by using perennial energy crops and, in the long term, also greater production of biomass-based materials that can be substituted for materials based on fossil energy resources or materials that are very energy-demanding to produce. At the same time the production of marine biomass in the form of algae for both energy and production of substances and materials should be established.

It is thought that Danish agriculture and the sea around Denmark will be able to supply all of the necessary biomass resources so that there is no need to import further biomass. It says that all biomass initiatives must be environmentally assessed from a global lifecycle perspective to ensure that they help to reduce the impact on the climate.

COMMERCIAL POTENTIALS

Implementation of IDA's Climate Plan 2050 will require a range of major investments and will be built on competences and production in Danish businesses. It should be emphasized that this type of quantification is naturally subject to great uncertainty and the calculation should be considered to be an estimate. However systematic input into the climate plan's technologies will significantly increase the potentials for export[1]. This input will occur through investments.

1. When calculating commercial potentials the same method as in the IDA Energy Plan 2030 is applied.

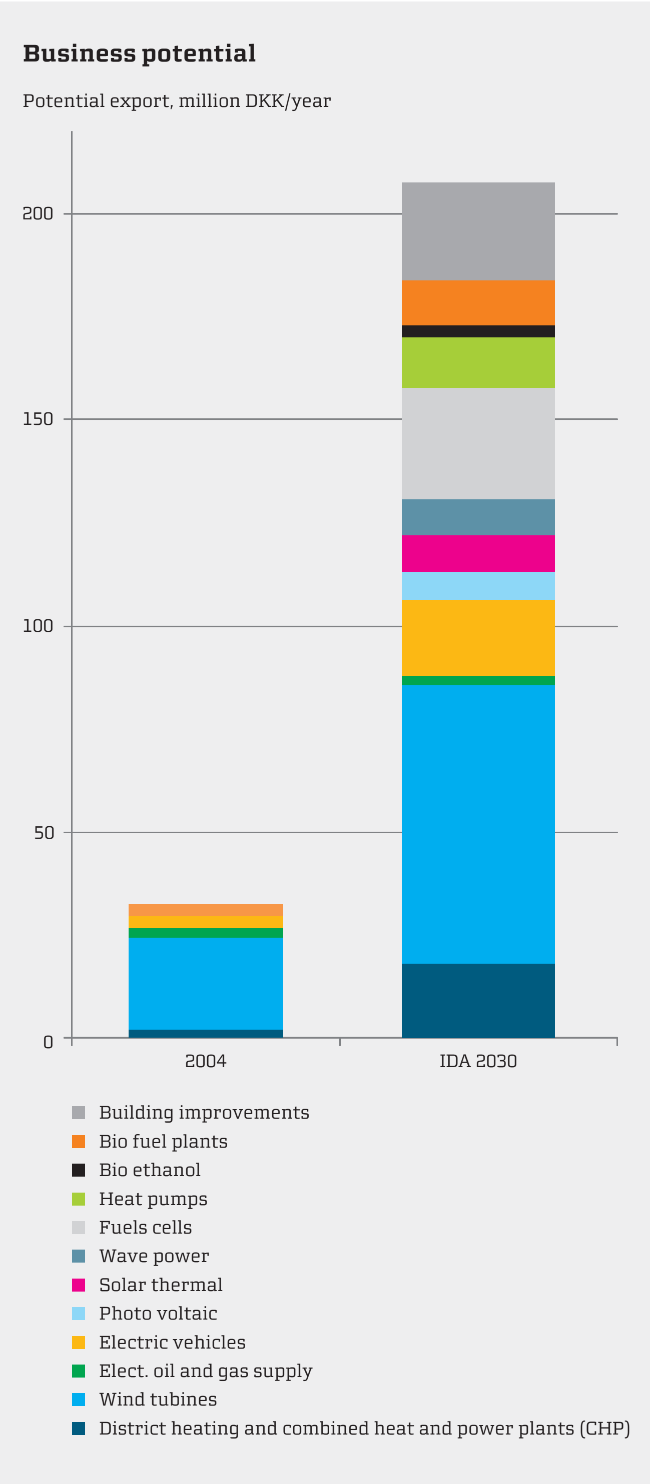


Figure 4: Buiness potential

This relates to total investments in climate related technologies of a total 350 billion kroner until the year 2030. The investments are split between building improvements, the district heating network, cars, biofuel power plants and energy savings[2]. In addition to these investments, the IDA Climate Plan includes investments in a range of supply technologies, e.g. solar thermal systems, additional window power, wave power, solar cells, heat pumps and fuel cells. In all cases this is a question of extra investments compared with the reference. The commercial potentials for IDA's Climate Plan 2050 are illustrated in Figure 4. As can be seen, the IDA Climate Plan is estimated to create the potential for an export of energy technology, which will increase from the current DKK 64 billion in 2008 to over DKK 200 billion /year by 2030.

EFFECTS ON EMPLOYMENT

Implementation of the IDA Climate Plan 2050 must entail the redistribution of costs for energy from the purchase of fossil fuels to capital investments without Danish society being subject to extra energy costs. Everything else being equal, this will lead to increased Danish employment whilst simultaneously improving the balance of payment. This effect will be further increased if the plan is implemented in such a way that the above-mentioned commercial potentials are realized in the form of increased export.

The basis for the calculation of effect on employment is the break down in annual costs for IDA's Climate Plan 2050 compared with the reference. The difference in costs can be divided into investments and operation. IDA's Climate Plan 2050 phases out the costs for purchasing fossil fuels whilst these are increased in the reference. In return the costs for biofuels as well as operation and maintenance are increased in the climate plan more than in the reference. The extra employment in Denmark upon implementation of IDA's Climate Plan 2050 compared with the reference is estimated to be approximately 30-40,000 jobs. In

2. See details on division in the Background Report.

addition to this, up to 200,000 jobs will arise depending on the extent that export is increased, i.e. to how great an extent commercial potential is realized.

CLIMATE ADAPTATION – A NECESSARY INPUT AREA

The IDA Climate Plan 2050 contains not only a plan and recommendations on how greenhouse gas emissions can be reduced, but also the climate adaptations that we certainly need to initiate.

In Denmark over the next 20 years, we can continuously expect longer dry periods, heavier and extreme downpours, more powerful storms and, to a certain extent, a higher water level. This development will continue for the next Century, irrespective of whether or not there is successful reduction in greenhouse gas emissions.

It is thought that the greatest challenges for Denmark are to put in place the administrative frameworks for a climate adaptation input. The technical tools are available, but there is lack of clarity surrounding the delegation of responsibility between citizen, municipality and government. Denmark does have a climate adaptation strategy, but it is not thought that it will make Denmark sufficiently robust in the face of future climate changes.

9 key recommendations

The following nine recommendations are key to being able to realise The IDA Climate Plan 2050, and said measures are necessary if Denmark's greenhouse gas emissions are to be reduced to a sustainable level.

The recommendations express an offensive strategy where society uses substantial investments to readjust and future assure the Danish energy and infrastructure. The plan is based on a number of different tools with emphasis on tightened requirements, innovation and market development plus knowledge accumulation.

The benefit to be gained is a society that uses fewer energy expenses, that is not dependent upon imports from unstable regimes and that will function as a commercial development laboratory for new and efficient technologies.

1. NATIONAL ENERGY-SAVING AGREEMENT

Energy savings and energy streamlining are the most efficient ways of reducing greenhouse gas emissions. Substantial socioeconomic savings are linked with the implementation of energy savings, and there is great potential for growth in employment and trade.

It is recommended that the Danish Parliament's parties enter into a national energy-saving agreement stating that the Danish energy consumption should be reduced by 2 % each year up until 2030. The agreement should cover all energy-consuming sectors and be continuously monitored.

2. ESTABLISHMENT OF A COORDINATED ENERGY-SAVING TRUST

The key word for the Danish energy conservation effort is coordination. The coordination could take place from a new foundation. This trust should take over the commitments and the funds that have been in the Danish Electricity Saving Trust thus far and the energy companies' energy-saving contribution. It must be ensured that knowledge and experiences from the good work of previous years is not lost through amalgamation. The aim is a coordinated and cost-effective energy savings input in all sectors

It is recommended that an energy-saving trust be established with the objective of promoting electricity and heat savings in households, public areas and trade and industry by means of information, advice and grants. The trust should have a budget of DKK 1.55 billion. The money will be distributed with around DKK 750 million for energy savings in households and in the public domain, and around DKK 800 million for energy savings in industry.

A trust of this size will simultaneously be able to give the strong Danish commercial position within energy saving technology a much needed lift by creating a substantial and technologically advanced demand for energy-efficient solutions on the Danish domestic market.

3. INNOVATION MARKETS AND FEED-IN TARIFFS TO PROMOTE RENEWABLE ENERGY

A market should be developed to support development and expansion using renewable energy technologies. Denmark occupies a leading position within renewable energy technologies, and if this position is to be maintained and expanded, an advanced domestic market that demands new and more efficient technologies is required.

In order for renewable energy to be able to achieve a dominant position in the Danish energy system, there should be feed-in tariffs for on-shore wind turbines that are at the same level as the tariffs for off-shore mills. This will ensure that investment in wind power is undertaken where it can best pay for itself. The feed-in tariffs can be scaled down over time to pressurise the producers into being innovative along the lines of the procedure in the current German legislation in that area. Where compensation is concerned, wind turbines are comparable with other plant, which means that the current depreciation scheme where neighbours can apply for compensation when a windmill is erected should cease.

The development of biogas should be supported by feed-in tariffs on equal terms with wind turbines.

A development plan should be drawn up for off-shore wind turbines whereby suitable areas are pointed out and invitations to tender are planned and implemented. It should also be ensured that off-shore plant tendered are directed to ensure that a certain share of the financing will come from a mixture of the municipalities, the electricity distribution companies, consumers, etc. in the neighbouring land areas. It could be 20 % for a big plant, for example.

Wave energy has the potential to contribute to the Danish energy supply, but this requires a special input. An innovation market should therefore be established for wave energy, where in the first instance a quota of 20 MW is offered with a fixed settlement price.

Futher more a national heating plan should be devised, that includes the implementation of renewable energy in the heat supply, either directly in buildings or in the district heating system.

4. INNOVATION BASED ON RESEARCH, DEVELOPMENT AND DEMONSTRATION

Research into and development of new technologies constitute the foundations of a radically changed energy system and are crucial to the possibility of developing new strong Danish commercial positions in the energy field. It is equally important to ensure that means are available to carry out full-scale demonstrations of the new technologies when the technologies are to be brought from the laboratory out onto the commercial market.

Since the expenses for a demonstration plant in particular add to the costs, the funds for research into and the development and demonstration of efficient and renewable energy technologies should be increased to DKK 4 billion a year in 2020. The decision to allocate DKK 1 billion to the area in 2010 is right and should be followed up with increased funds in the subsequent decade.

The funds must be used to develop a palette of renewable and efficient energy technologies within areas such as intelligent control, biofuels, wind, waves, solar cells, fuel cells, construction materials, process technology, storage technologies for electricity, the integration of electric cars onto the road network, low temperature district heating, etc.

5. INFRASTRUCTURE REORGANISATION

The streamlining of road transportation and the reorganisation of sections of road traffic into public transport, bicycles and walking are important to reduce transportation's energy consumption and CO_2 emissions. A number of tools should become valid as soon as possible. Some of the car taxes should be converted from fixed to consumption-dependent taxes at this present stage. In this connection, we can start by converting vehicle excise duty into a kilometre charge. A road pricing system should be developed and implemented as soon as possible and large cities should have the option of charging tolls.

There should be a requirement for all major infrastructure plans, as well as all municipal plans, to include considerations regarding the consequences of the plans for transportation and the latter's energy consumption. Municipal plans should support urban densification rather than spreading, and a stop should be introduced for measures that increase traffic on the road network.

The Danish vehicle fleet must be radically streamlined and Denmark should promote the electric car by adhering to the tax exemption on electric cars up until 2020, phasing out the exemption thereafter. Tighter requirements for the efficiency of cars should be drawn up through the EU.

There is a need for an active national input in the area, and the government's former target of reducing transport's CO_2 emissions by 25 % by 2020 in comparison with 1998 should be maintained.

6. REORGANISATION OF GOODS AND EXPANSION OF RAIL TRANSPORT

The reorganisation of goods and private transport from road to rail requires a significant expansion of rail transport. Investments in rail transport have a significant mobility effect and, in addition to the energy and environmental benefits, the improvement of rail transport will contribute to greater practicability.

A long-term plan for up to 2030 should be drawn up, including investments of DKK 200 billion for improvements to existing tracks, upgrading of the main tracks for high-speed trains, improved freight transport, light railway in the large cities and electrification of rail transport's main network.

7. CLIMATE-OPTIMISED PRODUCTION AND CONSUMPTION OF FOODS AND BIOMASS

Almost half of the greenhouse gases that originate from the Danish people's food consumption can be reduced through climate-optimised agriculture where the extent of waste in households is reduced and where the Danes eat according to the national dietary advice drawn up by the Danish National Council of Nutrition.

In order to climate-optimise agricultural production, it is recommended that the drained soils be removed from agricultural production as soon as possible, that the requirements regarding agriculture's nitrogen balance be tightened and a nitrogen surplus charge be introduced, that criteria for the allocation of agricultural support be used as an environment policy tool, and that the organic agricultural area be considerably increased. Information campaigns on a healthy diet and reductions in food waste with a view to reducing the climate impact of the Danish people's day-to-day diet should be implemented, and a strategy for the way in which food prices can show a greater reflection of the environmental impact and the impact on the climate should be drawn up. There is a need for research- and innovation programmes with a broad involvement of business- and environmental organisations to secure an enhanced production of bio mass on a environmental and socially renewable foundation.

8. DANISH CLIMATE ADAPTATION STRATEGY

The current Danish climate adaptation strategy is an ad hoc strategy that assumes that all relevant players do what they need to at the right time, thereby ensuring that Denmark is robust in the face of future climate changes. However, we cannot take it for granted that municipalities, public utilities, citizens and other key players are automatically aware of their responsibility in the way that it is taken for granted in the Danish climate adaptation strategy.

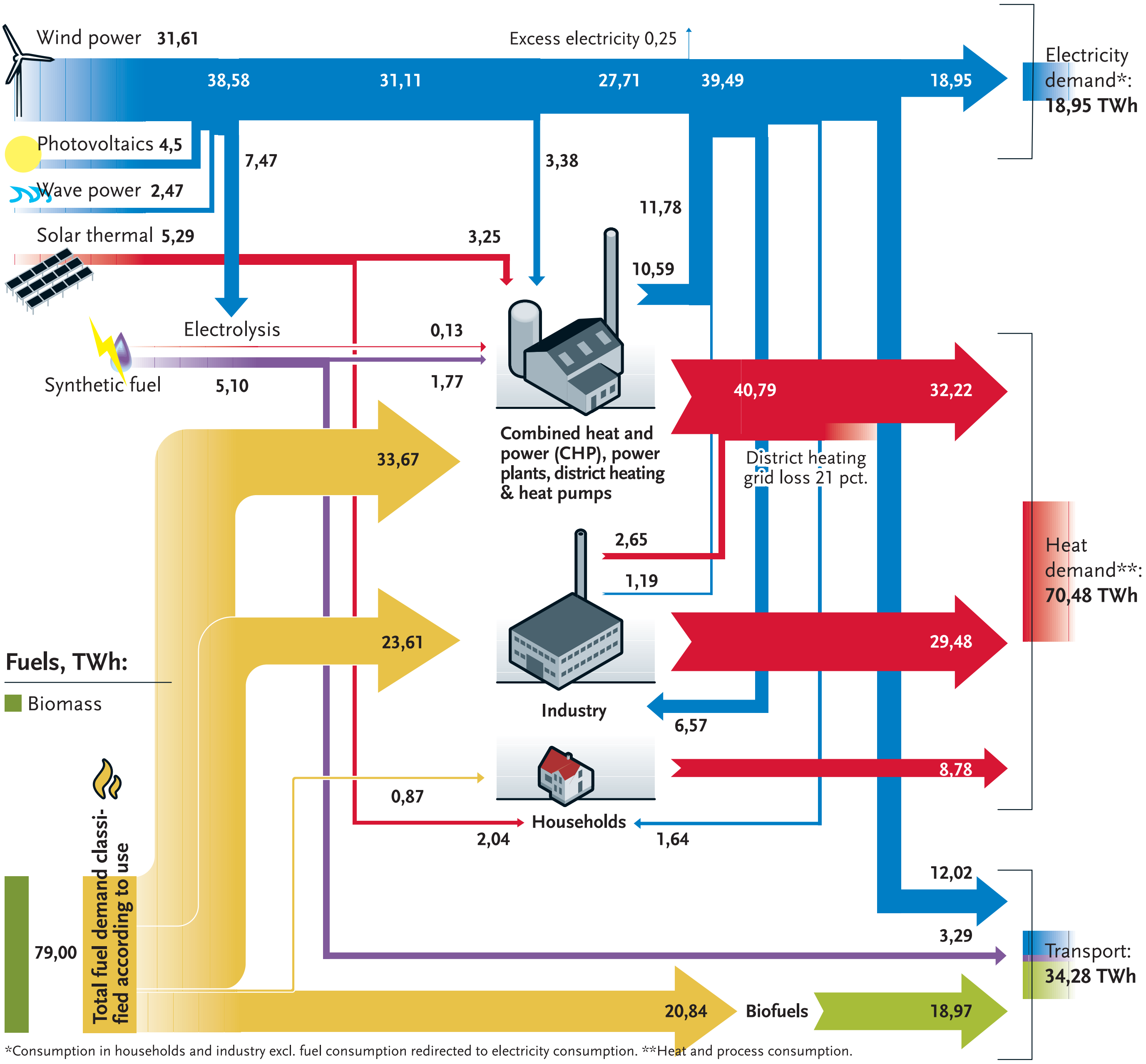
It is recommended that Denmark initiate a systematic listing of necessary measures within climate adaptation, and that an actual climate adaptation strategy be drawn up with indicators, guidelines and prioritised input areas for all relevant players. The government should initiate systematic monitoring of the area in order to ensure the necessary progress.

9. DENMARK SHOULD WORK TOWARDS AN AMBITIOUS INTERNATIONAL CLIMATE AGREEMENT AND PROCEED BY MEANS OF CONCRETE ACTION

Denmark should work towards as ambitious an international climate agreement as possible through the EU. Denmark itself should proceed by announcing a target that greenhouse gas emissions must be reduced by 90 % by 2050.

The IDA Climate Plan 2050

100% renewable energy. Primary energy supply, total: 122,86 terawatt-hour (TWh)



*Consumption in households and industry excl. fuel consumption redirected to electricity consumption. **Heat and process consumption.

The energy system and energy production

Summary:
The energy system and energy production

Gross energy consumption (2008): 845 PJ

Intermediate objectives, Climate Plan 2050

2015

- The total Danish energy consumption is at 707 PJ
- 67 % of the electricity consumption constitutes renewable energy
- 30 % of the total energy consumption constitute renewable energy
- The total heating consumption is around 160 PJ and district heating covers 53-63 % of the need for heating

2030

- The total Danish energy consumption is at 556 PJ
- 85 % of the electricity consumption constitutes renewable energy
- 47 % of the total energy consumption constitutes renewable energy
- The total heating consumption is around 141 PJ and district heating covers 63-70 % of the need for heating

2050

- The total Danish energy consumption is at 442 PJ
- The total electricity consumption is 45 TWh. Around 60-65 % thereof is covered by wind turbines, around 22 % by biomass and biogas, around 9 % by solar cells and around 1 % by syntetic fuel and around 5 % by wave power
- The whole of Denmark's energy consumption is based on renewable energy sources.
- The total heating consumption is around 138 PJ. It is supplied by district heating that is based on the combustion of biomass and some waste combustion in combined heat and power plants, heat pumps, solar heat and geothermics. The need for heating in buildings outside the district heating area is based on solar heat and heat pumps

MEANS

- A detailed expansion plan for off-shore and on-shore wind turbines that will last until 2050 and where suitable windmill locations are pointed out should be drawn up as soon as possible.
- National and local heating plans should be developed to outline the frameworks for the most efficient way in which the heating system can be developed. It should be possible to satisfy energy saving requirements collectively in areas with a common supply based on renewable energy sources and waste heating.
- Research and development of new technologies are the cornerstone of a radically altered energy system and are decisive as to whether new Danish commercial strong positions can be developed in the energy area. The funds for research, development and demonstration of efficient and renewable energy technologies should be increased to DKK 4 billion per year in 2020.
- The newly-established windmill secretariat should be ensured a fixed operating grant and the depreciation scheme for neighbours of wind turbines should be discontinued.

- The expansion of solar cells and wave power plants should be promoted by offering production quotas with a fixed settlement price.

- In order to promote flexible electricity consumption, requirements should be set stating that old electricity meters should be replaced with new energy meters that can measure by the minute and perform remote readings. At the same time, open communication standards for the purchase and sale of electricity should also be developed.

- At least DKK 150 million should be set aside for tests and demonstrations of large fuel cell plants.

- Combined heat and power plants should be able to gain up to 10 % of their tax from self-produced electricity that is used in heat pumps for the production of district heating.

- Requirements should be set regarding the use of thermal solar heat outside the district heating areas.

- Introduction of storage potentials is a central element of IDA's Climate Plan 2050, and this will be supported by measures that make it possible batteries charged in electric cars, for example, to be included in the energy system as well as the development of intelligent consumer goods for private use.

Energy system and production

With an aim of reducing greenhouse gas emissions by 90 % by 2050 while maintaining a high level of Danish self-sufficiency with regard to energy, requirements are set regarding a radically different energy system. The whole of the energy system's basis and paradigms must be carefully thought through.

The Danish energy system has been based on fossil fuels for over 200 years, and by far the majority of Danish energy consumption is still based on fossil energy today. It will therefore be necessary to break the blinkered train of thought and ensure that traditions, old plant and systems do not constitute an obstacle for innovation.

In 2050, the energy system in The IDA Climate Plan 2050 is based solely on renewable energy sources. The energy system will, as now, be based on an electrical system and a heating system. However, compared to now, the total energy system will be based on far more decentralised and distributed energy production from a broad range of technologies. A range of major "central" wind farms combined with individual wind turbines and biomass production split between different technologies will dominate the system. Simultaneously, the system is designed to be as flexible as possible when weighing up the effective energy utilization that co-production may generate. The heating systems and electricity system will be trialled separately so that they are not mutually dependent on each other

In The IDA Climate Plan 2050, the electricity system is sustained by wind power, biomass and biogas, solar cells, wave power, electrolysis and fuel cells, as well as by storage capacity. The heating systems in the cities and smaller urban areas are based on district heating systems that combust biomass and waste and use solar heat, geothermics and surplus heating from industry. District cooling is also a part of the systems. The heating systems of detached houses are based on biomass and solar heat.

It is absolutely necessary for the energy system of the future to be flexible. Tomorrow's energy systems will be integrated so that energy consumption and energy production are more closely linked. A minimised and efficiently-controlled energy consumption will enable the continuous adaptation and design of the production capacity according to this.

The introduction of storage opportunities is a key element of The IDA Climate Plan 2050. Storage in fuel cells and batteries in electric cars, for example, and utilisation of electricity in heat pumps, plus combining intelligent consumer devices up until 2050 will support even and low consumption at the same time.

Wind power will be the hub of the renewable energy system

Renewable energy production using wind turbines is currently Denmark's major strength, and wind power is also the hub of the Danish renewable energy system in The IDA Climate Plan 2050. With a wind share of 18-20 % of the electricity consumption in 2008, the strength lies both in knowledge that is at the international forefront of the integration of this fluctuating energy form in the electricity mains, and in the actual mill development.

The plan looks at rebuilding an innovative domestic market for windmill technology, where 60-65 % of the electricity consumption in 2050 will be covered by wind and where the demand for mills plus an active research and development environment is there to create and maintain knowledge about off-shore and on-shore wind turbines that is necessary to expand the export and a growing international market share, not to mention the development of the knowledge of system adaptation and regulation of the electricity mains.

The wind sector creates substantial national employment and significant international export that is based on close cooperation of research, distribution companies and production companies and the windmill industry. However, the international market leader position for both on-shore and off-shore wind turbines faces a strong threat. If the growth in the windmill industry continues to increase, it is absolutely necessary for the stagnating international leading position in wind energy to turn so that Denmark retakes the lead. In spite of the economic crisis and an immediate stagnation in 2009-2010, expected wind technology growth rates of up to 15-20 % per year on the international markets mean that there is still significant growth potential within the area. Different countries, with England, Germany and Spain as the European examples and China as the Asiatic example, have strong expansion plans. The IDA Climate Plan 2050 recommends that Denmark resume equally ambitious plans.

STATUS FOR WIND TURBINE EXPANSION IN DENMARK

In 2009, a good 5100 wind turbines were erected throughout Denmark. Of these, a good 4900 mills were located on land and 214 mills off-shore. The wind turbines constitute around 3100 MW installed wind power, and they produce around 7.3 TWh per year or around 20 % of Denmark's electricity consumption of 36 TWh in 2009. The mills are small 150 W mills and upwards. Over the past few years, no new on-shore wind turbines have been installed in Denmark and, following a long stoppage, the expansion of off-shore mills did not resume until 2009.

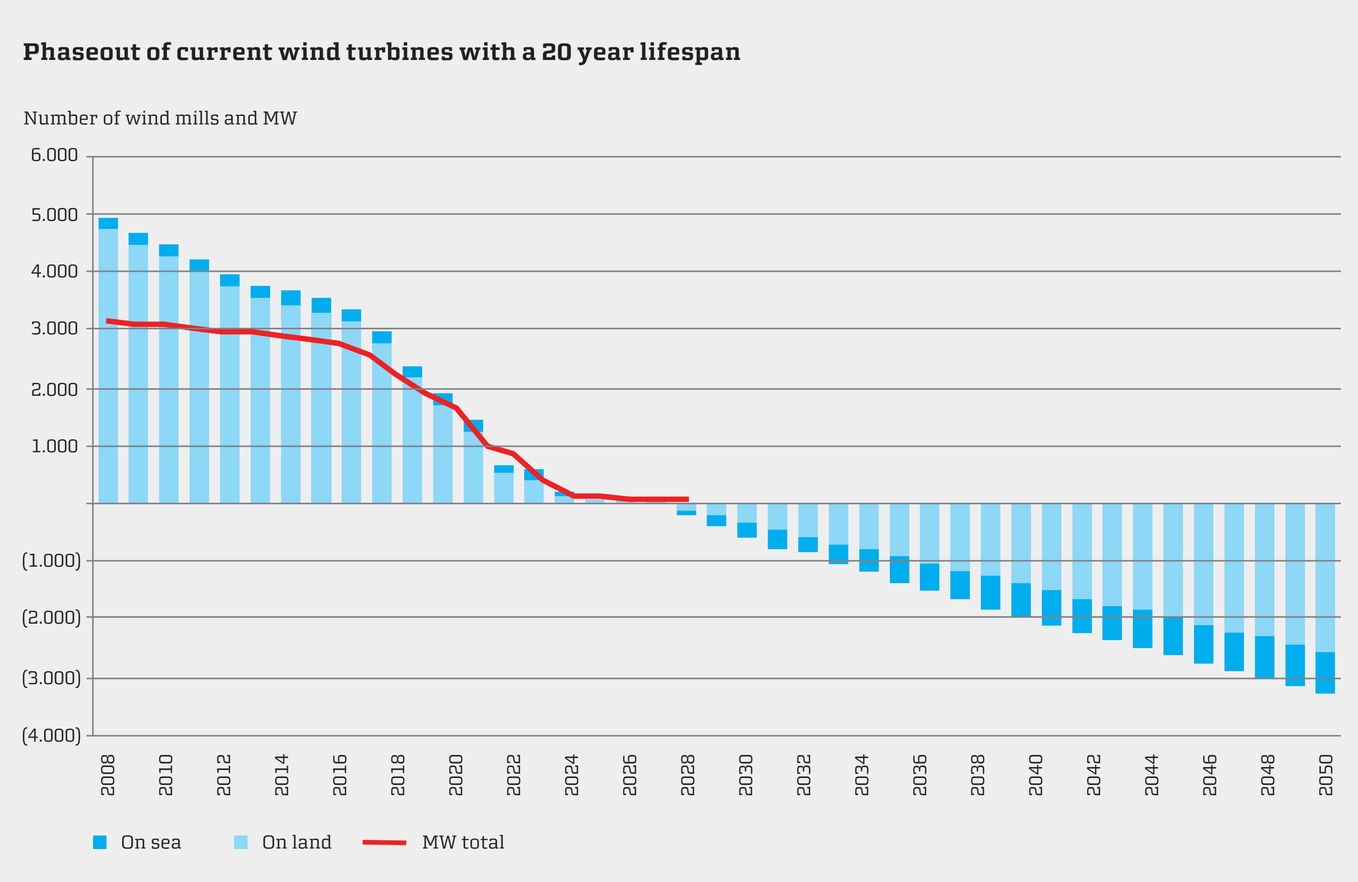
The lifetime of the mills is estimated to be around 20 years, whereupon they must be expected to have outlived their usefulness and be decommissioned. The total existing windmill park must therefore be expected to be decommissioned by 2025. Figur5 shows the way in which a number of mills and installed MW are expected to be phased out.

TECHNOLOGY POTENTIAL AND EXPANSION POTENTIAL OF WIND

The IDA Climate Plan 2050 looks at substituting the existing wind turbines with new, bigger and more efficient turbines on-shore and at setting up a further substantial capacity off-shore. 4500 MW will be installed on-shore and 4600 MW will be installed as off-shore and in-shore mills, a total of 9100 MW up until 2050[3].

The installed 4500 MW on-shore wind turbines will replace the current 3100 MW mills installed, but with fewer mills. In 2050, approximately 2300 on-shore mills can produce up to 12 TWh per year. The off-shore mills will principally be located at Vesterhavet where the efficiency is greatest, and up to 20 TWh per year can be produced with a quantity of 925 mills. However the location of offshore wind farms will be evaluated based on aesthetic, construction, production technology, practical and maritime considerations, and thus the North Sea, Kattegat and the Baltic Sea as well as the more coastal waters will all be involved.

3. Calculations in this section are based on known wind data from "Energy and Environment Data" up until January 2009 concerning the efficiency of the existing erected mills in Denmark, as well as data concerning the annual efficiency from both the in-shore mill park in Nysted and the off-shore mill park at Horns Rev (Vesterhavet). Data from Horns Rev is partly estimated on the basis of provisionally known data. The data is analogous to the Danish Energy Agency's ENS data concerning the wind conditions, but all according to the size, location and roughness class of the mills, the efficiency is greater in the calculations performed by the Society of Engineers and Energy and Environment Data. If average ENS data is used, the expected efficiency will be slightly lower.



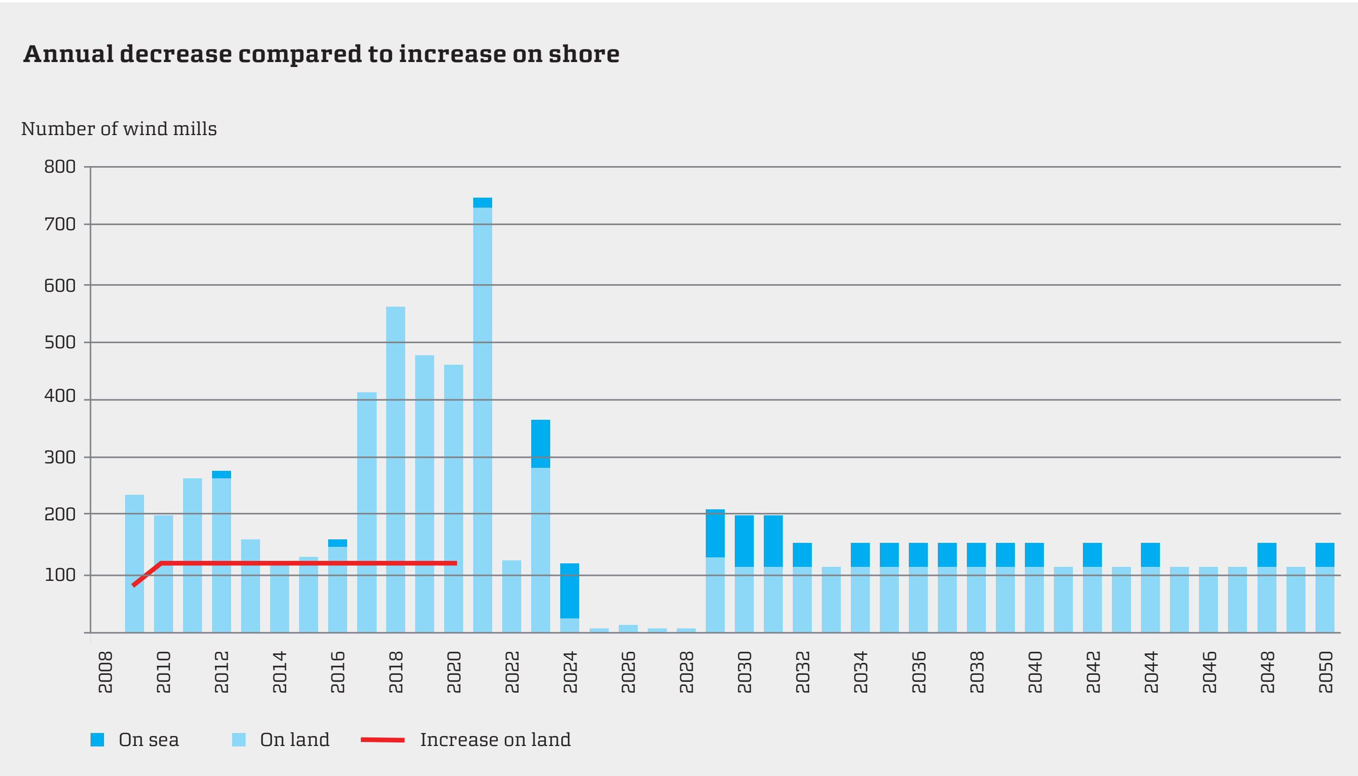
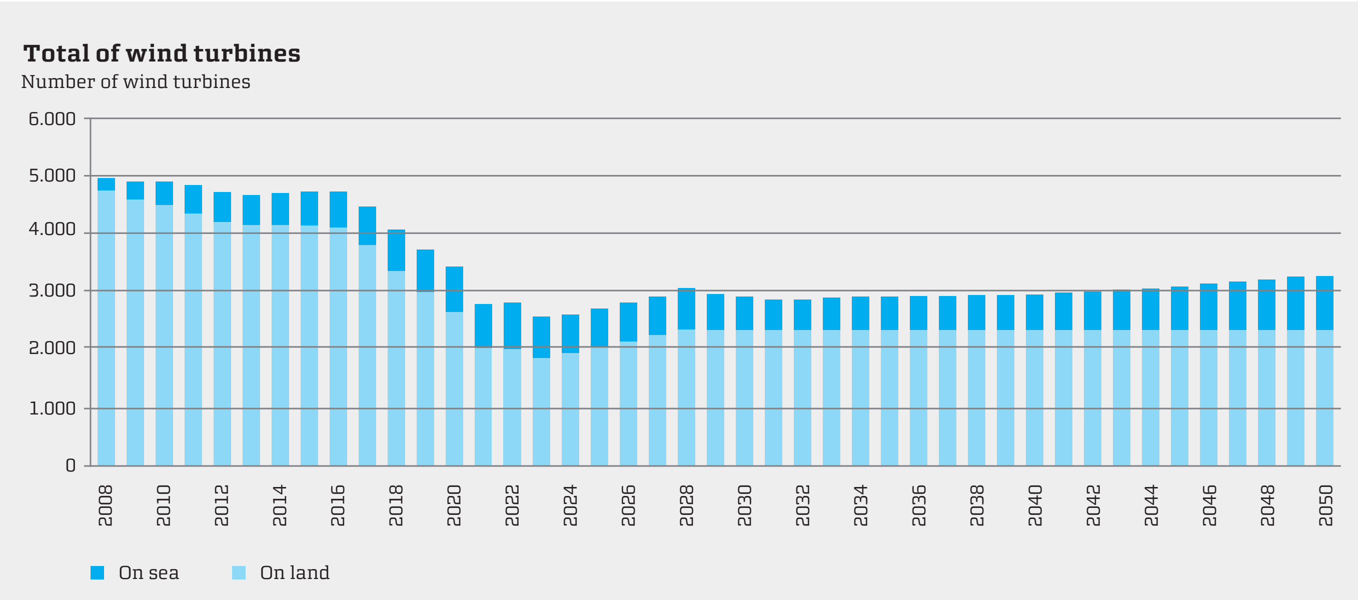


Figure 5: Wind turbine 2008-2050 Source: EMD (Energy and Environment Data, Per Nielsen), Danish Wind turbine Owner's and the Danish Society of Engineers.



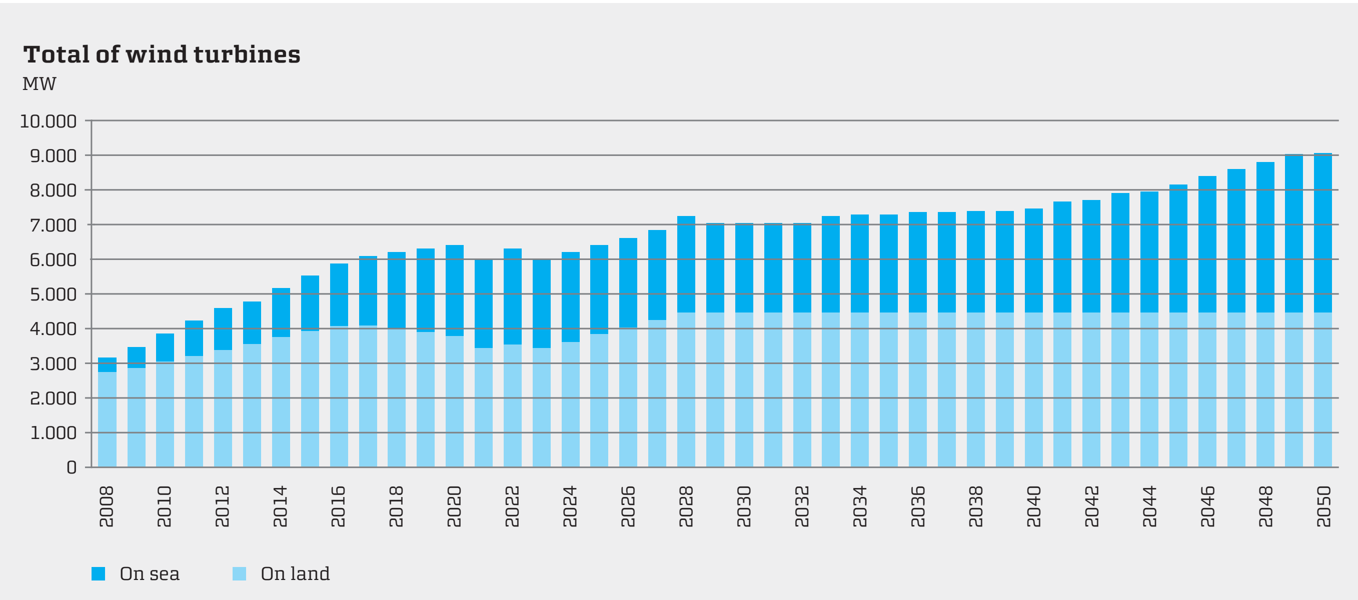
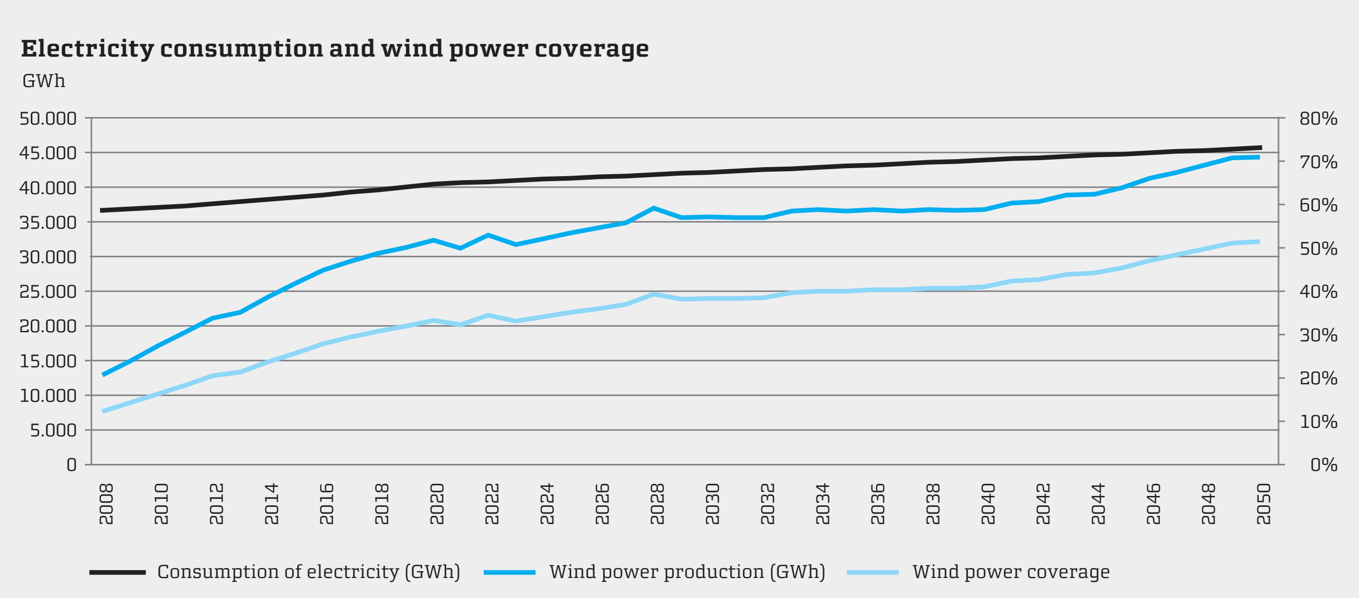


Figure 6: Windpower in Denmark,

Source: EMD (Energy and Environment Data, Per Nielsen),Danish Wind turbine Owner's and the Danish Society of Engineers

An expansion such as the one outlined means that between around 30 and 32 TWh per year can be produced using an approximate total number of 3260 mills. This corresponds to around 60-65 % of the estimated electricity consumption of around 50 TWh per year in 2050. When the electricity consumption in the Climate Plan increases, this is a consequence of electricity savings in households, industry and greater electricity consumption for electric cars and heat pumps.

Electricity consumption and wind power coverage



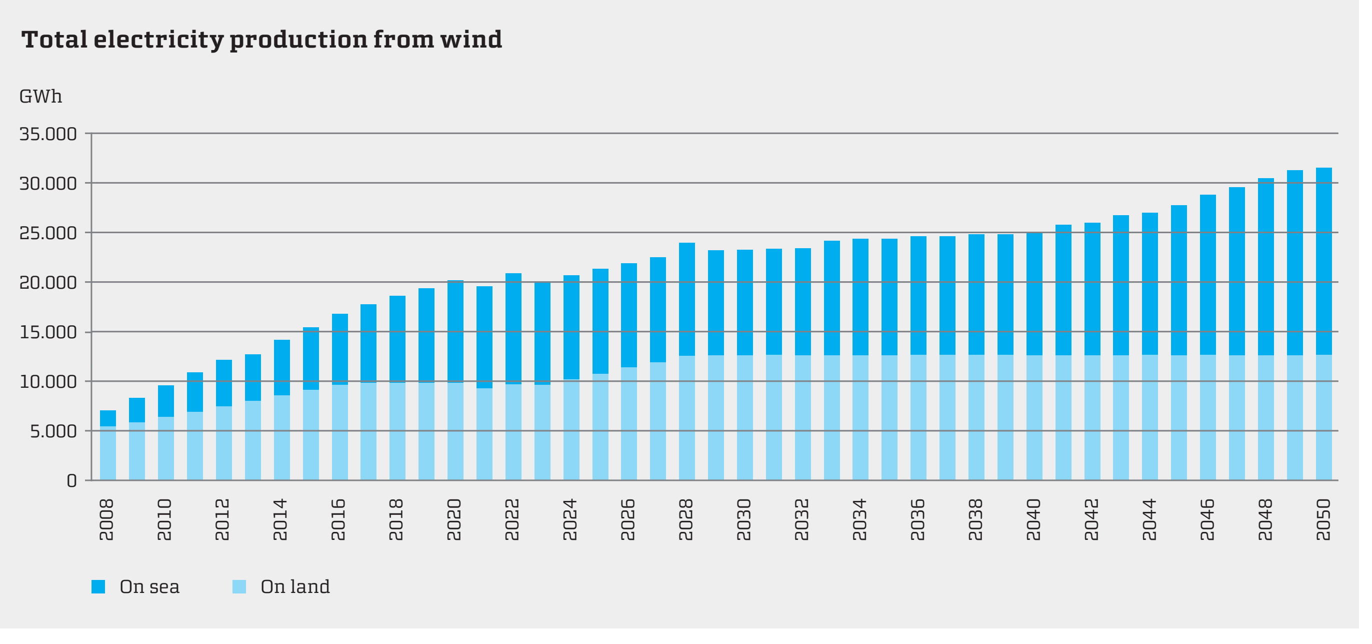
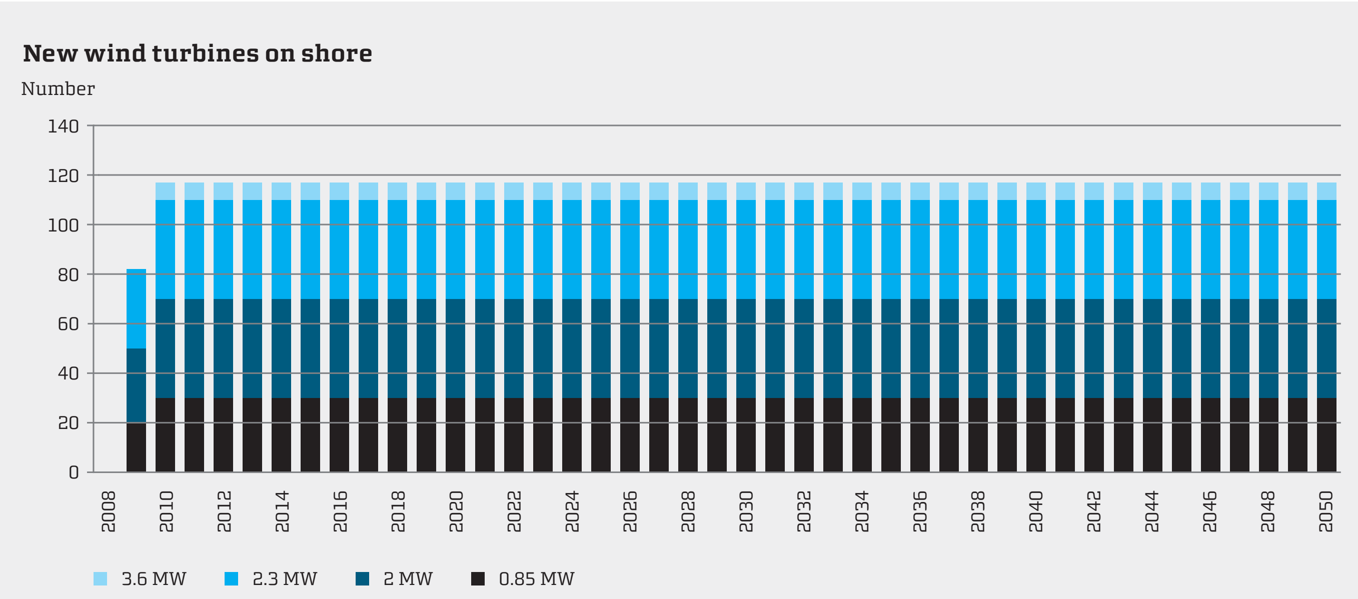


Figure 7: Wind turbines and electricity.

Source: EMD (Energy and Environment Data, Per Nielsen), Danish Wind turbine Owner's and the Danish Society of Engineers

The 2008 energy agreement has secured an off-shore mill expansion up until 2012, but a new expansion agreement in phase's right up until 2050 should be established as soon as possible.



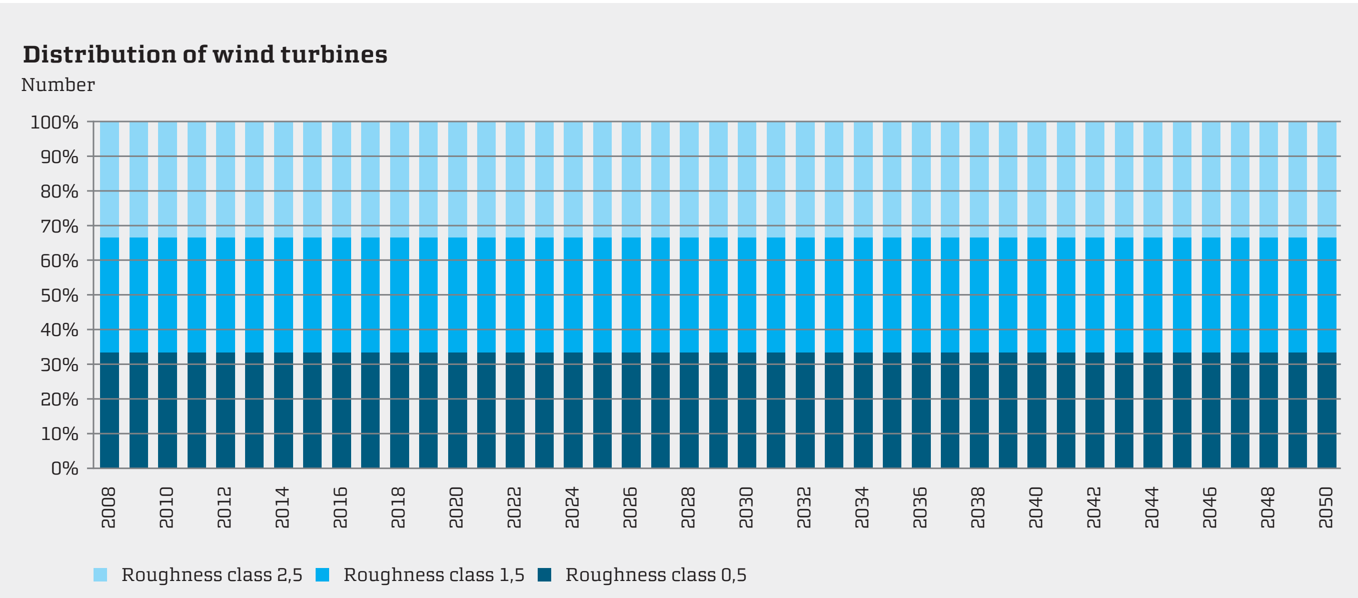
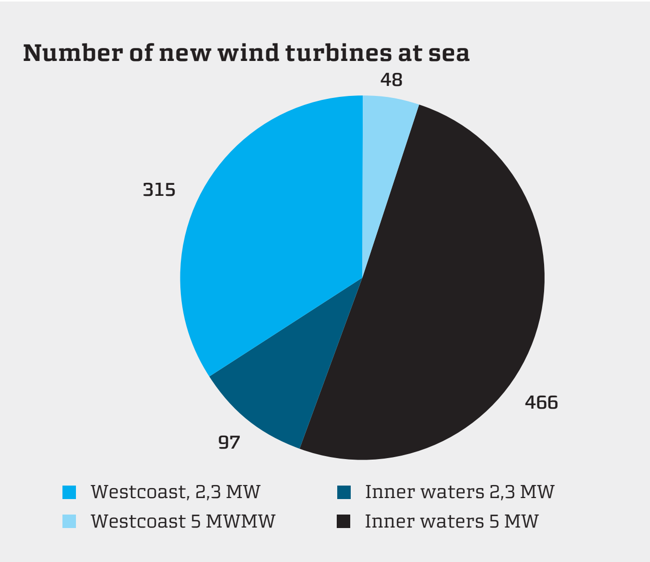


Figure 8: New wind turbines.

Source: EMD (Energy and Environment Data, Per Nielsen), Danish Wind turbine Owner's and the Danish Society of Engineers

The size and efficiency of the wind turbines is crucial to the implementation of the strategy. The proposed expansion plan is based on the fact that the established on-shore wind turbines are divided among 0.8 MW, 2 MW, 2.3 MW and 3.6 MW mills. The mills are located in different roughness classes. Their location is absolutely crucial to their efficiency, and it will therefore be of substantial significance if suitable locations can be found. In this connection, the newly-established windmill secretariat can ask for considerable help from the municipalities. An extension of the secretariat over and above the allocated 2 years should be ensured to encourage the municipalities to adhere to an expansion plan. The planning legislation is a factor for both off-shore and on-shore wind turbines, and may reduce the speed at which the expansion can take place. Codes of practice that make this process run more smoothly will be fortified to avoid delays to the expansion. The highlighting of suitable windmill locations that correspond to the desired capacity should be initiated as soon as possible.



Depending entirely upon the outcome of the municipalities' and plan system's locations and mill sizes, the on-shore wind turbines will contribute between around 10 and 12.6 MWh for the 2300 installed mills.

A substantial share of the on-shore wind turbines will be maintained for the benefit of the more efficient off-shore and in-shore mills. This is justified in that the involvement of the population in the expansion is necessary and important, but also that the set-up, maintenance and repair are less expensive.

Both the off-shore mill parks and the on-shore mills are expected to be 2.3 MW and 5 MW respectively for both the off-shore plant and the in-shore mills. The on-shore mill size is limited due to the visual impression that their height and rotating wings will have on the in-shore landscape. The effect of the mills is directly connected with height and rotor diameter, but since they will be adapted to the landscape and suitable locations will be found, the height must give way to other considerations. It cannot therefore be expected that 6 MW wind turbines or even larger will be located close to the coast or by bird migration routes.

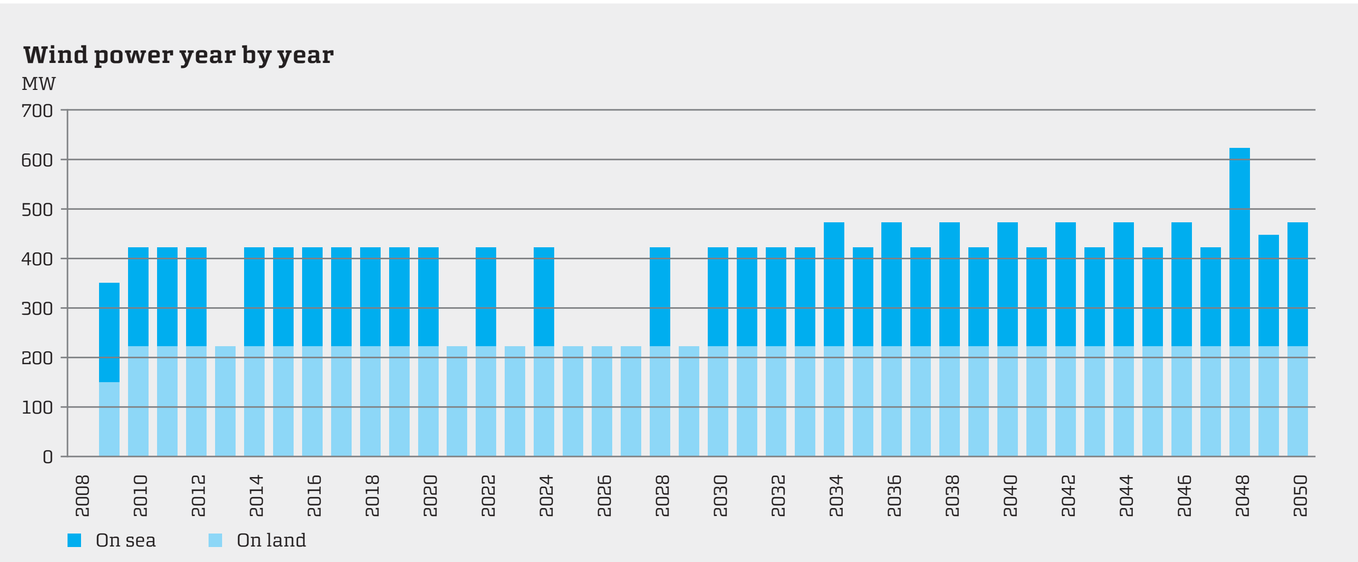


Figure 9: Number of new wind turbines.

Source: EMD (Energy and Environment Data, Per Nielsen), Danish Wind turbine Owner's and the Danish Society of Engineers

New on-shore mills are currently almost competitive with other forms of electricity production, but the settlement prices have been so vehemently downscaled that the expansion has come to a halt. The proposal is therefore to cancel the settlement in the form of a feed-in tariff so as to re-start the development. The settlement should be downscaled continuously with the expected technology development.

Due to expenses for foundations and infrastructure in particular, off-shore mills are much more expensive than on-shore wind turbines, and the proposal is therefore to continuously invite tenders for off-shore mill parks so there is free competition to construct the desired capacity as cheaply as possible.

The investment in wind energy plants up until 2050 is expected to amount to around DKK 55.5 billion for an expansion with 4600 MW off-shore mills, and for 4500 MW on-shore mills of around DKK 35.6 billion[4]. The re-introduction of feed-in tariffs and the purchase obligation and invitations to tender are expected to mean that the energy companies DONG Energy and Vattenfall will invest in the expansion of off-shore mills and on-shore mill parks, and the population will invest in on-shore windmill parks through a windmill guild.

A substantial contribution to the realisation of an expansion plan like the one outlined is the considerable backing from the population and the municipalities. Understanding for the necessity of the expansion can be fortified by involving the population in the production. Location of on-shore wind turbines (and solar cells) in the vicinity of the citizens requires their support, and there will be involvement like the interest that pushed the expansion through the 1980s. It will therefore be made easier for windmill (and solar cell) guilds and individual people to invest in both on-shore wind turbines and in quotes for off-shore mills through tenders.

4. The price per installed MW wind power is high since the demand for windmills is greater than the supply. However, the price of installed MW in both offshore mill parks and on-shore mill parks is expected to fall with an increase in supply.

4 new schemes and the new Promotion of Renewable Energy Act

With this Act, the Danish Parliament has agreed to strengthen the expansion of biomass, wind and other renewable energy by increasing the economic support and by establishing the four schemes: 1: the right to purchase, 2: the Green Scheme, 3: guarantee fund and 4: depreciation in the wind area.

The schemes cover 25 metre-high or taller on-shore and off-shore mills. The right to purchase does not apply to pilot mills. The Green Scheme applies only to on-shore mills. None of the schemes apply to off-shore mills for which the State sends invitations to tender, or to pilot mills.

Transition scheme in the new Promotion of Renewable Energy Act

The right to shares and depreciation applies to windmills that are connected to the electricity mains after 1 January 2009. Exemptions are windmill projects that have already started, i.e. on-shore mills where the municipality has published municipal plan measures with an associated environmental impact report before 1 March 2009 or has announced that the mill is not subject to an environmental impact assessment. Also exempt are off-shore mills where the erector has obtained permission for pilot studies before 1 March 2009. In order for mills to be exempt, they must also be connected to the mains before 1 September 2010.

Wind

The municipalities can obtain assistance with windmill planning from the newly established secretariat, the Windmill Secretariat. The Secretariat can provide guidance, initiate the planning, travel where this is necessary, supply analyses of landscapes and location options and supply nearly-completed action plans for municipalities that need them.

Figure 10: The Promotion of Renewable Energy Act.

The Danish Parliament has started work on the new windmill expansion and neighbours of wind turbines can now invest in local plant. However, the scheme will be strengthened so as to fortify the interest in ownership of energy production and reduce any opposition to new on-shore mills. Unfortunately, the new Renewable Energy Act includes two contradictory points of interest. The national interest in wind energy can now be converted into local initiatives and local responsibility for new mills. The legislation ensures that at least 20 % of all new capacity is offered in shares to the residents in the vicinity of the mills. On the other hand, the Promotion of Renewable Energy Act is a completely new compensation principle where neighbours of wind turbines are offered special treatment in comparison to neighbours of all other buildings. The special depreciation scheme may be an obstacle to the expansion of on-shore wind turbines and should be discontinued.

THE COMMERCIAL SUCCESS WILL BE MAINTAINED

In 2008 the Danish windmill industry employed more than 28 000 people with a drop to 26.000 by the end of the second quarter of 2009. The employees are distributed among 2 primary producers and a large number of subcontractors. The typical business in the industry has between 10 and 50 employees, with fewer than 10 businesses having more than 500 employees.[5] Exports increased to DKK 42 billion in 2008. Nationally turnover increased to DKK 53.0 billion in 2008 against DKK 42.2 billion in 2007. This is an increase of almost 11.0 billion kroner or 26 percent. Global turnover increased to DKK 84 billion in 2008 against DKK 65 billion in 2007. This was an increase of DKK 19 billion or 29 %.

The employment consists largely of highly educated and specially trained personnel. There is great potential to maintain a large share of highly educated people if the development of the domestic market is established for both off-shore and on-shore plant, and the considerable cooperation between distributors/producers, the windmill industry and research is maintained. While production of some of the mills can be expected to be moved to the local markets for the mills, development, pilot production and testing of the latest technology will maintain the share of personnel with a high level of knowledge and earnings in Denmark. The cooperation between the players will also fortify a high level of training for personnel in the sector.

5. Denmark as wind power hub. The windmill industry 2006

Biomass and bioenergy

Utilisation of biomass for energy and transportation purposes is absolutely necessary if significant success in reducing greenhouse gas emissions is to be achieved. The expectation is that Danish agriculture and forestry will be able to produce biomass in the form of straw, timber and biodegradable waste, corresponding to around 300 PJ per year. It is estimated that around 284 PJ is nessesary for energy and transportation purposes in 2050.

Biomass can be converted directly into thermal energy through combustion, or into biogas through gasification or liquid biofuels, e.g. through fermentation. The thermal energy can be used for the production of heating or combined heat and power. Biogas and liquid biofuels have a broader range of use, including fuel in the transport sector or as fuel in combined heat and power plants or in industry.

The processes of converting biomass into energy have different energy efficiencies, depending on the energy that has been spent to produce biomass and the process that transforms biomass into energy. If the sole purpose is to lower the CO_2 emissions, the biomass is best used for biogas and combined heat and power production, and the majority of the biomass resource should therefore be used for this purpose.

Today, the importation of foreign timber constitutes an increasing share of the biomass that was already the most substantial CO_2 neutral renewable resource in 2006 along with wind in Danish energy production.

PJ	1980	1990	1995	2000	2002	2004	2006
Straw	4,8	12,4	13,1	12,2	15,7	17,9	18,6
Wood chips	0,2	1,7	2,3	3,0	4,2	7,7	8,3
Timber waste	3,7	6,2	5,7	6,9	6,0	6,4	6,3
Timber pellets	0,1	1,7	2,3	4,2	6,7	12,8	15,6
Biogas	0,2	0,7	1,8	2,9	3,4	3,7	3,9
Fire wood	7,6	8,8	11,5	12,4	13,0	15,7	19,6
Biodegradable waste, etc.	7,6	11,1	17,5	23,7	26,4	29,4	31,0
Total biomass	**24,0**	**42,5**	**54,0**	**65,4**	**75,4**	**93,6**	**103,3**

Table 1: Biomass used for energy purposes Source: The Danish Energy Agency, Energy statistics 2006

BIOMASS IN COMBINED HEAT AND POWER PRODUCTION

The majority of plants produce combined heat and power. A smaller number of the decentralised plants – around one in three – still only produce heating. Largely all decentralised district heating plants and one in four decentralised combined heat and power plants currently use environmentally friendly fuels, i.e. straw, chips, timber pellets, biogas or waste. The remainder – by far the majority – use natural gas as fuel. The combined heat and power plants are municipally and cooperatively owned, and they supply the majority of homes, institutions and businesses in the area with heating by means of district heating pipes. The size varies from delivery to an individual institution to a whole urban society such as Viborg. As well as combined heat and power plants, there are some industrial plants that can also be connected to a special heating mains. Electrical energy is supplied to the mains.

Transportation of biomass from the place where the biomass is produced to the plant where biomass is combusted results in a minor loss in the total energy accounts. The location of the plants is therefore important. It is also important to expand with energy and seasonal adjusted storage facilities to ensure an adequate supply throughout the year. The number of power and heat plants, their sizes and placements is expected to be adjusted in comparison to the current number.

Number of combined power and heat plants and district heating plants in denmark

Collective heat supply (towns)

- 16 central power and heat plants
- 285 decentralised power and heat plants
- 130 decentralised district heating plants

Private heating supply (businesses and institutions)

- 380 power and heat plants
- 100 district heating plants

Total

- 665 power and heat plants
- 230 district heating plants

Figure 11: collective and private heating supply

Source : The Danish Energy Agency www.ens.dk 16/04/09

Combined heat and power based on simple combustion of biomass is efficient and will be a necessary contribution to the production of electricity and heating. Although the connection of electricity and heat production is not desirable for reasons of production flexibility based on seasonal and daily requirement/consumption, combined systems will continue to be included in the plan based on energy efficient use. District heating plant will be maintained to the extent that this can contribute to local flexibility in the production of heat that is not dependent on electricity production.

At the same time the plants will supply cleaned/scrubbed CO_2 to electrolysis plants. A national plan that analyses the number, size, construction and location of electrolysis plants in connection with biomass consuming heating plants must thereby be commenced before the plants are fully developed in commercial and reliable sizes. During periods where there is surplus wind energy, the electrolysis plants will produce fuels (Methanol, DME or similar) that can be stored and used in fuel cells. We are therefore looking at replacing the decentralised combined heat and power plants that are based on natural gas with biomass-based plants with connected electrolysis plants and heat pumps on a gradual basis as they wear out.

The conversion of biofuel to liquid fuel for use in fuel cells will involve an unknown minor energy loss. The Climate Plan 2050 adheres to the proposal to ensure flexibility in the system since the fuel cells can be rapidly put into and out of production as required. The requirement for a stable electricity system means that fuel cells must be accommodated within the system in interaction with fluctuating production from wind, wave and solar power. An appropriate number of gas based heating plants will be maintained and converted in order to decrease biogas. The biogas can be stored and distributed via the natural gas network to these plants

In The IDA Climate Plan 2050, 22 % of the total electricity consumption of 50 TWh will be covered by biomass corresponding to around 11 TWh in 2050, while the contribution to heating is shown by the heating section. The other quantities of biomass can be included as a resource for fuels in the transport sector.

Biogas in Denmark

The IDA Climate Plan 2050 looks at agriculture's domestic animal manure (organic fertilizer) and other types of organic waste being fully utilised for the production of biogas. The expectation is that the utilisation of domestic animal manure will be able to produce 26 PJ energy per year, and that with full utilisation of the other raw materials (organic types of waste), it will be possible to produce a further 14 PJ energy. A total of 40-50 large common biogas plants should be established to ensure full utilisation of all of the biogas resource.

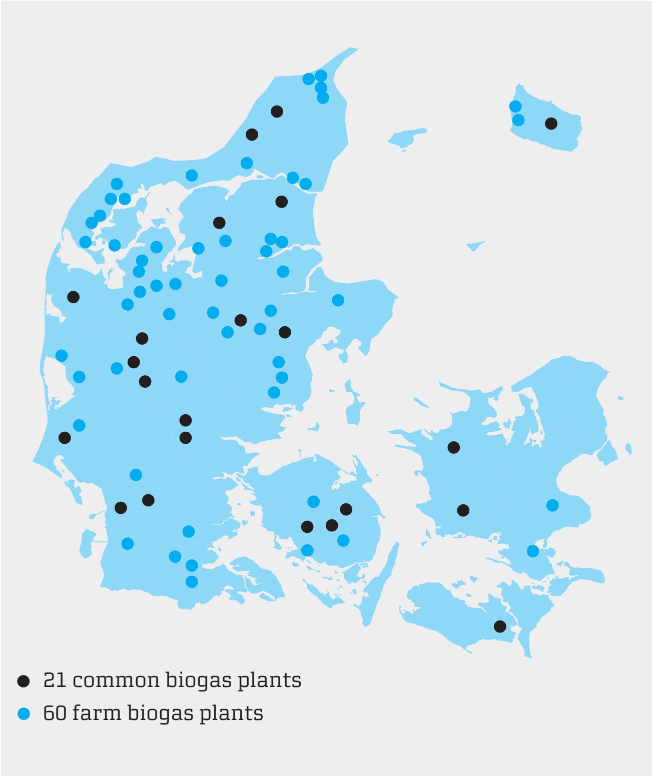


Figure 12: Biogas plants in DK.
Source: The Danish Biogas Association, 2009

The organic raw materials are treated at either a biogas farm plant or a large common biogas plant where the organic materials are degasified.

In order for the process to be able to function, it is currently necessary to mix around 20 % organic (waste) material that is different from domestic animal manure into the plant. In order to avoid lack of other organic waste innovative thinking will be needed with regard to the use of chicken manure and other organic residual products. In the long term, it is estimated that it will be possible to produce biogas exclusively from domestic animal manure. The gas will be delivered to decentralised combined heat and power plants that can relatively easily be transformed from natural gas to full or partial biogas input.

In The IDA Climate Plan 2050, the biogas plants should supply both electricity and heating. In order to ensure the total supply reliability of the energy systems, the biogas will be stored and form part of the electricity production during the plants' own production or at the nearest combined heat and power plant/fuel cell plant or through the natural gas mains. The plants that produce their own electricity will be connected to those responsible for the mains through intelligent control technologies.

The potential for additional production of biogas at 20 PJ when using more organic material, such as algae and grasses, maize etc. from new areas will be in place in 2050. A production goal of approximately 40 PJ is included in Climate Plan 2050 based on other considerations such as renewable agricultural and land use. Limitations on and any fall in animal production in Denmark and thereby the volume of animal manure, as well as the potential for different operating methods to utilize manure for biogas, will mean that the plan is not based on a higher biogas proportion. Climate Plan 2050 is robust enough to integrate and convert to a large proportion of biogas provided that the future clears the way for this potential.

The biogas will be stored in quantities so that these can function as the sole electricity suppliers for a specified period. Today, the biogas producers only have the option of establishing their own supply to selected customers. This takes place to a very limited extent with heating sales to surrounding neighbours.

THE LOCATION OF THE PLANTS AND BETTER STORAGE OF GAS ARE CRUCIAL

There are currently 21 common biogas plants and around 60 farm biogas plants in Denmark (➜ see figure 6) and the Danish production of biogas currently corresponds to 4 PJ per year.

Today, it is principally agriculture that constructs, owns and runs biogas plants like farm biogas plants and common plants. Whether there is a commercial basis on which to establish a common plant is determined largely by local conditions like the concentration of suppliers of substantial quantities of organic fertilizer and other usable biomass in the area, as well as transportation and sales opportunities. It is crucial that suppliers of organic fertilizer are not spread geographically too far apart, since this will cause major transportation expenses and weaken the plant's climate sustainability factor.

With the steady increase in agriculture, there will in many cases be a basis for a large farm biogas plant, and to a certain extent it may be a good solution to involve the neighbouring agricultural units in this and pipe their organic fertilizer to the plant.

An important condition is the sale of the biogas plant's products: gas, electricity and heating. There are a number of potential customers for biogas or biogas-based energy, but no real market. All trade takes place locally and is determined by individual conditions. Where the gas is concerned, the price is typically at DKK 80 – 90 per GJ, corresponding to around DKK 2.00 per m^3. However, there are locations where the price can be almost double. From a political point of view, an electricity settlement price for electricity produced by biogas has been secured at DKK 0.745 per kWh. The sale price for heating starts at around DKK 0.10 per kWh.

Today, it is most beneficial to supply the energy to consumers who use more expensive taxed energy in oil or natural gas-produced energy based on either individual plants or combined heat and power plants (e.g. the manufacturing industry). In terms of operation, there will be many interested commercial and industrial customers. Industry's conversion to biomass will be able to benefit from biogas in many cases. For industrial customers, however, the tax exemption will be of lesser significance since industry already pays lower charges for energy.

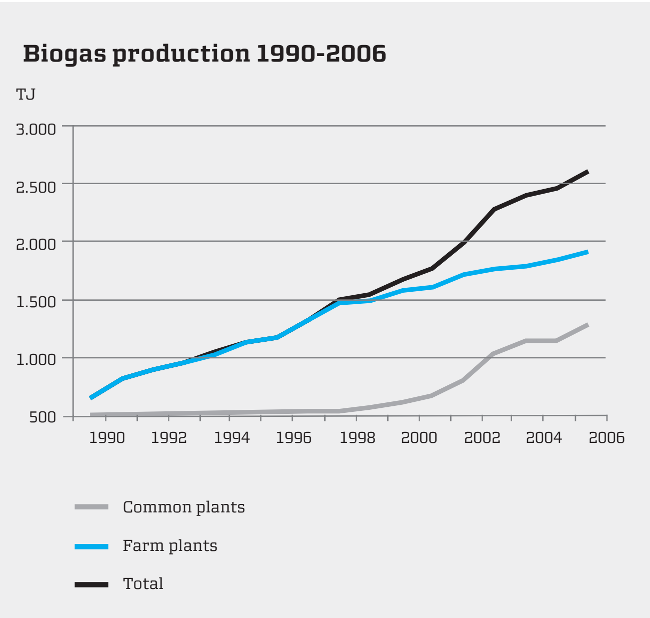


Figure 13: Biogas production.
Source: The Danish Biogas Association, 2009

Biogas is currently most suitable as a basic load supplier since the gas can be difficult to store due to a major risk of evaporation/diffusion of greenhouse gases to the surroundings. High-pressure storage is a relatively expensive solution in terms of both investment and energy. The solution is used to some extent in connection with gas-driven vehicles. This is relatively widespread in Sweden, where cars that run on biogas have been introduced into the system.

Locally at the biogas plants there are smaller operational storage areas that will compensate for the general fluctuation in gas production. These storage areas are low-pressure storage areas where the gas therefore has a large volume.

A technological gas storage input development without the risk of diffusion should therefore be initiated so as to assure the broader use of the gas. The best and most obvious storage option is to use the natural gas mains where there are storage solutions.

MEASURES TO BROADEN THE EXPANSION OF BIOGAS

The biggest barriers to the expansion of biogas are financing, the Danish Heat Supply Act and the Natural Gas Act. The requirement in order to achieve maximum expansion is that the necessary capital for the investment is available and that solutions are created to offer an acceptable economy for the owners of the plants.

The goal of the IDA Climate Plan 2050 is to create a national plan for the extension of biogas and that sale will be chiefly supplied to industrial customers and the natural gas network. For supply, production and marketing reasons, it is important that production units have a say in the marketing. Clarification between production and the distribution players is necessary.

In order to support biogas expansion, it is recommended that support in the form of governmental or municipal guarantee be given to start up new plants with the option of borrowing low-interest funds for the investment in The Credit Institution for Local and Regional Authorities in Denmark, for example. It is also recommended that funds, around DKK 100.000 per project, be allocated to pilot projects in connection with the construction of large common plants. At the same time, there should be an opportunity for neighbouring investments, the same as is possible in the windmill area.

It is also necessary to establish tax-free transmission of the energy produced at biogas plants. This would promote the biogas producers' opportunities to operate on a larger market and provide the necessary flexibility in relation to the technical solution opportunities. When this or tax-free biogas electricity is currently piped out to the electricity mains, it is taxed. The same applies to upgraded[6] biogas that is piped out to the natural gas mains. Solely from a tax point of view, it is relatively easy to keep the biogas or products thereof free from tax on the mains. This already takes place in other countries.

A national management plan for biogas will support the proposed initiatives

Solar cell technology and expansion potential

The IDA Climate Plan 2050 looks at solar cell plants covering 9-10 % of the electricity consumption by 2050. Well-positioned roofs on homes, industrial plant and public buildings and structures will be included. Renovations and investments in housing improvements will be coordinated with an investment in solar cells. An expansion plan will be established for public buildings and plants with a view to finding locations for larger solar energy plants.

Solar cell plants are relatively expensive at the moment. Nonetheless, the demand for solar cell plants on a world scale has in recent years far exceeded the production capacity which, among other things, has meant that the price of processed silicium on which the cells are based has risen from USD 32 per kilo at the end of 2004 to more than USD 150 in 2006[7]. This is not due to a lack of silicium, which is found in large quantities throughout the world, but exclusively to a lack of production capacity. The solar cells that are currently produced are based on silicium plates. However, the capacity is strongly increasing and the price is expected to gradually fall again as the production capacity rises.

The research into and expansion of solar cell plants is currently taking place principally in Germany, the USA and Japan, and is increasing in other Southern European countries. Denmark has one producer of silicium – Topsil, and a production of electricity converters for the electricity mains – Danfoss-Solar Inverters. 2nd and 3rd generation solar cell technology based on thin film or polymer technology is also being developed by Danish businesses and research institutions. Investments in and support for the innovation of these technologies is necessary for future Danish participation in the development of commercial plant.

Solar cells constitute a renewable energy technology that is expected to compete with conventional electricity within a few years, and for which a long term future is predicted as a significant element of both the EU's and the global electricity supply. In international studies, the global sales in the solar cell area are expected to exceed sales within wind energy by 2015 at the latest[8].

At the moment, the prevailing climatic conditions in Denmark may not seem to favour the use of solar cells; the fact is, however, that it is a question of values in line with the conditions in Germany, where around 200 times as many solar cells per inhabitant are installed than there are in Denmark, and where around 70.000 people are employed in the solar cell industry.

Solar cells are characterised in relation to other renewable energy technologies by being the only technology to be able to produce high value energy in the form of electricity and that can simultaneously be adapted to buildings and, as a distributed energy source, directly at the place of consumption. One fur-

6. Biogas consists of a mixture of methane and CO_2. The proportion can vary slightly over the year and the energy content per volume unit will therefore also vary. CO_2 must therefore be removed from the biogas so that there is only pure methane before the gas is sent to the natural gas mains. This so-called upgrading is still relatively expensive and costs around DKK 1.50 per m3 Natural Gas. This expense, together with a tax supplement, makes it impossible to use the solution.

7. Ingeniøren, 6 November 2006.

8. Photonics International, 2008

ther element worth emphasising is that the production profile for solar cell plants harmonises well with the prevailing electricity consumption profile. The solar cells produce electricity during the day when the electricity consumption is also at its highest.

STEEP LEARNING CURVES AND HIGH PRICE DROP EXPECTED

Based on learning curves (price per installed wattage) over the past 30 years' development of crystalline silicium cells, it is known that the annual price drops by an average of 20 %. However, it is difficult to predict whether or not this price drop will continue. In spite of the considerable annual price drops, electricity produced from solar cell plants is still significantly more expensive than electricity produced at traditional power plants, and the solar cell plants that have been established in Denmark thus far have therefore been established largely for purposes other than economic ones, including:

- On the basis of a desire to demonstrate environmentally friendly and climate-friendly conduct and/or to become partly self-sufficient in terms of electricity.
- Because the use of solar cells offers favourable opportunities in connection with the fulfilment of the energy framework conditions that are demanded in the Construction Products Directive in connection with new construction and major renovations.

Within a few years, however, the situation is expected to change radically, since solar cell plants are expected to make a breakthrough and the price is expected to fall considerably. It is thus expected that electricity produced from solar cells will be competitive with the consumer price upon the purchase of taxed electricity in Denmark within the period of 2015 to 2020, and that electricity produced from solar cells will become economically interesting around the year 2030 when the actual production price, excluding taxes, will be directly comparable with the equivalent for electricity produced by traditional power plants.

These projections are conditional upon a gradual implementation of the results of the research and development activity that is ongoing nationally and, in particular, internationally. So, continuous progress is being made within both the module area, where new types of thin film cells have achieved a commercial level in recent years and currently constitute around 10 % of new installations in 2008[9], and in the BOS area where new inverter technologies ensure optimal utilisation of the electricity that is produced. The development in thin film technologies and the major progress in the module area are leading to new integration opportunities in buildings and equipment and mean that use and expansion can take place more quickly than previously anticipated.

Another important parameter to assure a steady improvement in price/service is the reduction in expenses that appear in line with the increase in industrialisation and scale of the production process. Traditionally, the price per Wp has halved every 7 years, and on the basis of the development in recent years where annual growth rates of more than 40 % in production volume have been seen, this trend is expected to continue.

The above is reflected in a study put together at the request of the EU Commission[10], where the price of constructing a functional solar cell plant that is connected to the mains is expected to fall from EUR 3 per W in 2010[11], with EUR 2 per W in 2020 and to EUR 1 per W in 2030. The price development is a conservative estimate, and there are strong indications from the solar plants market that the price may fall further for both traditional silicium-based plants and thin film plants.

9. PA Energy 2009.
10. A Strategic Research Agenda for PV Solar Energy Technology
11. 22 500 DKK/W – at a price of DKK/€ 7.50

SOLAR CELLS INTEGRATED INTO BUILDINGS AND PLANT

The IDA Climate Plan 2050 looks at 10 % of the electricity consumption being based on solar energy in 2050. 5 % will be established as solar cells that are integrated into buildings, while the other 5 % will be integrated into public buildings and public plants (see chapter called "Buildings").

On the basis of the current solar cell technology plants and a total electricity consumption of 45 TWh in 2050, around 40 kmĐ solar cell plants need to be installed. However, with the expected increase in efficiencies in the plants and the continued development of plant types and possible integration into buildings, it may be possible to reduce the surface area that is needed.

From previous studies, it is estimated that Denmark will have a building area of around 150 kmĐ dedicated to solar cells, which is fully adequate to fulfil the above-mentioned area requirements without the need to involve areas that are currently used for other purposes.

The expansion of solar cells should be promoted by offering quotas for large solar energy plants as innovation markets with a fixed settlement price.

Wave energy – a possible forte

Renewable energy production using wave energy has not yet been fully technologically developed in full-scale plants and at an economically beneficial level. However, the collected energy potential of waves is far greater than that of wind. The energy is more stable, but the powers are far more difficult to "capture" and convert into electricity.

In spite of the technology being at its early development stage, there are good expectations for the efficiency of wave energy plants. The expansion of wave energy will also complement wind energy, since wave energy functions over longer periods and sees smaller abrupt fluctuations than wind, and its use is delayed to complement wind energy.

The IDA Climate Plan 2050 looks at wave energy covering around 5 % of the total electricity consumption by 2050, and at 700 MW wave power being installed by 2050. The share can be achieved only if the great expected operating efficiency of up to 40-45 % peak hours can be maintained.

WAVE TECHNOLOGY AND EXPANSION POTENTIAL

Denmark currently has around 9 initiators, a number of investors and at least one technological research institution working on developing wave energy plants. There are also a number of advisers who have great insight into the wave energy market. Denmark participates in the EU's wave power initiatives, but is also internationally recognised as being an active innovator on the development market. This position as an innovative wave energy nation is a good basis to create the first full-scale plant and achieve operational experience.

There are currently a good 200 creative proposals and plant types on a world scale, and plants that can produce on commercial terms have not yet been developed. The first foreign plants sold for electricity production were set up in Portugal where substantial grants are allocated towards the settlement price.

In contrast to the other renewable technologies, this technology cannot be continuously developed but has to be expanded slowly and made more efficient as experience is gained. Locating them offshore means that the plants will be designed according to the concrete terms at the concrete locations, and that maintenance, repairs and adaptations cannot be undertaken without considerable expenses. The technologies will be developed into operationally reliable full-scale plant before they can be positioned in the selected places, and the initial expenses are therefore relatively high before the first plant can be commissioned. On the other hand, functioning plants can quickly be scaled and adapted to other locations.

The potential of wave energy

- Denmark's electrical expenditure: 3,7 GW
- By the Danish western shore (offshore):
  - » up to 25 MW/km
  - » average about 16 MW/km
  - » About 150 km available ~ 2,4 GW
- In the North Atlantic by European shores: 25-75 MW/km
- The Mediterranian: 4-11 MW/km
- Total potentia by European shores: ca. 320 GW
- 10-30% of Denmark's expenditure can realistically be covered by wave energy

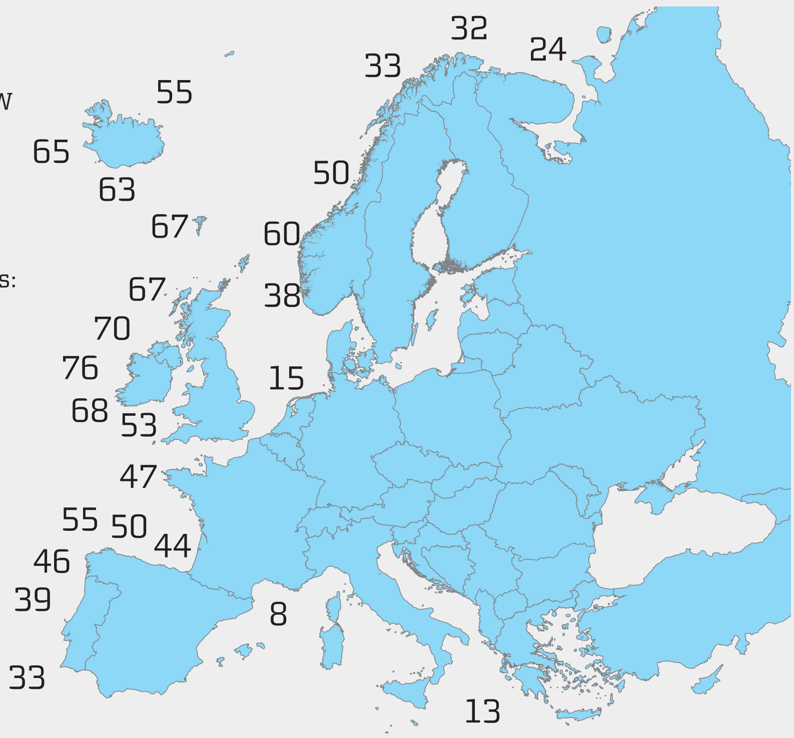


Figure 14: Wave energy. Source: Peter Frigaard, AAU 2006

In order to develop the technology, full-scale tests of a number of the most promising technologies will launched. There is a great need to test which of the technologies can withstand the wave power in the North Sea. The North Sea is also a good test location since the wave energy plants can be located close to the coast and the wave height is moderate compared with the big oceans. In contrast to the wind turbines, the development of wave plants may well consist of different concepts, all according to their geographical location.

The obvious thing to do is to locate wave plant close to other off-shore plants such as off-shore mill parks and platforms to minimise the infrastructure expenses for cables and connection to land. The maintenance can at the same time form part of the maintenance of the other plants, and the expansion can be undertaken concurrently with the off-shore mill expansion.

The IDA Climate Plan 2050 looks at selecting and investing in the most promising plants rather than investing in just one technology. The proposal is therefore to allocate substantial one-off amounts to demonstration projects. An allocation of DKK 75 million per year proposed is proposed regarding research, development and demonstration plants.

OPPORTUNITIES FOR A NEW BUSINESS ADVENTURE

Substantial investments are being made in wave energy. Based on the technology catalogue from the Danish Energy Agency, the price of construction is DKK 14 million per MWE, which is below the market's expectations. An installation of 700 MW makes the investment a good DKK 10 billion up until 2050, and the economy and viability of the plants depends greatly on the conditions persisting. The plants will produce 40-45 % during peak hours, there will be a high level of operational reliability and no major repairs and maintenance will be undertaken during that period. These are high requirements for a new, untried technology, but the expectation is that the technology can be developed up until 2050 if trials and tests of the first plant are launched shortly.

Production companies may be expected to be interested in investing in wave plant if the production conditions persist. The proposal is therefore to develop innovation markets where the market is initiated by offering a specific quota of 20 MW, for example, that assures a kWh price of DKK 2-2.50 per kWh in the plant's lifetime, for example. If there is interest from businesses that can produce electricity at the agreed price, the quota will be filled, otherwise not. Since the quota is small in relation to the total electricity production, its price effect at the proposed kWh price, after 5 years and with full utilisation of the quota during the period, will be around 0,02 DKK/KWh. At the same time, the different wave technologies will be in direct competition with one another, and non-viable concepts will gradually be weeded out. In the view of the Danes, supporting the development of wave energy provides good opportunities, like the windmill area, for creating a new business forte

Oil and gas – resources and recovery

Over the past 30 years, Denmark has gone from importing largely all of its oil and gas to currently being in the historic situation of producing considerably more gas and oil than it consumes, and oil has become one of Denmark's biggest export goods.

In relation to the IDA Energy Plan 2030[12] and the previous energy projection from the Danish Energy Agency, new agreements have been set up in the oil and gas area regarding the reduction of energy consumption for recovery. The expected development in energy consumption through oil and gas recovery will mean that industry implements a number of proposed savings using advanced techniques and technological improvements. In The Danish Energy Agency's new reference, energy consumption in the North Sea is expected to be around 30 PJ up until production ceases. The Climate Plan 2050 sets no additional targets for the reduction of energy consumption up until the production ceases. A brief description of the recovery is included in The IDA Climate Plan 2050, as the contribution thereafter is included in the calculation of the total greenhouse gas emissions and because oil and gas recovery is expected to occur for as long as production is possible.

Both oil and gas production are falling (Figure 15), but there are good opportunities for the Danish net self-sufficiency in oil to be maintained over the next 25 years (Figure 16) and in gas for the next 15 years, irrespective of what the oil and gas are used for. The level of self-sufficiency will be dependent upon whether there is success in finding and developing new reserves, increasing the level of recovery in the known fields and reducing the domestic consumption of oil and gas with renewable energies for example[13]. Reduction of oil consumption via innovation in the transport sector in particular will be able to delay the time for returning to the net import of oil by many more years.

Correspondingly, it will be possible to phase out the use of natural gas for heating and replace it by other heating sources such as geothermal heat, solar heat and geothermics. It will thus be possible to maintain the use of natural gas resources in electricity production for a further number of years without net import

12. Energy Plan 2030, IDA 2006

13. With the increasing oil price, some oil and natural gas resources will change over to being reserves. They will be available while being economically attractive to recover and can be put to use with more expensive efficient technology.

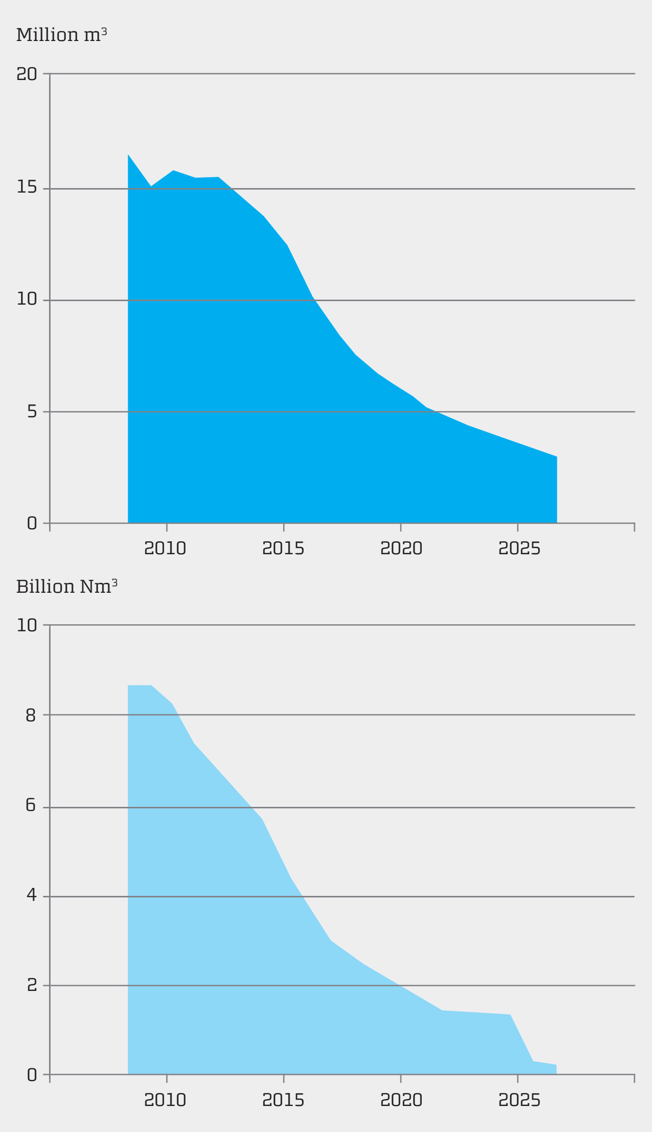


Figure 15: Forecast for Denmark's oil and gas production, if known reserves are taken into account
(the Danish Energy Agency 2008)

An improved level of recovery will be of substantial economic value. One percentage point of the level of recovery represents a value of DKK 40 – 50 billion. Around 60 % of the earnings from the North Sea will fall to the government, who are therefore very interested in a higher level of recovery. Greater recovery of oil and gas in Denmark is expected to be achievable through an increase in the level of recovery in the existing fields (the technology contribution), partly through exploration where more fields are expected to be found (the exploration contribution). The technology contribution is a way of saying that oil recovery techniques are being constantly developed. It is thought that the level of recovery with the long-term planning for use of advanced techniques may reach up to 50 % in new fields.

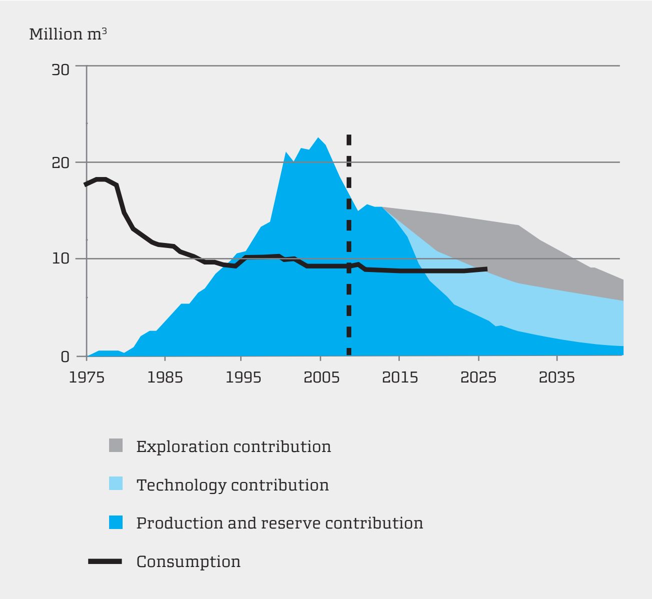


Figure 16: Forecast for Denmark's oil production and consumption. Reserve contribution is the expected oil production from known fields with known technology. Technology contribution is production as a result of expected improvements in recovery methods, etc. Exploration contribution is production from deposits that are expected to be found during forthcoming exploration activities. The expected oil consumption is given here as a direct projection of the current one. If the oil consumption falls, it will be possible to delay the time of the net oil import (the Danish Energy Agency 2008)

An oil field's production period is divided into three production phases. The tertiary production phase drives the level of recovery up very high by using a number of more advanced techniques, known as Enhanced Oil Recovery (EOR), such as steam injection, polymer injection and CO_2 injection. CO_2 injection works like an injection of natural gas in that the oil is forced towards the borehead. This will typically use 1-3 tonnes CO_2 per extra tonne recovered oil[14]. An action plan for technological development within oil recovery should be set up as is the case in Norway. The provisional plan is that by 2020, EOR will take place in the form of CO_2 injection (CO_2 storage and CO_2 WAG), water injection with production-boosting chemicals. Since several of the EOR methods are very energy demanding, CO_2 budgets and accounts should be used as steering instruments in connection with research into and development of EOR technology. The windmill industry is also demanding knowledge from the oil/gas sector for the continued expansion and requirements of off-shore plant.

THE POSSIBILITY OF CO_2 INJECTION AND STORAGE

Technologies, Carbon Capture Storage (CCS), for the collection, treatment and distribution of CO_2 have been developed where storage and use of CO_2 for oil recovery on land are concerned. The EU has worked for a long time with a demo programme where 12 full-scale plants will be erected around Europe, and in Denmark, Vattenfall is working to erect a plant north of Ålborg.

CCS consists concretely of "flue gas cleaners" that are inserted into the flue gas pipe between the power plant and the chimney and that can separate CO_2 for storage following compression. The separated CO_2 is stored underground, in sandstone or the equivalent that is characterised by having a covering layer that prevents the CO_2 from oozing up to the surface again. Worn out oilfields will often be used or new stores will be bored corresponding to the stores that have previously been used to store natural gas. Denmark is in a very good immediate location in relation to storage, among other things by virtue of the North Sea.

In oil fields the collected CO_2 can also be used to increase the recovery of oil, Enhanced Oil Recovery (EOR), by up to 10 %. There is no unambiguous environmental assessment of the risks of CO_2 storage, including technological and geological-related risks.

A number of different technologies for CO_2 recovery from point sources are being developed and the time perspective for these is estimated to be as shown in Figure 17.

2010

Post-combustion capture (collection of CO_2 following combustion).

2015

O_2/CO_2 recycle combustion (Oxyfuel) with capture (collection following combustion and partial recirculation of CO_2 as a part of the fuel).

2020

Pre-combustion capture – Integrated Gasification Combined Cycle (IGCC) (collection of CO_2 in connection with the gasification process for combustion).

2030

IGCC with Oxyfuel[15].

Figure 17: CCS Technologies

It is important that plans for CO_2 collection and storage are developed and assessed from a system perspective where the opportunities to collect and use CO_2 are simultaneously considered. Furthermore, technologies for the reduction of CO_2 emissions will be compared with other measures for the reduction of CO_2 emissions and energy savings and greater use of renewable energy.

One important problem is that the collection of CO_2 from power plants is a so called "add-on"- technolo-

14. Wolfram Kleinitz, Gaz du France. Edition Oil/Gas Knowledge Seminar 2006

15. Mogens B. Laursen, Dong Energy. Road map seminar, oil and gas, 2006

gy, that is very energy demanding, and will increase the fuel consumption of power plants by between 10 and 40 %[16].

The IDA Climate Plan 2050 contains a gradual phase out of coal, oil and gas at the same time as a phase out of a large proportion of the total emission of greenhouse gasses that occurs from various CO_2 sources. This means that the extent of future Danish CO_2 emissions that can be collected is limited, as the collection of CO_2 must necessarily occur from major point sources such as power stations.

Model calculations that are based on plans to extend the North Jutland market with CCS also demonstrate that it will not be expedient to implement CCS in IDA's Climate Plan 2050 for financial reasons[17]. No targets have therefore been included for the extraction and disposal of CO_2 in IDA's Climate Plan 2050.

If the technology is implemented to a greater degree at an international level, it can be expected that the upper CO_2 price in the future will be determined by the cost of CO_2 storage.

Adaptation of renewable electricity production in the energy system

The increasing quantity of fluctuating and fixed electricity production[18] creates a need for storage capacity in the energy system and flexibility in the use of electricity. At the moment, it is already sometimes necessary to export electricity at very low prices, known as electricity overflow. This takes place on a cold and windy winter's day where the wind turbines produce their maximum and the combined heat and power plants cover a substantial need for heating and production of electricity at the same time. If there is too great an electricity overflow, it will economically undermine further expansion of things like wind turbines.

The electricity overflow problem can be solved using different means – either by expanding and improving the transmission connections to Norway, Sweden and Germany or by creating a more flexible domestic energy system that can be adapted to the fluctuating energy production. The technological opportunities and economic conditions dictate that emphasis be placed first and foremost on the latter-mentioned.

The regional transmission companies and Energinet.dk have prepared a cabling handling plan in connection with the adoption of cabling, new and ongoing cabling as well as old transmission lines. The focus here is on the 132-150 kV transmission network. The plan shows that if replacement occurs over a 30 year period the network can be redesigned so that it supports much more renewable energy. The current electricity transmission network is originally based on the location of central power stations in relation to consumers in urban and industrial areas.

In connection with this it has been chosen consider

16. IPCC special report on Carbon Dioxide Capture and Storage, 2005.
17. Expert note "Consequence analysis of addition of CCS to IDA's Climate Plan 2050".
18. Electricity from renewable energy sources such as solar cells, wind and wave power, and electricity produced at power and heating plants where the electricity production is linked to the heating production.

the potentials for redesigning the total transmission network, and optimising this in relation to the massive extension in renewable energy, the location of future wind farms, electricity consumption projections including an expected increased use in electricity for heating supply and electric cars, and the integration of wind power. It is thus proposed that conversion be performed in connection with the principles for cabling and in connection with the extent of the remaining lifetimes in the existing system. The plans thus support the plans that the transmission company Energinet.dk has drafted for the transmission network and the conversions that are performed under IDA's Climate Plan 2050

Investment expenses in expanding the transmission capacity to our neighbouring countries are very high compared with the earnings from the export of "overflow electricity"[19]. The acute electricity market situation, where Denmark has an over-production of electricity and wants to export, can at the same time be expected to be compromised further in line with wind turbines being erected in North Germany, Norway and Sweden. With the measures that are initiated in The IDA Climate Plan 2050, Denmark will be assured of not being forced to export electricity at low market prices, but instead being able to export electricity to a lesser extent when the market prices are more favourable.

The expansion of solar cells and wave power means that electricity production from the renewable energy sources of sun, wind and waves will be levelled out. Wave energy plants will continue to produce for a while after the wind has dropped, and solar cell plants produce mainly in the summer where the other forms of production produce their least. A more varied mixture of weather-dependent energy sources is thus beneficial and must be encouraged in the long term, but will be far from solving the challenges in connection with the fluctuating electricity production. It will also be necessary to a far greater extent than is the case today to bring into play regulation capacity for the combined heat and power systems. Likewise, work must take place to create a more flexible electricity and heating consumption at consumer level.

Electrolysis and fuel cell plants are key to the power plant structure of the future

The principle behind electrolysis and fuel cells is that the electrolysis process produces a fuel that can be stored and used later in fuel cells. In this connection, the fuel cell can supply electricity when other renewable energy sources are not producing. The electrolysis process will be initiated when there is a surplus (electricity overflow) on the mains and thereby achieve a stabilising effect on the plants.

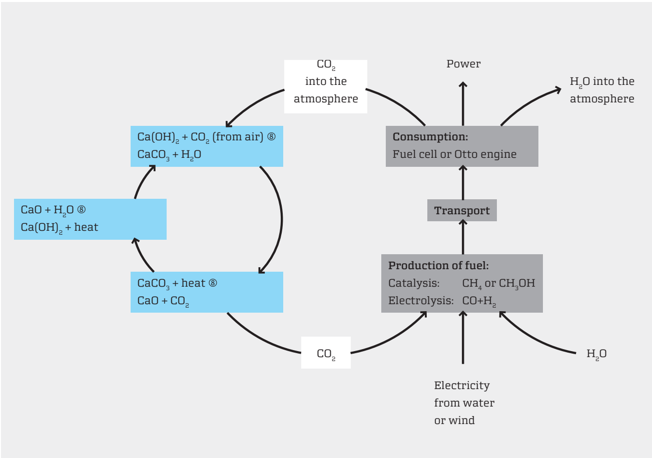


Figure 18: The electrolysis principle.
Source: Mogens Mogensen, Risø.

Fuel cells are a promising technology and fuel cell combined heat and power units will be able to offer rapid up-regulation and down-regulation of electricity and heating production independently of one another. Fuel cells are first and foremost characterised by having a very high electrical efficiency in relation to other combustion technologies and, in contrast

19. Report from the work group on power and heating and sustainable electricity. The Danish Energy Agency, 2001.

to other combustion technologies, they will be able to provide quicker and more flexible regulation between heating and electricity production without noticeable losses in the overall efficiency. Fuel cells at central and decentralised combined heat and power units can thus help to ensure energy-efficient flexibility in the energy system.

Fuel cells produce direct current that is converted to the electrical system's alternating current through an inverter. The inverter can also contribute to the necessary voltage regulation and stabilisation in the electricity mains and thereby replace other active units in the electricity the system, e.g. some of the thermal power plant units that are otherwise kept in operation due to the stability in the electricity mains.

The electrical efficiency of fuel cells is largely scale-neutral. However, it is possible to achieve even higher efficiency levels at large plants by combining them with gas turbine plants. Fuel cell plants are built up on a modular basis of many small fuel cells, and even small fuel cell plants have a high electrical efficiency. Fuel cells therefore also hold potential in relation to household-sized micro combined heat and power plants, which is an area in which several Danish businesses are investing. However, several analyses show that individual heating should in the future be based on geothermal heat plants or other heat pumps[20]. Individual micro combined heat and power plants are therefore assumed not to have been established in The IDA Climate Plan 2050.

The potential expectation is that SOFC fuel cell plants, for example, will be able to achieve electrical efficiencies of up to 60-70 % (today, they are at around 55-56 %) where the maximum expectation for plants with combined-cycle gas turbines is to achieve an electrical efficiency of around 60 %, and coal-based plants 50-55 %[21]. SOFC (Solid Oxide Fuel Cells) fuel cells also have the advantage that they can use different biofuels. For both combined heat and power, the fuel cell efficiency is as high as 90 %

Case	El Eff. %	Cogen Eff %
NG or SNG	56	90
Biogas 50 % CH_4/50 % CO_2	54	86
Methanol	54	90
DME	54	89
Ethanol	55	80
Ammonia	57	90
Diesel	40	90

Table 2: Fuel efficiency in SOFC.
Source: Haldor Topsøe. 2009

The fuel cell development over the past 10–15 years has progressed rapidly, and commercial fuel cell plants of both power plant and household size are expected to be on the market and ready for large-scale demonstration by 2015. The first place in the world for a factory with a production capacity of 5 MW/year to be established was Denmark in 2008. A factory with a capacity of 100-200 MW/year[22] is expected to be established in 2014 or 2015.

In connection with energy supply, we anticipate that the fuel cell technology will firstly be competitive within different niches and then within stationary

20. Heating plan Denmark, Rambøll, 2008, Fuel cells and electrolysers in future energy systems, Mathiesen, BV. 2008.

21. Energy Technology Perspectives, Scenarios & strategies to 2050. EIA 2006.
22. Based on information from Topsoe Fuel Cells

combined heat and power units. In the long term, the fuel cell technology may also be interesting within mobile uses, i.e. the transport sector, in connection with hybrid cars, for example, where the fuel cell unit will function as a charge unit for the batteries and thereby ensure longer distance than the purely electric cars. Niche uses for fuel cell technologies such as emergency power plants, hospital vehicles and power supply for portable uses will contribute to the general development of the technology, but if the fuel cell technology will help to solve the energy challenges, targeted investment will take place towards the development of these technology uses.

EXPANSION OF FUEL CELL-BASED COMBINED HEAT AND POWER PLANTS

The IDA Climate Plan 2050 looks at central and decentralised combined heat and power plants after 2015 gradually being replaced by SOFC fuel cell-based combined heat and power plants. This means that around 1/3 of the Danish combined heat and power plants in 2030 will be fuel cell-based[23], corresponding to an average yearly expansion of 150 MW.

Denmark has built up a comprehensive knowledge resource in the fuel cell area[24]. In research terms, Denmark is among the world elite, and a number of major Danish businesses are working actively with the area. There is extremely substantial commercial potential in the area in that fuel cells, by virtue of a high efficiency level, can be imagined to out-compete a large number of the current combustion technologies used in the energy system and in the transport sector.

In order to support the expansion of fuel cell-based combined heat and power plants and a development as described above, and to support Danish business development in the area, it will be crucial to establish a Danish plan for the development and expansion of fuel cells in Denmark. Such a plan will include significant funds of around DKK 150 million per year for test and demonstration projects in the area and incentive structures that include fixed electricity settlement prices to ensure the expansion of the technology. As of 2015, partnership agreements should be entered into with electricity producers where the government co-finances the erection of fuel cell combined heat and power plants with specified efficiency targets for demonstration and market technology market maturity purposes.

Heat pumps in the combined heat and power system

The Danish energy system is one of the world's most energy-economic, which is largely attributed to a comprehensive expansion of district heating that uses renewable energy and surplus heating, including combined heat and power. The level of expansion of district heating currently constitutes around 60 % of the heating market, and more than 95 % of the heating is produced using renewable energy or surplus heating, 81 % of which constitutes combined heat and power. This utilisation of marginal energy sources has been crucial to Denmark's gross energy consumption having remained largely constant over the past 30 years. The share of fossil fuel per m^2 of heated area has fallen to around half of the consumption 30 years ago, and it is still falling. It has therefore fallen by 30 % over the past 8 years[25]. It is important to maintain and expand this opportunity to improve the fuel efficiency of the system.

23. "Basic projection of electricity and district heating production 2005 –2025" for table on planned scrapping", Technical background report to Energy Strategy 2025. The Danish Energy Agency, 2005.

24. Primarily within the PEM (Proton Exchange Membrane) fuel cell technologies, a low-temperature fuel cell that functions on hydrogen, and SOFC (Solid Oxide Fuel Cell), a high-temperature fuel cell that can combust hydrogen, methane, natural gas, etc.

25. Benchmarking statistics 2005-2006. Danish District Heating

When in the near future electric cartridges are allowed for heating production in the district heating system, the fuel efficiency of the energy system will be significantly reduced. On the other hand, heat pumps in combination with central and decentralised combined heat and power plants can improve the fuel efficiency of the system.

Expansion of electricity-driven heat pumps in the central and decentralised combined heat and power plants constitutes an option to increase the regulation capacity of power plants and maintain the fuel efficiency of the system. Trials using simultaneous operation of heat pumps and a combined heat and power unit also show that the total efficiency of a plant can be increased[26]. This expansion will be especially beneficial to society.

In order to create the right framework conditions for an expansion of electricity-driven heat pumps, we are looking at combined heat and power plants being able to gain up to 10 % of their tax from self-produced electricity used in heat pumps for the production of district heating. It is thought that such a measure will make it economically attractive for combined heat and power plants to invest in electricity-driven heating pumps[27].

A radically changed energy system

The above gives a clear picture showing that the future's energy systems will be changed radically. The production of energy in the energy system will, as now, be based on a power and a heating share, but in order to achieve as flexible a system as possible, it is essential that these are not dependent upon one another. However, synergy between combined heat and power production will be used where this strengthens efficiency levels and energy utilisation by means of electrolysis plants, fuel cells and heat pumps for example.

The key factor is that the systems consist of a decentralised and distributed production based on a substantial range of technologies that will be integrated into an electricity mains and several heating mains. In this connection, there will be many production units or plants that will supply energy. Some of these will be very small and individually owned and run, while the majority can be large common plants run by smaller amalgamations of owners or major producers.

For supply and plant energy efficiency reasons, it is essential that the producers include reasonably-sized production companies that can ensure that the system has a continuous regulation capacity and basic production. The regulation and connection and disconnection of production plants corresponding to the consumption pattern will be essential to the stability of the systems. With many plants on the mains, it should be possible to monitor and regulate these as necessary, and a combined heat and power storage capacity will be built up during the over-production times for use in peak consumption hours. The systems will be built up as intelligently as possible and so that they are flexible and robust in the face of fluctuations in both consumption and production over hours, days and weeks.

Intelligent energy consumption and control

Expansion of heat pumps and fuel cell combined heat and power plants will make a significant contribution to more flexible electricity consumption, but it should be possible to further improve the energy system's efficiency and capacity to handle fluctuating production, and measures should be initiated to support flexible and price-sensitive energy consumption.

26. See The Danish Society of Engineers' Energy Plan 2030 (2006), Appendix, note 1.
27. See The Danish Society of Engineers' Energy Plan 2030 (2006), Appendix, note 1.

Today, the individual consumer pays a fixed kW price for electricity and district heating and, as a consumer, you cannot see the day-to-day fluctuation since the bill shows only the average. Businesses that are large consumers of electricity can purchase electricity from Nord Pool where the price is established one day beforehand on the basis of expectations regarding the day's electricity production and consumption. There will also be experiments with disconnecting major consumers against payment and as regulating power instead of starting up more plants during short periods.

Today's energy system has largely been developed at a time where the power of communication and calculation were not what they are today. There are no longer any technical problems in constructing an energy system with constantly varying electricity and heating prices where these are communicated to the individual energy consumers and where households or businesses adjust their electricity and heating consumption according to this.

In spite of a large share of the energy consumption being difficult to move in terms of time, there are good opportunities to move a share of the consumption in a shorter period, which will in particular be of great significance to the balance in the electricity system. For example, the electricity consumption in the total amount of refrigerators and freezers is so great that only a 15-minute interruption to the consumption (which would not lead to inconvenience for the consumers) will deliver the main part of Denmark's primary regulating power (220 MW). If the electricity consumption in industry's refrigerators and freezers is included, the figure is even higher[28].

The current plan looks at up to 80 % of private car transportation being electrified (see the chapter on Transport). Since cars are primarily used in the daytime and generally stand still for most of the time, the batteries in electrical cars are suitable for a flexible electricity system where prices vary. There will be good opportunities for the electric car being able to charge when the price is at its lowest and in the long term also function as regulating power and send electricity back to the mains if there is lack of capacity and electricity prices are high[29].

A number of production businesses will also have the benefit of moving their most energy-demanding processes to night time when the prices are generally lower. Major industrial businesses can also function as regulating power, since they can interrupt the production against payment if there is a sudden lack of capacity.

INITIATIVES TO PROMOTE AN ELECTRICITY MARKET WHERE PRICES VARY CONSTANTLY

Activation of the flexible energy consumption potential means that intelligent communication systems need to be developed that constantly communicate the current electricity and heating price, and that electricity and heating consuming devices and installations need to be equipped with electronics that mean that they can automatically react to the market situation. It is of crucial importance that the system can run as automatically as possible and that the consumer's comfort is not negatively affected.

In order to promote the development, it will be important for political initiatives to be taken to support the expansion of remotely read energy meters, and for requirements to be set for these stating that they can measure energy consumption by the minute. The proposal is therefore that a law set requirements

28. Adaptation of renewable energy in the existing Danish energy system. Peter Maibom, Department of Systems Analysis at the Risø Research Centre, 2005.

29. Energinet.dk has analysed whether or not electric cars and heat pumps can be used to take the substantial quantities of electricity overflow that occurs during periods and deliver it back to the mains during periods where there is a production shortfall. The conclusion is that this will lead to substantial CO_2 reductions and that it will be beneficial to both consumers and mains stability.

regarding the energy companies stating that during the continuous replacement of old electricity meters, they are replaced by energy meters that can measure by the minute and perform remote reading. The meters will also make the consumption visible so as to increase consumer awareness. For example, this can be done by showing day-to-day, weekly and yearly energy flows out of and into the house on a central display.

Under the auspices of Energinet.dk, it will be important to initiate development projects for an appropriate presentation of dynamic tariffs for district heating and electricity. Development work that aims to formulate and promote open communication standards in connection with home automation should be initiated as soon as possible with a view to establishing an actual market for equipment that can monitor, measure and control energy consumption according to the users' needs and according to relevant energy prices.

Since the market price of electricity constitutes only a small share of households' electricity bills, it will promote the flexible energy consumption if the tax system also follows the hourly prices and reflect the current production situation. It will be possible to introduce time differentiation for the tax on electricity so as to levy a higher level of tax on the more expensive electricity that impacts on the environment where further consumption requires investments in the mains or something else. Energinet.dk should take the initiative to stuffy whether or not time differentiation can be established for the tax on electricity that is yield neutral for the government from the start.

RESIDENTIAL HEATING OF THE FUTURE

Heating for mass housing is a considerable challenge in the transition from a fossil energy system to a renewable energy system. Denmark has been successful in increasing the number of square metres at the same time as causing the fuel consumption and the CO_2 emissions for residential heating to fall substantially. This has occurred through a combination of room heating savings and expansion of co-produced electricity and heating. At the same time as this development, there has been success with replacing oil for heating with other fuels and gradually introducing more renewable energy into residential heating.

Key questions regarding the residential heating of the future concern fundamental problems such as how will existing buildings be heated in the future? How will new buildings be heated in the future? How far can the district heating and block heating be expanded? How will buildings that are outside district heating areas be heated?

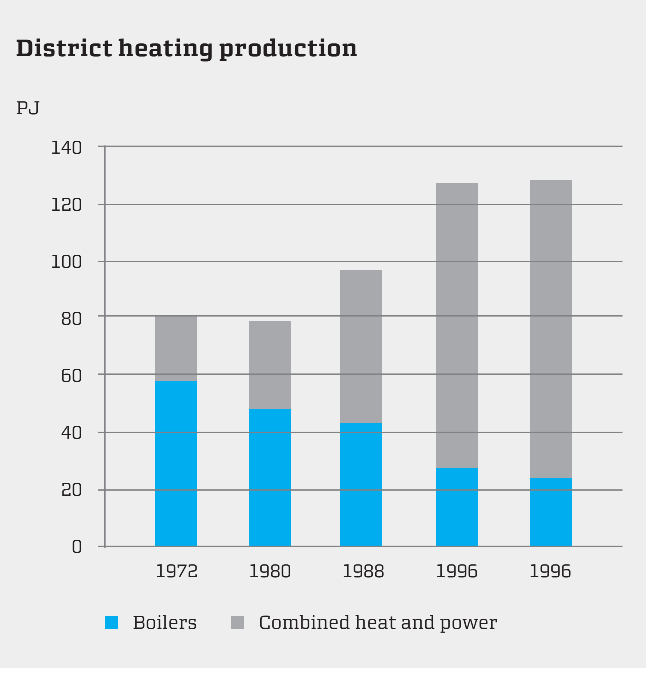
Flexible energy consumption is not only a possibility in the electricity system. There are also good arguments for district heating consumption to be made flexible, since hot water containers and underfloor heating can be used very well as energy stores and, due to the thermal inertia, are well suited to short-term interruptions.

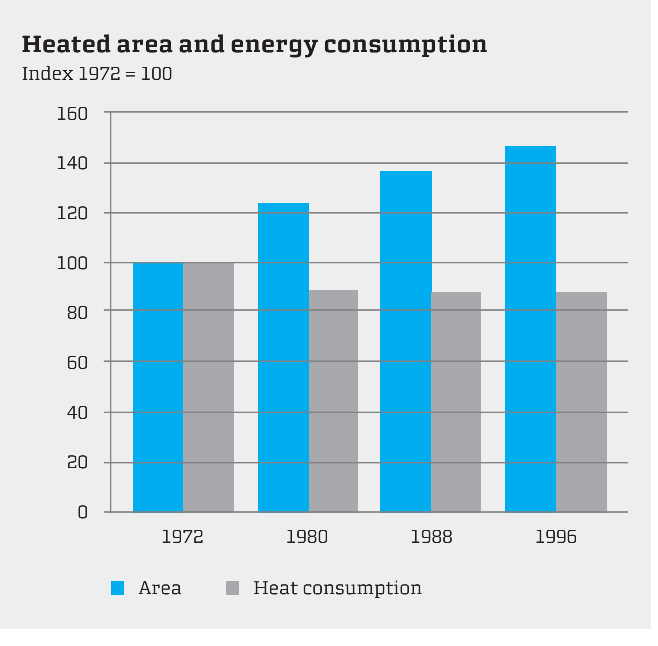
An overall analysis of energy savings and the above-mentioned problems has recently been carried out in Denmark[30] for an energy system that is gradually moving towards a 100 % renewable energy supply. At the moment, around 40 % of Danish homes are heated by natural gas, oil and biomass boilers and electric heating also in the vicinity of areas that have district heating[31].

30. Heating Plan for Denmark, Rambøll and AAU, 2008
31. Energy Statistics 2007, The Danish Energy Agency 2007

With regard to fuel efficiency, CO_2 emissions and economics, the analysis emphasises that it is a good solution to combine a gradual expansion of the district heating areas with the implementation of individual heat pumps in the remaining buildings. This also applies even though the buildings are gradually given better insulation and the need for heating is reduced. The analysis indicates that the most optimum approach is to expand the current district heating share of 46 % to somewhere between 63 % and 70 % of the net need for heating.

This expansion of the district heating areas and reorganisation to geothermal heat pumps is of short term benefit to the current system, but is also closely connected with a strong expansion of wind power in the longer term[32].





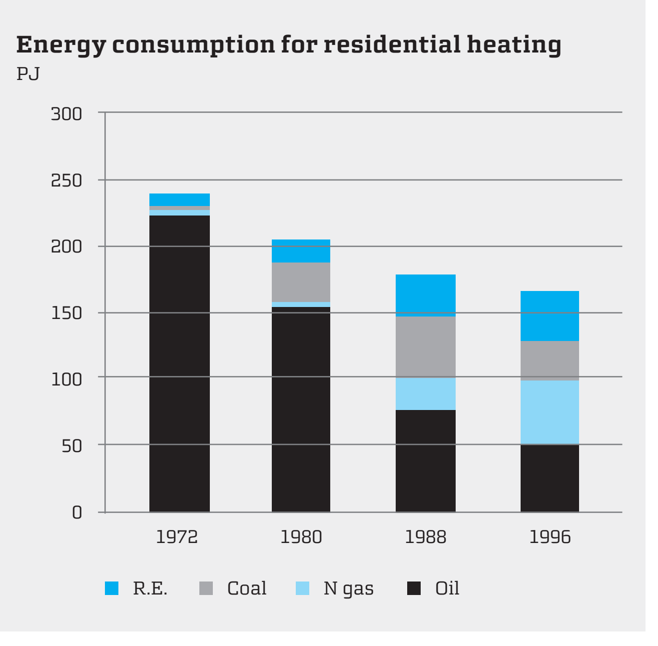


Figure 19: Heating area, district heating production and energy consumption for residential heating

32. Efficient use of wind-based electricity in Denmark, Energinet.dk, 2008; Heating Plan for Denmark, Rambøll and AAU, 2008

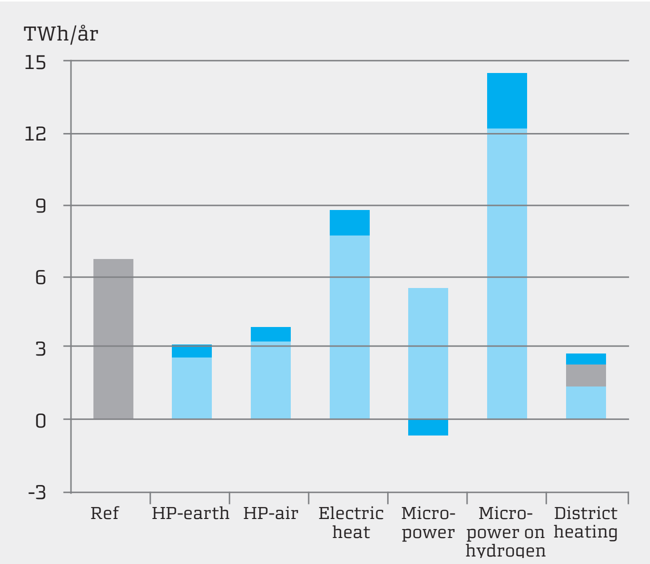


Figure 20: Fuel consumption in a 100 per cent energy system with the analysis of different forms of heating for boilers up to one kilometre from existing district heating areas and with 75 per cent room heating savings

Expansion of district heating areas

The IDA Climate Plan 2050 looks at the district heating areas gradually being expanded up until 2030 until they cover 70 % of the net Danish need for heating. It is assumed that the district heating will be expanded so that individual boilers up to one kilometre from existing district heating areas are supplied with district heating. The plan looks at sub-objectives of the district heating areas being expanded in 2020 to also cover neighbouring areas with heating boilers, i.e. areas that border on the existing district heating areas. Such expansions utilise the synergy effect by combining savings in room heating consumption and a lowering of the return temperature with marginal expansions of the district heating mains and adaptations of pipe dimensions and peak-load boilers. Energy savings have been made in some areas, but it has also been shown that the building mass is on the increase, so the energy density is still significant.

The gradual expansion of the district heating market share is summarised in the table below.

- The expansion in scenario 1 up to a 53 % market share is the most beneficial expansion that is very economically advantageous with the current fuel prices.
- The further expansion from scenario 1 to 2, from 53 % to 63 %, is both beneficial and could be implemented by 2020 subject to increasing fuel prices.
- The further expansion from scenario 2 to 3, from 63 % to 70 % by 2030, will be beneficial only if the fossil fuels are to be completely phased out and the fuel prices rise further.

One of the greatest challenges in the municipal heating planning will be to arrange this expansion in an optimal way and achieve the most beneficial area delimitation between the collective district heating and block heating plants and the individual heat pumps.

Current need for heating	District heating market share	New district heating GWh/year
Reference	46 %	
Scenario 1	53 %	4.746
Scenario 2	63 %	10.205
Scenario 3	70 %	15.364
Fra 1 til 2		5.459
Fra 2 til 3		5.159

Table 3: Gradual expansion of the district heating market share with regard to the Heating Plan for Denmark.

Reorganisation to low temperature district heating and the possibility of decentralised production

In combination with the expansion of district heating areas, the proposal is for district heating to also be reorganised to operate at low temperature. This means that the end consumers will be better at using the district heating so that the return temperature becomes lower and the highest requirements regarding flow temperature are lowered.

According to the Heating Plan for Denmark, this can take place with a combination of technical improvements to the heating installations in housing and an incentive structure in the form of tariffs that promote conduct that lowers the temperature. Lowering the return temperature to 30-35 ºC will lead to savings and thereby the possibility of supplying more homes with the same district heating. It will also lead to lower expenses in investments in district heating, lower operating expenses and more efficient production from combined heat and power, large heat pumps, geothermics, solar heat, industrial surplus heating and condensing boilers, etc.

There is a need to develop concepts for the way in which low temperature heating plants in low energy structures can be most efficiently designed in cooperation with the district heating supply so as to minimise the total expenses (e.g. underfloor heating that is distributed along the length of terraced houses as an alternative to traditional plants). It is therefore a challenge for parties involved in the construction and the district heating companies to design simple, efficient waterborne heating plants in cooperation with the district heating in new low energy buildings. The most crucial thing to ensure suitable and appropriate replacement is for long-term politically binding agreements to be entered into regarding reductions in heating consumption and return temperature in buildings so that the district heating producers know the need for the future in plenty of time and can therefore dimension their new plants and pipes to this.

Where new buildings are concerned, the fact that fuel savings in the district heating systems cannot be included in the energy framework constitutes a source for socioeconomically erroneous investments in the housing sector. It is therefore crucial from a socioeconomic perspective for the building regulations' energy frameworks to also be extended to include surplus heating and solar heat, etc. from the collective systems.

At the moment, decentralised areas are being established for producing district heating from solar heat, for example. These concepts lead to the possibility of reducing the pipe dimensions and creating large solar heating plants that have lower expenses, for example.

District cooling technology

Today, cooling is used in many different buildings, primarily shopping centres and office properties. The need for cooling has been increasing with new methods and forms of construction and in the denser urban areas. The cooling will typically be produced by more or less individual cooling machines that are run on electricity. The individual cooling can be replaced by common cooling. District cooling will in principle only be a possible solution in large urban concentrations with a substantial need for cooling, irrespective of whether or not the technology can be introduced overall.

The definition of district cooling is the production and distribution of cold water through a district cooling pipe system (the distribution mains) where the cold water is produced by central and decentralised cooling centres respectively. The idea behind district cooling is to use as many resources as possible so as to minimise the energy consumption. These resources are things such as waste heating, combined heat and power, solar heat or free cooling. Free cooling is the utilisation of a local resource in the form of off-shore, ground or sea water that can be recovered at a useful temperature for cooling purposes, i.e. a temperature that is lower than the return temperature so that the recovered water can be used to cool the return water. This then means that a share of the cooling energy can be produced without using energy. There are district cooling methods other than free cooling, but free cooling is thought to have the greatest potential.

A district cooling plant will distribute cold water to the consumers' cooling surfaces at a flow temperature of around 5 degrees C. The return temperature will be around 15-20 degrees C. A new pipe system will therefore be constructed for a district cooling plant. Since district cooling works with a temperature differential of 10-15 degrees C, the dimensions of such a pipe system will be relatively large. Large district cooling plants will therefore need more cold water production places than we see for production places in a district heating system.

INSTALLATION AND CO_2 DISPLACEMENT

The adoption of "the Municipal District Cooling Act" of 17/06/2008 opened up the way for the possibility for municipal heating plants to establish district cooling companies. However, the Act has not removed all obstacles since district cooling is not likened to other energy supply types because district cooling is not covered by the credit line ministerial order.

If district cooling is produced using free cooling, solar heat or by using surplus heating, this will not, over and above some flow to some pumps, lead to any extra fuel consumption since the surplus heating will instead have been cooled away.

A fully expanded district cooling system will lead to a saving of 235 935 tonnes CO_2 per year, which corresponds to an investment of DKK 5 948 per saved tonne CO_2 with a lifetime of at least 10 years, corresponding to a total saving of 2 359 346 tonnes CO_2. (Budget figures from a known large plant in the capital city area were used for the calculations and should be seen as a product thereof.) It can be concluded that the biggest saving from district cooling plants comes from the free cooling's share of the total cooling effect.

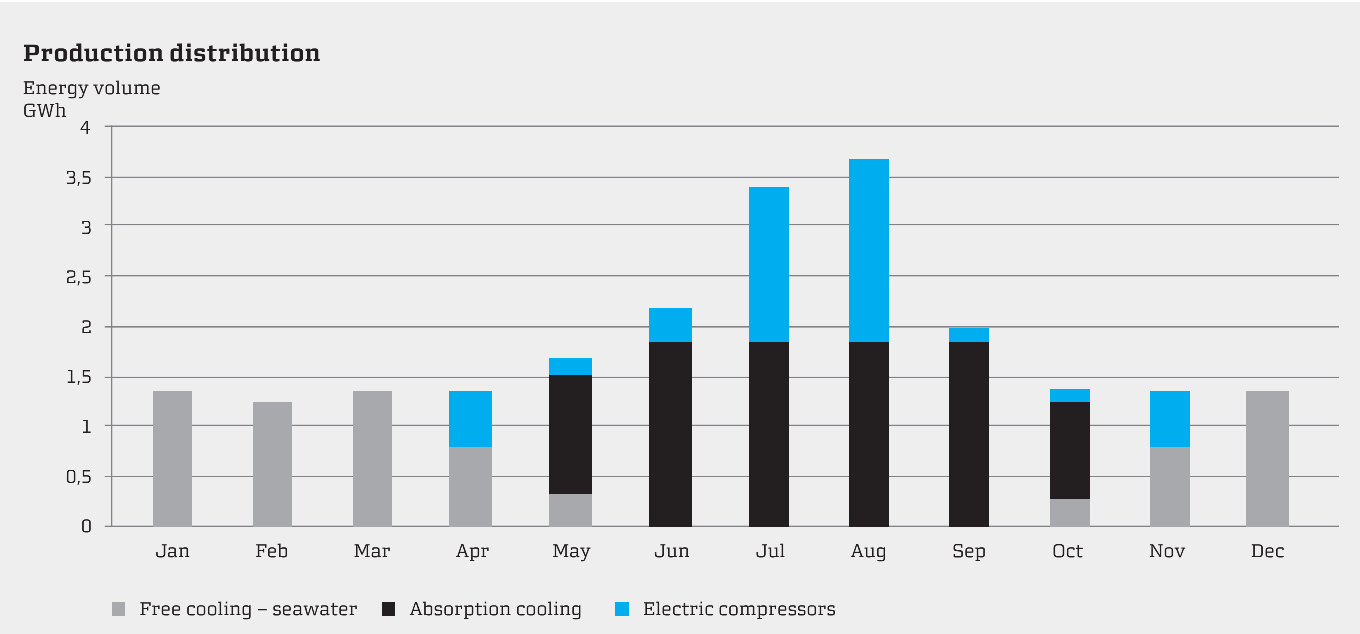


Figure 21: The distribution of cooling production among production methods over the year for a known district cooling plant.

REORGANISATIONS OUTSIDE DISTRICT HEATING AREAS TO GEOTHERMAL HEAT AND HEAT PUMPS

Heat pumps are an efficient way of heating a house in areas that are not supplied with district heating. The conditions are that the heat pump must have a high level of efficiency, be based on geothermal heat (to ensure a high level of efficiency), and supply hot domestic water and heating throughout the building so as to avoid direct electric heating and electricity panels and so that the heating is distributed through a central heating system at a low temperature. The high level of efficiency should be ensured through product standards.

According to Energinet.dk, it will also be very beneficial in the long term if the heat pumps can be interrupted during periods when electricity prices are high, typically during periods where the wind power is at a minimum.

Heat pumps currently have a very low coverage in Denmark. With sharpened requirements for the total energy load for new buildings, it can be expected that efficient heating pump systems will be important in new construction and renovation. This tendency is seen already today in connection with the latest types of house.

It is proposed that 90 % of all current boilers outside the areas that cannot be supplied with district heating be replaced by heat pumps, 80 % of which are geothermal heat pumps and 10 % air to water heat pumps, both on a gradual basis up until 2020. The remaining 10 % are assumed to be biomass boilers. All electric heating outside the district heating areas will be converted to air to air heat pumps. No further changes are implied up until 2050.

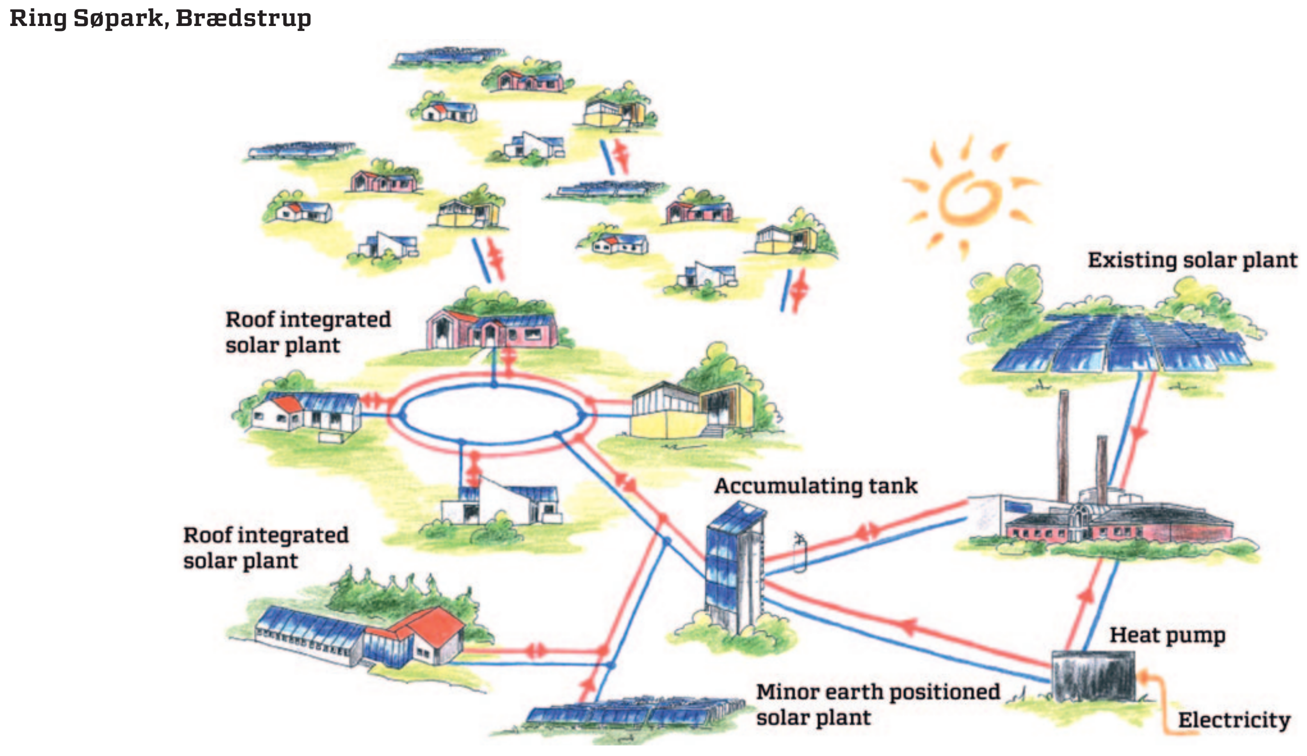


Figure 22: 2. Generation district heating concept in Brædstrup

Solar heat

Solar heat makes an important contribution to reducing the use of fossil fuels in the short term, but also helps in the longer term to reduce the consumption of biomass. There is great potential for solar heat in Denmark, and the price of solar heat plants has fallen considerably so plants can currently compete with conventional technologies. This applies to both small, individual plants and to large plants for district heating production.

The Danish District Heating Platform's aim is for 50 % of the need for heating to be covered by solar heat in 2050. The Climate Plan 2050 looks at a less ambitious target but an economically more viable solution of a total of around 30 % solar heat coverage in 2030[33].

The expansion of large solar heating plants for the district heating mains is most beneficial in that district heating often has heating storage and because large-scale plant and heating storage for district heating is more cost-effective than individually-based solar heating systems. The Heating Plan for Denmark[34] estimates that up until 2030, 4 million m^2 large-scale solar heating will be established for district heating mains that do not already have a surplus of CO_2 neutral surplus heating in the summer.

Outside district heating areas, solar heat will be integrated into the roofs of buildings or small local systems will be created where large-scale operating advantages can be gained. The idea is that 90 % of the buildings outside the district heating system will have had solar heat integrated by 2030. Half of these plants are dimensioned so that they cover 20 % of the building's total need for heating and are located together with disconnectable heat pumps and biomass boilers. The remaining half of the plants is dimensioned so that they cover 40 % of the building's total need for heating and are located in areas with boilers. This is an ambitious objective, but a significant expansion of individual plants is already currently taking place, and this development may be assumed to continue in line with the fall in the prices of solar heat plants[35] and the setting of further requirements regarding the buildings' energy supply.

For individual plants, heat pumps and solar heat can be beneficially combined with a heating accumulator that can increase the efficiency of heat pumps[36]. These plants have not been implemented here, however.

In order to ensure expansion and the use of solar heat, requirements should be set regarding the use of thermal solar heat outside the district heating areas, and energy legislation and construction regulations should be adapted so that energy saving requirements can be fulfilled collectively in areas that have a common supply based on renewable energy sources and waste heating.

WASTE-FUELLED COMBINED HEAT AND POWER

The waste quantities are expected to fall by around 1/3 up to 2040[37]. This assumes that a greater and greater share can be reused, but it also assumes that the part that is not reused will go towards combustion.

Up until 2050, the expectation is that the efficiency level of electricity and the total efficiency level will increase significantly by virtue of the fact that all new plants are combined heat and power plants, that low temperature district heating has been promoted, that the technology continues to improve, and that new plants have flue gas condensation or condensation with the help of heat pumps. It is also assumed that cooling away in the summer can be removed through a combination of the following measures:

33. In 2020, it is assumed that half of the necessary plants will have been erected, but no further expansion is implied after 2030.
34. Heating Plan for Denmark, Rambøll and AAU, 2008

35. Integration of thermal solar heat for both water and residential heating in construction can on average be implemented for DKK 35 000 per building (home) at 2006 prices and is expected to fall to DKK 25 000 per building during 2030-2050.
36. An example is the SUNWELL concept, developed by N. K. Knudsen.
37. Heating Plan for Denmark

- improved intermediate deposition, and/or sorting of organic waste
- transmission of surplus summer heating to neighbouring cities
- seasonal storage of heating in dam storage in connection with geothermics.

GEOTHERMICS

Geothermics are currently utilised in two places in Denmark – in Thisted since 1984 and in the metropolitan area of Amager since 2005, and a total of around 1/3 PJ is produced. However, the potential to use geothermics in Denmark is far greater. A survey of the potential in Copenhagen showed that the reserves constituted 60 000 PJ as the reservoirs are heated from the surrounding layer, which must be compared with an annual need for 30-40 PJ of heating.

In theory, the whole of the Danish district heating need of around 120 PJ can be covered by heating from geothermics. However, it is not viable or physically possible to establish a geothermic plant in all places. It is thought that between 25 and 40 PJ of the need for heating can be covered by geothermics by 2030[38] and, with further collection of experience and technology development, this share can be increased by 2050 according to needs, and be combined with the other heating sources such as waste heating. Geothermic plants are currently competitive in many places. It is expected that with the increase in experience, new drill technologies and "the incorporation" of heating storage, the plants will be profitable in a large number of areas where they are not today.

A geothermic plant can supply around 5 000 households, and it is thought that cities like Ålborg, Brønderslev, Frederikshavn, Helsingør, Hillerød, Hjørring, the capital city area, Næstved, Randers, Ringsted, Slagelse, Sønderborg, Thisted and Århus can be supplied with heating from geothermic plants. Drilling normally takes place down to a depth of 1-2.5 km and the water is normally between 35 and 80 ºC. The heat pumps for geothermics are normally run on 160 ºC heating from a combined heat and power plant or otherwise.

Geothermics also have the advantage that they can be used together with a storage hole for surplus heating from things such as combined heat and power from waste or from heat pumps. Around 90 % can be returned and reused. Experiments with seasonal storage are still lacking, however.

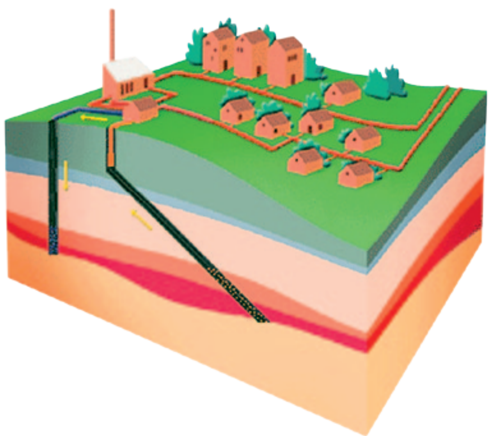


Figure 23: Geothermic plant model

The IDA Climate Plan 2050 assumes that geothermics will cover 15 % of need for heating in central combined heat and power areas in 2030, corresponding to the establishment of around 8-10 plants in the large cities and 10 % in decentralised combined heat and power areas (number of plants depends on local conditions). A storage option will also be established in combination with combined heat and power from waste, so that all surplus heating from combined heat and power from waste can be seasonally stored in 2030 in Ålborg, Århus, Esbjerg, Odense and Copenhagen. In 2020, it is assumed that half of these plants will be established, but no further expansion is anticipated up until 2050.

STRATEGIC HEATING PLANNING

One condition to ensure the abovementioned reorganisations and expansion of the heating system so as to make it as efficient as possible is that both national and local heating planning be drawn up.

38. Jesper Magtengaard, Dong Energy and *www.geothermics.dk*

Geothermics in Denmark

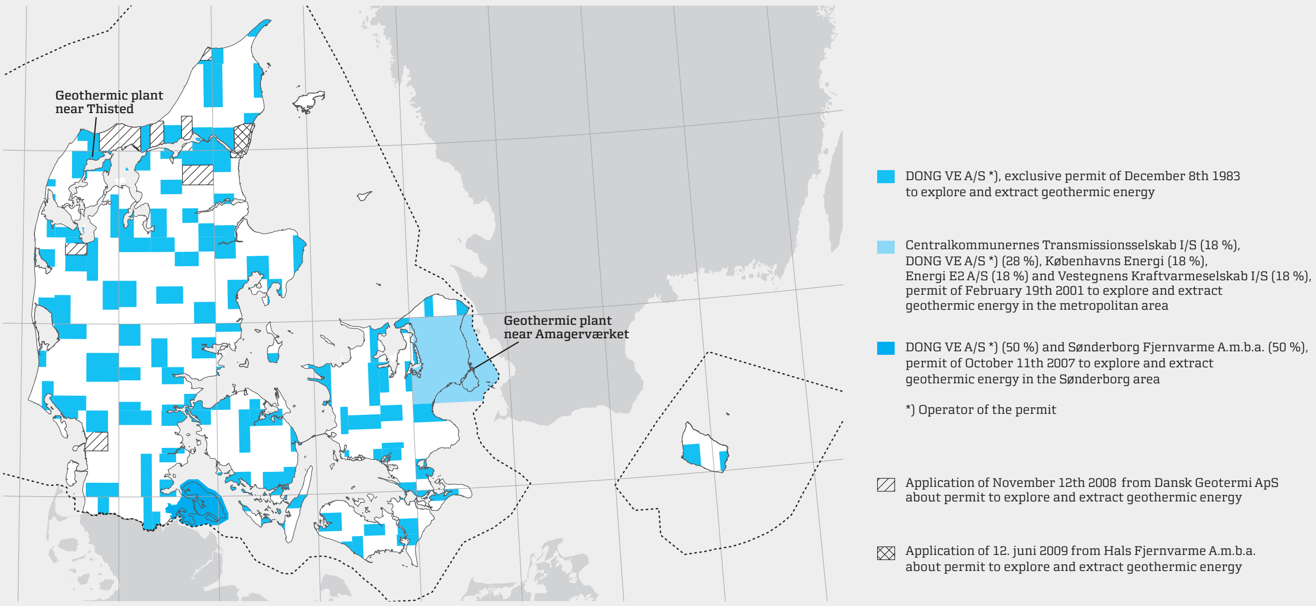


Figure 24: Geothermics plant and permits in Denmark (The Danish Energy Agency 2008).

The purpose of the Heating Supply Act must be extended with a view to satisfying the thermal comfort in buildings in the best socioeconomic way and with the long term aim of reducing the emission of CO_2. The socioeconomic evaluation must take into account the opportunities within all relevant areas, including heating, cooling, electricity and weather screen.

The national strategy will mark out the frameworks and the local heating planning will support the national targets based on local calculations. The technological terms require the implementation of long-term planning that takes into account the fact that it takes between 4 and 6 years to establish geothermics, for example.

Nuclear power

Nuclear power is not included in Danish energy planning and will not be included in IDA's Climate Plan 2050.

There are several reasons for this. The construction price of a nuclear power station is high. The plants are most suitable for continuous production for basic load operations for business and operational purposes. The plants are not optimal for flexible and fluctuating energy production (with wind), which constitutes the backbone of IDA's Climate Plan 2050.

In addition a discharge of CO_2 occurs in connection with the mining and enrichment of uranium. Furthermore, Denmark has no commercial competence of significance in the area.

Neither is it likely that Denmark has geologically secure waste disposal locations and thus agreements with other nations would be necessary, which would create an uncertain situation. Secure transport and secure waste disposals have thus not been completely solved even where other nations have plans for disposal in bedrock and equivalent geological occurrences.

Agriculture, foods and materials

Summary:
Agriculture, foods and materials

Intermediate objectives, Climate Plan 2050

2015

- Drained soil removed from agricultural operations
- Reduction of nitrogen surplus in agriculture
- Better feed practice with emphasis on a lesser impact on the climate
- Doubling of the organic agricultural area
- Reduction of 1.6 million tonnes CO_2 equivalents from agriculture and food production in Denmark.

2030

- Quadrupling of the organic agricultural area by around 25 %
- Reduction of 5 million tonnes CO_2 equivalents from agriculture and food production in Denmark.

2050

- Increase in biomass production on land to around 200 PJ and of marin biomass from algae to around 100 PJ
- Reduction of 9.5 million tonnes CO_2 equivalents from agriculture and food production in Denmark.
- Impact on the climate from diet will be 0.9 tonnes CO_2 equivalents per Dane per year for Danish and imported foods.

MEANS

- Reduction of impact on the climate from agriculture should be integrated into the agricultural policy and into the principles for the allocation of agricultural support and used to promote the implementation of a number of environmental and climate measures in agriculture.

- Natural carbon capture, i.e. greater CO_2 uptake in plants and carbon binding in the soil, should be part of a future integrated nature and agricultural policy and be promoted through changed criteria for the allocation of agricultural support, which is something that the EU is already open to.

- The implementations of initiatives that promote healthy and climate-optimal diet and reducing household food waste. This can be done through information campaigns, cook books, food price mechanisms, etc. aimed at households, retail, the food industry and restaurants and canteens. It is estimated that there is need for a permanent contribution of around DKK 50 million per year, incl. resources, to continuously analyse the experiences and further develop the activities.

- All biomass initiatives should be environmentally and socially assessed from a global lifecycle perspective. There is a need to develop legal frameworks for municipalities' and businesses' involvement of citizens, environmental organizations etc. in planning and evaluation of biomass initiatives.

- A research and innovation programme for multiannual energy crops will be implemented with a view to developing and using methods for analysing environmental (including ecological, natural, bio diversity and material flow) and social aspects of Danish production of this form of energy crops.

- A research and innovation programme for marine based production of biomass from algae will be implemented with a view to implementing environmental and socially renewable Danish production of biomass from algae.

- Research and innovation programmes for biomass based materials and products from biomass for agricultural, forestry and marine areas will be commenced. The programmes must be based on involving commercial and environmental organizations and must be focussed on integrated environmental evaluation of innovation processes and the development of strategies for market development of various biomass based materials with a view to reducing environmental and climate impacts from the production and consumption of materials and products. A requirement of approximately DKK 200 million per year has been estimated.

- Development of long-term strategy for Danish agriculture that is based less on animal production and more on a combination of vegetable and animal products as a part of climate optimisation and the safeguarding of employment and export. A 10-year development programme should be initiated with a grant of DKK 15 million per year with the establishment of a dialogue forum and economic funds to give interest groups the possibility of initiating analysis and dialogue projects.

Agriculture, foods and materials

The use of surface area in society, including agriculture, is in practice a competition between different purposes. The limitations constitute many factors – environmental requirements, aesthetic requirements, organic opportunities, economic opportunities and other social factors. Agriculture currently produces and is also expected in the future to produce raw materials for foods, energy and materials in cooperation with a number of industries.

Agriculture as producer of foods, energy, feed and materials

Opportunities to reduce greenhouse gas emissions from the production of foods, energy, feed and materials depend on the conditions that are set up for future production and consumption:

- Will the food production have the composition that it has today where 80 % of the agricultural area, both globally and in Denmark, is used for the production of feed for meat production?
- How will nature and environmental requirements in the Water Framework Directive, the Biodiversity Convention, etc. be satisfied?
- How will soil quality, including building up and maintaining the carbon content in the soil, be assured in the long-term?
- How large a share of the energy supply will depend on biomass?
- Will Danish biomass also be able to supply Denmark with materials for construction, household products, etc.?

The impact on the climate from agriculture and foods can, as for all other sectors, be calculated on the basis of both a production and a consumption perspective[39]. Calculations of Danish agriculture and food production impacts on the climate from a *national production perspective*, which is the perspective that is used in the Kyoto Treaty, i.e. including foods for export, but excluding feed importation, etc., around 2006 show a total impact on the climate of around 19 million tonnes CO_2 equivalents per year. Of these, around 12 million tonnes of the non-energy-related constitute contributions from domestic animal digestion, various decomposition processes linked to the use of manure, and changes in the use of soil and the significance of this to CO_2 uptake and release, while around 7 million tonnes CO_2 equivalents originate from energy consumption in agriculture and the food industry.

If Danish agricultural and food production impacts on the climate are calculated from an *international production perspective*, a climate impact from the importation of foreign feed will be added, which is around 25 % of the total feed consumption, corresponding to around 16 million tonnes CO_2 equivalents per year. This means that dansih agriculture seen in a international perspective has a total impact on the climate of 35 million tonnes CO_2 equivalents per year.

The biggest contribution to the impact of agricultural and food production on the climate in Denmark constitutes domestic animal digestion, laughing gas from the leaching and evaporation of nitrogen compounds, oxidation of carbon in humus, storage and delivery of domestic animal manure and artificial fertilizer and the energy consumption in agriculture and industry.

39. The latter-mentioned also called an end user or end consumer perspective

If you calculate climate impacts from a *consumption perspective* and look at the impact on the climate linked to the Danish food consumption (i.e. including the importation of feed and foods, but excluding food exportation), the climate impact is around 2,8 tonnes CO_2 equivalents per Dane per year, corresponding to 15-16 million tonnes CO_2 equivalents per year for the Danish population's total consumption.

The analyses presented later in the chapter show the way in which the impact on the climate from Danish production and consumption of foods can be reduced by reducing food waste, changing dietary habits as regards the national dietary advice, i.e. including less consumption of dairy products, meat and meat products and greater consumption of vegetables and certain types of fish, and a more environmentally friendly agricultural practice. The potential for reduction depends on how a change in dietary habits of the Danish people affects the total future Danish agricultural production: if a reduction in the Danish consumption of animal foods does not lead to reduced production but leads to an increase in the exportation of the same products, the reduction of the climate impact will be considerably less.

There is an opportunity for an increase in the production of biomass from the current agricultural area – over and above the production of foods (from a calorific content of around 87 PJ to around 207 PJ) – corresponding to an increase of around 120 PJ. Add to this that it is deemed possible to produce biomass from Danish marine areas in form of algae corresponding to a calorific content of around 100 PJ. The way in which this increase in the production of biomass will affect the climate impact from Danish production and consumption depends, among other things, on the types of biomass concerned, including which CO_2 binding is achieved through cultivation and the way in which the biomass is used. If no greater CO_2 uptake in plants is achieved and biomass are used to a great extent for combustion, the reduction of the climate impact will be limited.

The IDA Climate Plan 2050 proposes that the biomass be used for a combination of feed, manure, and biomass-based materials (discussed in this chapter) and combined heat and power production in biogas plants (see chapter on energy systems and energy production), and biofuels for transport (see chapter on transport). In The IDA Climate Plan 2050, the future production of biomass-based materials is analysed through calculations of the need for biomass and agricultural area linked to a few examples of possible future biomass-based materials.

Looking at Denmark in isolation, as proposed by the Kyoto Protocol, is slightly misrepresentative since both foods and biomass are international products. There will also be competition between different utilisations of biomass (feed/foods v energy v materials), so energy crops will compete with energy crops from other places in the world. Conversely, on the basis of principles of recirculation and proximity and on the basis of a desire in the future not to solve the Danish climate commitment by simply importing materials from larger foreign areas than today, it is important to analyse the climatic aspects of Danish agriculture. It is therefore necessary to carefully assess the future production of different types of foods and biomass and the extent to which this will lead to competition for acreage on land and at sea , nationally and internationally. Evaluations of the environmental effects of changes in the production and consumption of different forms of foodstuffs and biomass with a view to affecting emissions of greenhouse gasses, nutrients and pesticides, biodiversity and the ground water status are also required.

One basis for the development of a climate strategy for agriculture, foodstuffs and biomass for energy and materials has therefore been that the climate impact must be reduced without negatively effecting other environmental parameters, as well as the fact that cultivated land in Denmark must not be "increased" and thus more foreign land be cultivated than previously.

Impact of foods on the climate

Seen from an earth to table perspective (lifecycle perspective), foods contribute to the climate impact in all ways. The main types of contribution in the different parts of a general "from earth to table" food product chain are seen in Figure 25 and 26.

Agriculture and fishing

- CH_4 from domestic animals and domestic animal manure
- N_2O from application and decomposition of domestic animal and commercial fertilizer and leaching of nitrogen from the soil
- CO_2 from combustion of carbon in the humus layer of the soil, including CO_2 from changes in area use (e.g. felling of forest for the cultivation of crops)
- CO_2 from direct energy consumption for machines, etc.
- CO_2 from indirect energy consumption for the production of aids, particularly fertilizers

Figure 25: Climate contribution from agriculture and fishing.

Food production

- CO_2 from direct energy consumption (depending on energy source) for processing and storage
- CO_2 from indirect energy consumption for production of packaging

Food distribution

- CO_2 from transport (depending on engine type and fuel)
- CO_2 from direct energy consumption for storage

Food consumption

- CO_2 from transport in connection with purchase (depending on type of transport and fuel)
- CO_2 related to direct energy consumption during storage and preparation

Figure 26: Climate contribution from food.

The size of the climate impact from the various stages of a product chain for a foodstuff depends on the efficiency of the different processes, i.e. which waste occurs, e.g. in the form of foods that are discarded in connection with distribution and consumption.

The climate impact from the overall food sector depends on which foods are produced and in which quantities. There is thus a substantial difference in climate impact from different types of food, something that is illustrated by the following CO_2 pyramid where a number of foods are located according to their impact on the climate, so products with the biggest impact per kilo are located a the top. As shown by the pyramid, a number of animal products have a relatively high impact on the climate while there are differences within the individual food groups[40]

40. Updated figure from Philip G. Lund & Lars K. Madsen. Climate Effect of Meals, Project, DTU Management 2008, which illustrates the difference between climate impact within and between different groups of foodstuffs. The figure is first and foremost based on figures for energy consumption from Carlsson-Kanyma, Ekström & Shanahan 2003: Food and life cycle energy inputs: consequences of diet and ways to increase efficiency, Ecological Economics, vol. 44, pp. 293-307. The article calculates energy consumption in a lifecycle perspective, including transport in agriculture and industry. In certain cases different forms of processing the same foodstuffs are shown in order to illustrate the significance of the manner of processing. In certain cases the figures used in the pyramid are averages for an entire foodstuff group.

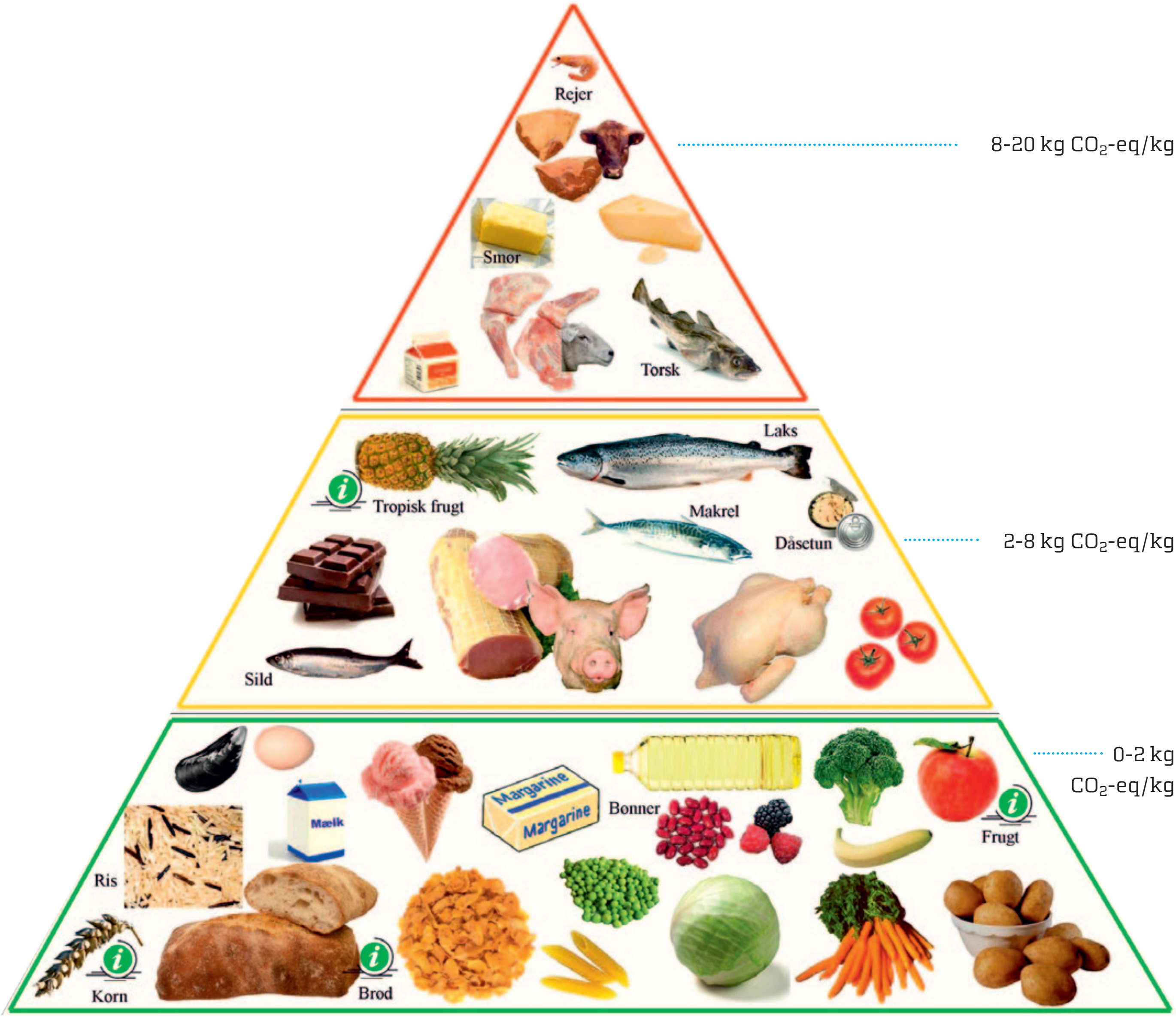


Figure 27: CO_2 pyramid based on (Lund & Madsen 2008).
(LULUCF contribution not included)

LISTINGS FROM A PRODUCTION AND CONSUMPTION PERSPECTIVE

From a *production perspective* on foods, the impact that arises from the production in a country (including that which is exported) is listed. A production perspective can be *national* where, for example, the importation of feed, artificial fertilizer, etc. and the climate impact from their production beyond the country's borders is not included or *international* where the impact of importation is included. As previously mentioned, the Kyoto Protocol adopts a national production perspective, since the impact on the climate that takes place within a country's borders is assessed, but not the impact that originates from import for the production.

A *consumption perspective* assesses the impact that originates from that which is consumed in a country (including the impact of importation), while the export from the country is deducted, e.g. the impact from the substantial share of Danish-produced pork that is exported is deducted from a Danish consumption perspective.

As far as Denmark's is concerned, there is a major difference in calculations and strategies from a production and a consumption perspective, since Denmark exports a great deal of food, e.g. it has a self-sufficiency level of 622 % for pork, of for 228 % cheese, of 157 % for butter and of 139 % for poultry[41]. That is to say that Denmark exports around 80 % of the production of pork, around 60 % of the quantity of cheese produced, etc. In other words, there is a considerable difference, not least where some of the animal products are concerned, from a production and consumption perspective. At the same time, as mentioned earlier, Denmark imports food that corresponds to around 25 % of the Danish food consumption, also including imports of some animal products.

The following assesses both a production perspective (both national and international where possible) and a consumption perspective of Danish agriculture and foods.

PRODUCTION PERSPECTIVE ON FOOD

Denmark's acreage constitutes a total of 4 310 000 ha, 62 % of which are cultivated[42] and around 80 % of the agricultural area is currently used for feed production[43]. The Danish feed production covers around 75 % of the feed use in Denmark in terms of weight, but only 58 % in terms of protein, i.e. some feed is imported[44], particularly soya protein[45].

The climate impact of agriculture itself is often divided among the *energy related* greenhouse gas emissions, i.e. from the consumption of energy for tractors, in stalls, greenhouses, etc., and the *non-energy-related* emissions that arise from decomposition of nutrition, domestic animals' digestion, etc. This chapter first and foremost analyses the non-energy-related emissions, since the chapter on industry analyses the energy consumption and the optimisation thereof in all businesses. To give a full picture of the climate impact that is linked to agriculture and foods, however, energy consumption is also touched on in the analysis of agriculture and foods.

An analysis from 2003 (➜ see table 4) shows that the greatest contribution to agriculture's impact on the climate in Denmark consists of domestic animals' digestion (around 20 %), laughing gas from leaching and evaporation of nitrogen compounds (around 20 %), oxidation of carbon in humus (approx. 17 %), the energy consumption (approx. 15 %) and storage and delivery of domestic animal manure (approx. 15 %) and artificial fertilizer (approx. 8 %)[46]. The table shows that the total national impact on the climate from agriculture itself in 1990 was around 18 million tonnes CO_2 equivalents, while the impact in 2003 had fallen to around 14 million tonnes CO_2 equivalents, of which around 12 million tonnes were non-energy-related and around 2 million tonnes were from the agricultural energy consumption (tractors, etc.). The fall is attributed particularly to the reduction in the use of artificial fertilizer, reduced energy consumption and greater carbon binding in mineral soil.

41. The Agricultural Council of Denmark (2008): Energy statistics. Danish Agriculture 2006
42. In 2007, 2 663 000 ha were cultivated
43. The Agricultural Council of Denmark (2008): Energy statistics. Danish Agriculture 2006
44. Feed corresponding to 25 % of the feed weight and around 40 % of the protein content
45. The Agricultural Council of Denmark (2008): Energy statistics. Danish Agriculture 2006
46. Evaluation from Olesen et al, 2004

Emission	Source	1990	2003	Ændring (%)
Metane (CH_4)	Domestic animals' digestion	3.05	2.66	
	Domestic animal manure	0.75	0.99	
	Reduction biogas plant	0.00	-0.02	
	Total	**3.79**	**3.63**	**-4**
Laughing gas (N_2O)	Domestic animal manure	0.66	0.55	
	Grazing	0.29	0.27	
	Artificial fertilizer	2.35	1.17	
	Domestic animal manure spread	1.08	1.06	
	Slurry spread	0.02	0.06	
	Ammonia evaporation	0.53	0.38	
	Leaching	3.35	2.22	
	Nitrogen fixation	0.27	0.20	
	Crop remains	0.35	0.32	
	Humus	0.07	0.07	
	Reduction biogas plant	0.00	0.01	
	Total	**8.97**	**6.31**	**-30**
Carbon dioxide (CO_2)	Energy consumption	2.42	2.13	
	Liming	0.56	0.23	
	Carbon in mineral soil	-0.14	-0.63	
	Carbon in humus	2.60	2.42	
	Hedging	0.02	-0.13	
	Forestation	0.00	-0.11	
	Miscellaneous	0.13	0.12	
	Total	**5.59**	**4.03**	**-26**

Table 4: Agriculture's greenhouse gas emissions in 1990 and 2003 and change 1990-2003 (Olesen et al. 2004).

There is a very substantial difference between how far different soil types affect the impact on the climate. While mineral soils helps to reduce the impact on the climate, oxidation of carbon from drained soil helps to increase the impact on the climate, and constitutes 15-20 % of the impact on the climate, while these soils constitute only 5 % of the agricultural area and lead to a relatively low outcome.

Also, some imported feed is cultivated in areas where timber used to grow or that were wetland areas, i.e. the natural area is used for other purposes, like with Danish soil drainage, for example. Such changes to the natural surroundings lead to a greater impact on the climate as a consequence of combustion of the previous growth and oxidation of the carbon layer of the soil that can last for up to 30 – 40 years[47].

47. The non-energy-related greenhouse gases from agriculture that are attributed to changes in area use and changes associated therewith to the absorption and emission of CO_2 from the soil and vegetation are often jointly called "Land Use and Land Use Change and Forestry", abbreviated to LULUCF.

Organic agriculture has a number of environmental, natural and health benefits compared with conventional agriculture, as a consequence of greater crop diversity, use of organic manure instead of artificial fertilizer, lower nutrient surplus in the soil, etc.[48] This form of cultivation also influences the climate impact from foods. Studies highlight the fact that the climate impact per kilogramme organic greenhouse vegetables is greater than that of conventional vegetables as a consequence of a lower outcome per m^2 greenhouse, while the impact on the climate of an animal product like pork is less because organic agriculture typically has a lower nitrogen surplus than conventional agriculture, and thereby gives rise to a lower production of laughing gas.

A calculation of agriculture's and the co-owned food processing's energy consumption calculated as primary energy consumption and the energy-related greenhouse gas emissions in 2006 can be seen in Table 5.

Agriculture uses around 50 % of the energy, horticulture around 10 %, the dairies around 13 % and the butchers around 11 %. The table shows a major difference between the use of the different forms of energy in the different shares of food trade. Assessed by product groups, the energy consumption in pig production in agriculture and processing at the butchers constitutes 29 % of the energy consumption. The consumption of energy has been fairly constant since the mid 1990s, and there have also been no major changes in the roles of the different energy sources. These figures conceal a reduction in the energy consumption of primary agriculture and a corresponding increase within supply and processing. There has been a reduction of around 10 %, in the sector's total electricity consumption through horticultural savings[49].

If the non-cooperatively-owned share of the food industry is assumed to have emissions of the same magnitude as the co-owned supply and processing, i.e. around 2 million tonnes CO_2 equivalents, agriculture and the food industry have total energy-related greenhouse gas emissions of around 7 million tonnes CO_2 equivalents. The same with the previously mentioned non-energy-related greenhouse gas emissions from the decomposition of nutrients in the soil, etc. of around 12 million tonnes CO_2 equivalents means that there are total greenhouse gas emission from agriculture and the food industry in Denmark (national production perspective) of around 19 million tonnes CO_2 equivalents per year.

If you want to assess an *international* agriculture and foods production perspective, it is necessary to also involve the foreign feed production and the production of artificial fertilizer, etc. A step in the direction of such a calculation is to start from the basis that around 25 % of the feed for Danish agriculture is, as previously mentioned, imported. In particular this concerns protein feed, as 42 percent of the protein in animal feeds is imported[50]. The LULUCF effect of foreign feed is central since, as previously stated, the global average amounts to 16 kg CO_2 equivalents per kg meat. If it is presumed that the climate impact from foreign feed production for Danish animals (in total approximately 2.4 million tons meat) is based on this LULUCF effect, this corresponds to a climate impact of 0.42 x 2.4 x 16 = approximately 16 million tons CO_2 equivalents per year[51]. This means that seen from a global level, Danish agricultural production has an overall climate impact of 19 + 16 = 35 million tons CO_2 equivalents per year. The international production perspective is not used in IDA's Climate Plan 2050, however it is of interest in relation to what Danish production means from a global perspective, and this perspective may be relevant in future international climate agreements

48. Alrøe & Halberg (red.): Development, growth and integrity of the Danish organic sector. Vidensyntese [Synthesis of knowledge], ICROFS, 2008
49. Danish Agriculture in Figures 2008
50. Danish Agriculture in Figures 2008
51. Evaluation of Torben Chrintz 2009 on the basis of FAO: Livestock's long shadow. Environmental issues and options, 2006

	Oil products	Natural gas	Carbon and coke	Elect-ricity	District heating	Town gas	Renew-able energy	Total gross energy, TJ	CO_2 equiva-lents, 1000 tonnes
Agriculture	19 777	840	197	12 556	0	119	2 554	36 045	2 390
Horticulture	1 633	1 154	2 001	625	1 969	12	60	7 454	489
Total primary agriculture	21 410	1 994	2 198	13 181	1 969	131	2 614	43 499	2 879
Supply and processing (co-owned)	7 668	8 191	1 508	10 127	397	58	21	27 969	1 898
Total co-owned food trade	29 078	10 185	3 706	23 308	2 366	189	2 635	71 468	4 777

Table 5: Agriculture's and the co-owned food processing's energy consumption and the related greenhouse gas emissions assessed as primary energy consumption and CO_2 equivalents in 2006
(Agricultural Council of Denmark, 2008).

CONSUMPTION PERSPECTIVE ON FOODS

Denmark has had a tradition of implementing national dietary surveys since the 1990s. Using figures from such surveys along with figures for the climate impact of individual foods from the lifecycle perspective, it is possible to perform a calculation of the Danish food consumption's impact on the climate from a consumption perspective, i.e. a perspective that also includes the import of foods, but where the agricultural export is conversely not included. A calculation based on 14 different food groups is shown in table 6.

The table shows that the biggest contribution comes from animal products that account for more than 50 % of the impact on the climate (by adding the numbers for milk, cheese, meat and poultry from the table). Different forms of calculation show very different figures for the Danish meat consumption, which is particularly crucial since meat, as shown by the table above, is a product that has a high impact on the climate. While the table above shows an average annual meat consumption per Dane of around 50 kg, Statistics Denmark shows an annual meat consumption of around 93 kg and a calculation from the World Resources Institute shows 140 – 145 kg per Dane per year in 2002[52]. According to the last calculation the Danish meat consumption is one of the highest in the world. The differences in the various calculations can be attributed to the calculation method, e.g. if you count in quantity on the plate or quantities sold by butchers to the retail trade. It is important in the further work with a Danish climate strategy in the food area to clarify such incompatibilities in consumption calculations.

52. *http://earthtrends.wri.org/searchable_db/index.php?step=countries&cID%5B%5D=50&theme=8&variable_ID=192&action=select_years* (4 May 2009)

Food group	**Quantity per per adult Dane per day** (grams)	**Quantity per Danish child per day** (grams)	**Impact on the climate** (kg CO_2 equivalents per kg food)	**Share of the diet's annual impact on the climate** (weighted average for children and adults)
Milk and milk products	323	466	1.35	12.5
Cheese and cheese products	33	21	12.14	9.8
Cereal and bread	213	204	1.34	7.5
Vegetables (e.g. Potatoes)	157	124	1.57	6.2
Fruit (excl. juice)	204	178	1.66	8.8
Meat and meat products	108	87	10.23	27.7
Fish and fish products	21	11	6.95	3.5
Poultry and poultry products	23	19	2.71	0.7
Eggs and egg products	17	12	1.65	1.4
Fats and fat products	35	32	3.05	13.2
Sugar and suchlike	34	41	1.73	2.6
Beverages, excl. water, milk, juice and soft drinks	1357	390	0.41	13.2
Potatoes	102	71	1.03	2.6
Juice	73	94	0.78	1.6
Average consumption per Dane per day (grams)	**2700**	**1750**		
Average impact on the climate per Dane per year (CO_2 equivalents)				**1.4 tonnes**

Table 6: Current food consumption in grams per Dane for adults and children respectively and the consumption's contribution to the impact on the climate in tonnes CO_2 equivalents per Dane per year as a weighted average for children and adults[53]

53. Calculations performed on the basis of Danish food habits 1995 – 2006: Status and development with a focus on fruit, vegetables and sugar, National Food Institute 2008, (Carlsson-Kanyama et al 2003) and (Lund and Madsen 2008) covering individual food habits in a lifecycle perspective from agriculture or fisheries up to the processed foodstuffs, however excluding consumer transport. By taking as its basis foodstuff consumption's individual products in a lifecycle perspective, it is possible to propose changes in consumption as part of a climate strategy. Typically only the environmental impacts that are closely related to the production of individual foodstuffs are included in this way and not the impacts that relate to the production of machinery and other forms of equipment that are used in a product's lifecycle. On the other hand, this form of impact will be included in so-called input/output calculations, which leads to a certain uncertainty in the figures, as some rough conversions from value to the volume of material etc. must be calculated for entire product groups. Here cited from Danish Agriculture in Figures 2008

The climate impact can thus be reduced if foodstuff consumption is changed. This knowledge can be used by individual consumers to change to a food that is both healthy and climate friendly, however it can also be used in all the aspects where the public is responsible for food or where private businesses are responsible for the operation of canteens, restaurants etc.[54]

The above calculation includes a number of climate impacts that are outside of Denmark since the food investigations do not take into consideration whether foodstuffs or feed is from Denmark or from abroad. An average figure is thus used for the food goods where figures for products from different parts of the world have been available. As previously stated, 25 % of feed for Danish agriculture is imported and the foodstuff import itself is of the same order of size – approximately 25 %.

PROPORTION OF CLIMATE IMPACT FROM THE TRANSPORT OF FOODSTUFFS

A calculation of the transport contribution from different Danish and foreign foodstuffs sold in Denmark reveals that the transport of a product from raw goods production and processing up to the retail chain can amount to up to 2/3 of climate impact for imported fruit and up to approximately 15 % for imported meat (including transport of feed)[55]. Conversely, the climate impact from Danish greenhouse gases may be significantly higher than equivalent imported products from southern Europe, also including transport from southern Europe to Denmark, as a result of major energy consumption for heating and lighting Danish greenhouses.

54. See a more thorough description in the IDA sustainability report "Green Future – Steps towards a Sustainable Development
55. Charlotte Jensen: Significance of Transport on the Environmental Impact of Foodstuffs Bachelor project, DTU Management 2008

FOOD WASTE

In order to obtain calculations from a consumption perspective based on the quantity of foodstuffs that are produced (and thereby have impacted on the climate) and not only the quantity that is eaten, a figure for food waste must be added to the above figure. An examination of food waste from England shows that approximately 30 % of purchased foodstuffs end as waste. Danish calculations indicate the same order of size. The English investigation revealed that 2/3 of food waste is thrown out (called "avoidable" waste) whilst one final third is carrot peelings etc. (called "unavoidable" waste). This means that approximately 20 % of purchased foodstuffs end as waste[56] that can be avoided[57].

The climate impact of 1.4 tons per Dane per year calculated in Table 6 is thus only a token of the climate impact from approximately 70 % of purchased foodstuffs. The climate impact for total foodstuff consumption including food waste is thus approximately 2 tons CO_2 equivalents per Dane per year[58].

IMPACT FROM CHANGES IN LAND USE

A calculation of the climate impact of foodstuff's production from the perspective of consumption should also include the climate impact from changes in land use upon clearance and subsequent cultivation of forest areas or wetland areas in the form of the previously stated LULUCF emissions, which can thus be connected to the agricultural part of a foodstuff's production. In this case, animal products in particular, as previously stated, are the cause of such emissions. As a rough estimate for LULUCF, the oxidation

56. Of approximately 20 %, approximately 8 % is waste that is due to prepared meals, whilst approximately 12 % of purchased food is thrown out without being prepared due to over purchase.
57. The food We Waste, WRAP 2008
58. This figure is a little lower than the calculation by Chrintz 2009 of foodstuff consumption's total climate impact evaluated using input/output analyses, which show a climate impact per Dane of approximately 2.4 tons CO_2 equivalents per Dane per year.

of coal in drained earth for Danish feed as shown in table 4 can be estimated to be approximately 2.4 million tons CO_2 equivalents per year for 58 % of the feed for 2.4 million tons meat – equivalent to a contribution of approximately 0.58 kg CO_2 equivalents per kg meat. For the 42 % of foreign protein feeds, the global average of 16 kg CO_2 equivalents per kg meat applies– equivalent to a contribution of 6.72 CO_2 equivalents per kg meat.

An average for the feed's LULUCF contribution is thus approximately 7 kg CO_2 equivalents per kg meat. If this is calculated with a gross meat consumption per Dane of approximately 93 kg per year and a LULUCF contribution of 7 kg CO_2 equivalents per kg meat including waste is added to the climate impact, this means an LULUCF contribution of approximately 0.7 tons CO_2 equivalents per Dane per year, and thus the total climate impact from an average Dane's food is approximately 2.8 tons CO_2 equivalents per Dane per year[59].

Proposal for reducing the climate impact of agriculture and foodstuffs

In the following section a range of options are presented for reducing climate impact on the basis of analyses of the extent and causes of climate impact from the agriculture and foodstuffs that are presented in the previous section.

REDUCTION OF FOOD WASTE IN HOUSEHOLDS

It is expected to be possible to halve "avoidable" food waste in households so that in future "only" a waste of 10 % of purchased products will be achieved (in addition to "unavoidable" waste of approximately 10 %). On the assumption of a total current climate impact of 2.8 tons CO_2 equivalents per year, the reduced waste will lower food consumption by 10 % – equivalent to a reduction in impact of approximately 0.28 tons CO_2 equivalents per Dane per year.

If it is assumed that waste today is equally divided into different food groups and between imported and exported goods, and 75 % of Danish food consumption is produced in Denmark, the savings from a national production perspective (if it is assumed that reduced waste leads to reduced purchase and production) will be approximately 0.21 tons per Dane per year, equivalent to a total of approximately 1.2 million tons CO_2 equivalents per year for the part of production consumed by the Danish population[60].

CHANGING FOOD HABITS

If Danes ate more in line with national food guidance and at the same time the selection of foodstuffs within individual food groups was performed on an optimal basis in terms of climate (e.g. mussels and shellfish instead of prawns), the climate impact from the Danish population's food in 2050 could be reduced by approximately 30 % though reduced consumption of diary products, meat and meat products as well as increased consumption of vegetables and fish, where these are also chosen in the most optimum climate terms for these product groups. In terms of milk this is calculated at a reduction of 10 %, for cheese at a

59. This figure is somewhat lower than the calculation of Chrintz 2009 of foodstuff consumption's total climate impact including LULUCF effect evaluated using input/output analyses of approximately 4.1 tons with LULUCF, where the global LULUCF value for the entire meat consumption is applied. The difference of approximately 50 % is due to the fact that in Chrintz's calculation the global average for meat's LULUCF impact is applied to all of Danish meat production.

60. The assumption of equal distribution is based on the following considerations: A large part of the reduced climate impact will come from reduced waste of meat products as this contributes to a significant proportion of overall climate impact. Conversely, part of the reduction from reduced waste meat products will occur abroad from savings in foreign feeds, which have a very high climate impact, see the calculations of meat's LULUCF contribution to climate impact.

reduction of 50 % and for meat and meat products at a reduction of 75 % in 2050. The proposal for reduced consumption of meat and meat products must be seen in addition to health benefits in light of the average meat consumption per Danes, which as stated is amongst the highest in the world.

A detailed analysis of typical Danish midday meals from the most recent national food investigation demonstrates that it is possible to reduce climate impact from midday meals by approximately 40 % by eating more vegetables, more fish and more poultry and at the same time eating less beef and veal – e.g. by changing the proportion of meat and vegetables in individual dishes or by eating purely vegetable dishes 1-2 times a week. The consumption of fish must simultaneously be changed in the direction of greater consumption of less climate impacting fish such as mackerel and herring and reduced consumption of cod and salmon[61].

A 30 % reduction of the climate impact from food is equivalent to a reduction of an average 0.84 tons CO_2 equivalents per Dane per year. If it is assumed that this reduction is equally distributed between Danish and foreign foodstuffs, the reduction for the 75 % Danish produced section of consumption will be approximately 0.63 tons CO_2 equivalents per Dane per year, equivalent to 3.5 million CO_2 equivalents per year.

A more climate friendly Danish agriculture

It will also be possible to reduce the climate impact from foodstuffs through more climate friendly practice in agriculture and different use of agricultural land. Table 7 shows a range of proposals for reducing the climate impact from Danish agriculture with a focus on cultivation practice with less nitrogen excess in the earth, cultivation of multiannual crops on areas that are released from feed production as a result of lower meat and milk production as well as the removal of low lying ground from agricultural operations.

In total these proposals result in a reduction of agriculture's climate impact from a national production perspective of approximately 5.4 million tons CO_2 equivalents per year from a current 12 million tons related to the emission of methane and laughing gas as well as the carbon content in the earth. In addition there will be a reduction in climate impact from an increased level of biomass repression of fossil energy (here considered as a repression of natural gas[62]) – in total approximately 3.7 million tons CO_2 equivalents per year). The proposal for a reduced cattle population and pig population is a consequence of the proposal for food habits altering in the direction of reduced consumption of dairy products, meat and meat products. In order for these changes to significantly reduce climate impact (and not to be outweighed by increased exports) whilst reducing the animal population, it will necessary to release agricultural land for the cultivation of multiannual energy crops, see the released area of 300,000 ha.

Comparable analyses of the environmental impact from the production of pork in different countries indicate that Danish production is no less environmentally damaging than production in Holland, the USA and Brazil[63]. In other words, apart from environmental considerations it could be argued that Denmark must maintain the greatest possible production of animal products.

61. This concerns long-term changes, as current fish quotas can be expected to lead to more difficult changes in the supply (capture) of fish.

62. Proposal for multiannual energy crops, Uffe Jørgensen, Århus University, 10th June 2009

63. Environmental Project 1028, the Danish Ministry of the Environment 2005

Mill tons CO_2 equiv	Reduction potential $CH_4 + N_2O$	Reduction potential Carbon in earth	Reduction potential Bioenergy	Reduction potential Total	Conditions
Reduced N excess	1,48			1,48	A duty of 12 kr/kg N
Multiannual energy crops (elephant grass)	0,33	0,99	2,76*	4,08	At 300,000 ha
Wood chips for biofuel			0,55	0,55	Utilization of thinned trees and felling waste
Increased fat in cattle feed	0,44			0,44	563,000 dairy cows
Removal of low lying ground from agricultural operations	0,07	1,01		1,08	At 100,000 ha
Afforestation on high ground	0,06	0,26		0,32	100,00 ha afforrestation
Reduced cattle population	(0,45)			(0,45)	15 % reduction**
Reduced pig population	(0,24)			(0,24)	15 % reduction***
Nitrification restriction	0,30			0,30	200,000 N per year in trade manure
Animal manure for biogas	0,55	-0,09	0,35	0,81	45% of remaining slurry
Total	**3,23**	**2,17**	**3,66**	**9,06**	**With consideration to overlap********

Table 7: Proposal for reducing the climate impact of agriculture calculated as a reduction in CO_2 equivalents.

Own calculations as well as (Olesen (red.) 2005), (Jørgensen 2009)64 and (Ministry of Agriculture, Food and Fisheries 2008)65

* Also includes a minor reduction in energy consumption during cultivation if it is assumed that replacement occurs from previous cultivation of corn.

** An estimate evaluated on how great a section of the cattle population can be deemed to be connected to Danish consumption of milk, cheese and beef.

*** An estimated based on a reduction of 75 % of pork consumption also occurring in 2050. As there is currently a self-sufficiency level for pork in Denmark of 622 % (Danish Agriculture in Figures 2008), a reduction of 75 % of Danish consumption will result in a reduction of approximately 15% of total pork production.

**** It is assumed that the reduced climate impact from a reduced population of cattle and pigs is included in the reduction from changed food habits, which also includes the impact from agriculture.

64. Proposal for multiannual energy crops, Uffe Jørgensen, Århus University, 10th June 2009
65. Agriculture and Climate Analysis of agricultural means for reducing greenhouse gases and its financial consequences, Ministry of Food, December 2008

Based on the stated proposal, increased conversion to ecological agriculture may also lead to a reduction in climate impact since ecological agriculture, as previously stated, often results in reduced nitrogen excess and thereby reduced climate impact than conventional agriculture. A replacement of approximately 25 % ecological agriculture area in 2030 – i.e. a quadrupling from the current approximate 6 % of areas – will lead to a reduction in climate impact of approximately 0.7 million tons CO_2 equivalents per year. A reduced climate impact may also result from more climate friendly ecological agriculture – i.e. when current and future ecological agriculture is performed in a more climate friendly way. A calculation of the potential for reducing gas from plant material from ecological agriculture will be increased, following which utilization of the gas to return the part of degassed material to the earth is estimated to be able to reduce climate impact by approximately a further 0.4 million tons CO_2 equivalents per year[66].

If this reduction is added to the aforementioned proposal, which is first and foremost aimed at conventional agriculture, a reduction in climate impact from Danish agriculture of approximately 7 million tons CO_2 equivalents per year can be achieved excluding bio fuel matter, and approximately 11 million tons including biofuels (the reduction from biomass's repression of fossil energy is included in the calculations in the chapter on energy systems and energy production).

The total reduction upon implementations of initiatives relating to food production and food consumption

Seen from a *national production perspective*, the proposals for changed practice by Danish consumers in the form of a reduction in the climate impact from reduced food waste (1.2 million tons CO_2 equivalents per year) is as follows. If eating habits alter in accordance with food advice (3.5 million tons CO_2 equivalents per year) and agricultural practice is improved including a quadrupling of ecological agriculture (7 million tons CO_2 equivalents per year), this will result in a total reduction of climate impacts relating to Danish agriculture and food production of approximately 11.7 million tons CO_2 equivalents per year from an annual impact of approximately 19 million tons CO_2 equivalents per year – equivalent to a reduction of just over 60 %. **The climate impact from Danish agriculture and food production (i.e. including export) in 2050 will thus be approximately 7.3 tons CO2 equivalents per year,** corresponding to approximately 1.3 tons CO_2 equivalents per Dane per year. In addition to this there will be reductions from energy savings in agriculture and industry in line with other businesses, as calculated in the chapter on industry and production. Furthermore there will be a reduction from increased production and consumption of biomass for energy purposes as a part of the substitution of fossil energy of approximately 3.7 million tons CO_2 equivalents per year, which is included in the chapters on biomass (biomass for energy and material purposes are discussed later in this chapter).

From an *international* production perspective, changes in the climate impact from activities abroad relating to supplies for Danish agriculture will also be included, which first and foremost will concern the supply of protein containing feed for animal production (the production of artificial fertilizer is another foreign supply in Danish agriculture that could be included). As a reduction of animal production of approximately 15 % in 2050 (➜ see table 7) is included, this will mean that the foreign LULUCF contribution relating to Danish meat production will be reduced by 15 % from 16 million tons CO_2 equivalents per year – equivalent to 2.4 million tons CO_2 equivalents per year, and thus the LULUCF contribution will amount to 13.6 million tons CO_2 equivalents per year. This means that Danish agriculture's climate impact from an international perspective in 2050 will be 7.3 million tons CO_2 equivalents per year from activities in Denmark and 13.6 from activities abroad, in total approximately 21 million tons CO_2 equivalents per year – equivalent to a reduction of only 40 %

66. Note from Michael Tersbøl, Ecological Land Association, 2009

	Basis	Climate plan 2050	Reduction in % of the basis
Danish agriculture and food production from a national production perspective (total)	19 million tons CO_2 equivalents per year, of which 7 million tons CO_2 equivalents per year from energy consumption.	Approximately 7 million tons CO_2 equivalents per year excluding improvements from energy savings and biomass's substitution of fossil energy	Approximately 60 %
Danish agriculture and food production from an international production perspective (total)	35 million tons CO_2 equivalents per year.	21 million tons CO_2 equivalents per year excluding improvements from energy savings and biomass's substitution of fossil energy	Approximately 40 %
Danish food consumption from a consumption perspective (total)	15.4 million tons CO_2 equivalents per year.	5.0 million tons CO_2 equivalents per year.	Approximately 68 %
Danish food consumption from a consumption perspective per Dane	2.8 tons CO_2 equivalents per Dane per year	0.9 tons CO_2 equivalents per Dane per year	Approximately 68 %

Table 8: Summary of climate impact from agriculture and foodstuffs – basis and potential reductions in 2050

A combination of the stated proposal from a *consumption perspective* for the average Dane's food consumption results in the following reduction potentials: The current climate impact relating to a Dane's annual Danish food consumption of 2.8 tons CO_2 equivalents per year per Dane could be reduced by 0.28 tons from reduced food waste and 0.84 tons from changed food habits. The reduced climate impact from more climate friendly Danish agriculture of 11.7 million tons CO_2 equivalents per year will only lead to a reduction in the climate impact of Danish food consumption that is equivalent to the Danish consumer's share of Danish agricultural production.

As there is a major difference with regards to the Danish domestic market's consumption of agricultural production, it will be necessary to perform certain estimates. Feed production for animal production is key and this amounts to approximately 80 % of agricultural land. The domestic market's consumption of feed consumption can be used as an indicator of domestic market consumption's share of agriculture's climate impact.

The Danish domestic market consumption's share of milk (consumed as milk for consumption and cheese) is estimated to be approximately 30 %; beef and veal are likewise approximately 30 % and pork approximately 16 %[67]. Based on the relative volumes of the three product groups, feed consumption related to domestic market consumption is estimated to be approximately 20 %. The Danish consumption's share of the reduced climate impact from better agricultural practice can thus be estimated to be 20 % of 11.7 million tons CO_2 equivalents per year – equivalent to approximately 2.3 million tons CO_2 equivalents per year – equivalent to 0.4 tons CO_2 equivalents per Dane per year.

67. Own calculations on the basis of Danish Agriculture in Figures 2008

Similarly Danish consumption's share of the LULUCF effect from foreign feed is also estimated to be approximately 20 % – equivalent to a reduction in Danish consumption's impact from a reduced LULUCF impact of 20 % of approximately 2.4 million tons CO_2 equivalents per year – equivalent to a further 0.4 tons CO_2 equivalents per Dane per year. If the contribution from the reduced impact of waste is added to changed food habits and changed agricultural practice, the total reduction from a consumption perspective will be 0.28 + 0.84 + 0.4 + 0.4 = approximately 1.9 tons CO_2 equivalents per Dane per year. This means that the Climate Plan's proposal will result in a **reduction in the climate impact from the current average food consumption per Dane of approximately 2.8 tons CO2 equivalents per year to approximately** 0.9 million tons CO_2 equivalents per year – equivalent to a reduction of 68 %. No reductions from increased use of biomass and energy savings in agriculture and the food industry are included here.

Table 8 shows a summary of the climate impact from agriculture and foodstuffs based on different perspectives and the reductions that can be achieved in 2050 if the plan's recommendations are realized.

The biomass potential for energy and materials in Denmark

In addition to producing food, agriculture also has a role in the production of energy and materials. In line with an increased focus on the need to reduce the use of energy and materials based on fossil energy sources, the demands on the supply of resources for energy and materials from agriculture will tremendously increase. This may lead to increased pressure on agricultural land and an increase in what the agricultural land is used for; see the discussion on food habits in the previous section of the chapter.

In this part of the chapter, the opportunities for a renewable way of producing biomass for energy purposes are analysed first and foremost, however the analyses of the use of biomass for materials are more overarching.

By far the majority of scenarios and prognoses for the use of biomass that we have seen in recent years have focused on the use of biomass for energy purposes (electricity, heating, fuel for transport).

In principle, bioenergy could cater for the whole of the world's energy supply but, in reality, the technical and economic potential is much lower. In 2008, biomass in Denmark accounted for approx. 7 % of energy consumption. The average in developing countries is around 35 % and, in the least industrialised African countries, bioenergy accounts for up to 90 % of total energy consumption[68].

In line with focus on the need to substitute fossil-based raw materials in general – and not merely raw materials for energy purposes – there is increasing focus on the integrated use of biomass, e.g. so-called biorefining whereby primary energy products and other products that are able to replace fossil-based materials (e.g. for the chemical industry) are produced at the same time as a number of agricultural products.

The integrated use of biomass from agriculture, horticulture, aquaculture, fisheries and associated industries is shown in the figure below.[69]

SCENARIOS FOR BIOMASS IN DENMARK

The considerations of the future production of biomass for energy and material purposes in Denmark are partly based on evaluations of the need for biomass and partly on considerations with regards to nature and environment. In the table below the status of production and imports of a range of forms of biomass, the Ministry of Energy's proposal for Danish potential for biomass, IDA's proposal and potential from the Energy Plan 2030 as well as the Climate Plan's proposal are shown.

68. *http://www.risoe.dk/rispubl/Risnyt/risnytpdf/ris0403/risnyt_4_2003.pdf*

69. Biotechnological research strategy for non-food products and feeds, 2006.

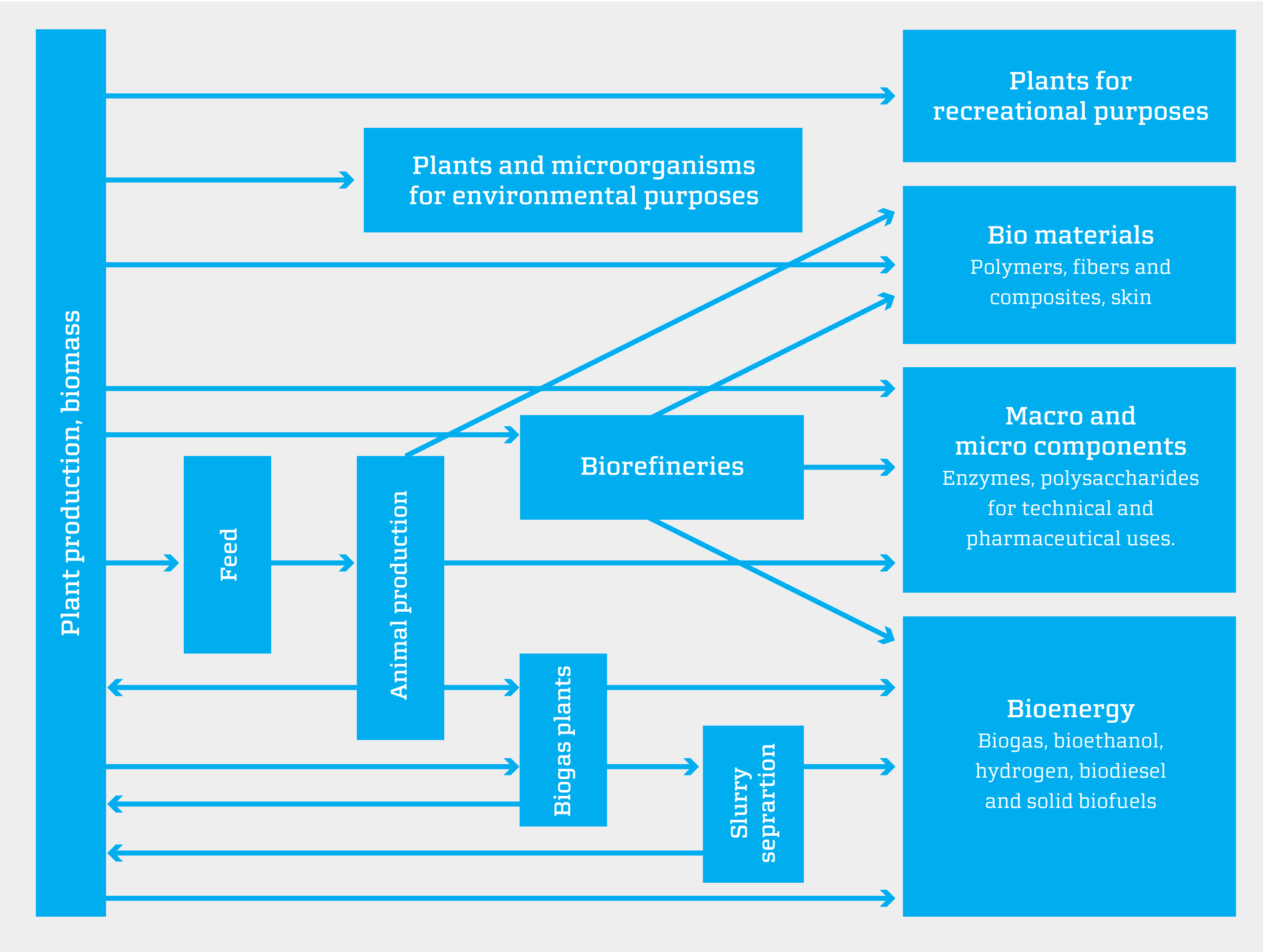


Figure 28: **Integrated use of biomass and secondary products resulting from agriculture, horticulture, aquaculture, fisheries and associated industries**

(Biotechnological research strategy for non-food products and feeds, 2006).

The differences in the different potentials of biomass in Denmark (the Ministry of Energy, IDA's Energy Plan and the Climate Plan) are due to differences in evaluations of the yield from energy crops, the size of area with such crops, the volume of straw that is necessary for other purposes than energy, types of crop and essential necessary environmental considerations (pesticides, nutrient leaching, nature etc.).

The scenario upon which IDA's Climate Plan 2050 is built, compared with the potential identified in the Energy Plan 2030, is a reduced use of straw for energy purposes (in order to maintain the potential for use for ground structure, food and litter). It also has a more environmentally cautious approach towards energy crops on land in order to avoid too great a natural impact, both ecologically and aesthetically. Neither has it been evaluated whether there is potential in slurry fibre, as foreseen in 2006.

Ressource \ PJ	Consumption of Danish resources (ENS 2006)	Import (ENS 2006)	Danish potential (ENS 2006)	IDA Energy Plan 2030	Potential in IDA Energy Plan	IDA Climate Plan 2050
Straw	18	0,0	55	25	55	30
Wood	38	16,1	40	40	40	50
Slurry for biogas	4	0,0	40	32	40	40
Fibre from slurry			0	0	108	5
Multiannual energy crops			0	54	144	52
Biodegradable waste	30	0,0	30	30	30	30
Algae						100
Total	**90**	**16,1**	**165**	**180**	**417**	**307**

Table 9: Resources of biomass for energy purposes in Denmark: Consumption 2006 and different scenarios. Figures stated as PJ (in form of the fuel value of the different forms of biomass).

Conversely, in IDA's Climate Plan 2050 the scenario includes a significant contribution based on algae, as it is deemed that it will be more likely to improve the sustainability of future energy consumption with this crop than with a greater contribution of multiannual energy crops (where areas of natural sensitivity may come under pressure as cultivation areas) or by including a yet greater contribution from slurry. The latter would lock Danish agriculture into very high pig production for many years ahead. The potential for the sketched production of multiannual energy crops is possible due to land use, which as previously stated would reduce animal production and thereby reduce the need for fodder land. In this way it will be possible to strengthen other forms of biomass in these areas and at the same time to avoid using fallow and low lying areas, which will be used for commercial biomass production. All these areas can thus be taken out of agricultural operation.

MULTIANNUAL AND ANNUAL ENERGY CROPS

In the majority of cases, the cultivation of annual crops will eat into the earth's carbon pool – however the extent to which this occurs will depend on whether fertilization with animal fertilizer is performed or whether straw is removed and decomposed. Multiannual energy crops are normally hardy and the quality requirements for energy crops are less than for food crops. The pesticide consumption in willow production is therefore considerably less than in other agriculture. The long growth season of multiannual crops leads to major water consumption and willow in particular consumes a great deal of water. This may be a problem in eastern Denmark where precipitation is limited and water consumption is high. On the other hand, elephant grass consumes less water than willow[70].

70. Uffe Jørgensen 2009

The net energy yield from the production of biomass highly depends on which crops are cultivated, and which biomass product is intended as the end product. As a gross estimate the following net energy yield (i.e. where energy consumption for cultivation and replacement is deducted) is expected when producing:[71]

- Willow chips or whole seed corn 150 GJ/ha.
- Biogas from clover grass 60 GJ/ha.
- Ethanol and similar from whole seed 45 GJ/ha.
- Ethanol from wheat kernels 20 GJ/ha.
- Rape oil or bio-diesel from rape 15 GJ/ha.

The impact of the energy crops on nature and the landscape is also a significant aspect when larger areas must be cultivated. For example, willow trees will be 6 m high and thus fill a lot of the landscape, whilst elephant grass grows to the same extent as a maize field and will normally be harvested each year[72].

Algae as a marine biomass resource

As stated in the biomass scenario for 2050 it is deemed possible to produce a total 100 PJ from algae for energy and material purposes. This is calculated based on a combination of production of brown algae (macro algae) in deep water equivalent to approximately 50 PJ and a production of green algae (micro algae) in low water or in basins equivalent to approximately 50 PJ.

For both of these products this concerns concepts that are currently still under development for biomass production on a large scale. Work is being performed on brown algae on the Faeroe Islands and green algae on Lolland. Developing these two concepts for production to such a great extent involves a range of challenges of a technological, biological and environmental nature, which require comprehensive research and innovation activities with the involvement of a range of players and the integration of social and environmental considerations in order to continuously perform thorough and transparent – and thereby legitimate – evaluations of improvement, potentials and barriers.

Brown algae are today known as raw goods in the production of a food additive such as carrageen. Future systematic production of this form of algae in the Danish marine areas may be expected to occur once algae can be "cultivated" (grown) on lines that hang down from one long main line. It is estimated that production of brown algae with a fuel value of 50 PJ per year will require a marine area of 80 – 100 km^2 [73].

At the same time an essential condition for such production is that it can be combined with a production of so-called "high value products" such as carrageen etc., as 20 % of the brown algae's mass can be used for such productions whilst the remaining 80 % of the biomass will be used for energy purposes. This will presumably involve extensive quantities of such high value products from Danish production in the planning stage that it will affect the world's market prices for these chemical substances. The manner of algae production will thus depend not just on business plans for biomass for energy but also on a range of chemical substances. The concept is based upon cultivating marine areas at a depth of water in which this form of algae does not naturally grow. Whilst this will mean that there is no risk of a shade effect as per naturally occurring algae, it will entail introducing algae into areas in which it is not naturally established. The production of green algae may be performed at low water depths offshore, in basins or in closed reactors. One of the challenges when cultivating in low water is considered to be the effects on ecosystems that may occur when comprehensive production of biomass is established at low water.

71. Uffe Jørgensen etc.: Energy from Biomass – Resources and Technologies: evaluated from a regional perspective, DJF ground use no. 134, January 2008
72. Uffe Jørgensen 2009
73. Note from Gilli Trond and Viljhjamur Nielsen, June 2009. Expert note on Algae in Energy Production.

Conversely, production can be expected to be established in areas where there is a relatively high nutritional content so that biomass production can simultaneously be used as a water treatment technology. This might similarly occur when cultivating green algae on land where there is a focus on nutrients from wastewater and CO_2 from burning biomass in biogas systems as nutrients for green algae production.

There is a particular focus on green algae as a source of starch and thereby a basis for fermenting bioethanol. This form of synergy is considered to be necessary for establishing environmentally and economically renewable production of green algae on land. From an economical viewpoint, there are major costs when cultivating in tank systems, in harvesting processes and in drying algae that contain a great deal of water that must be covered partly by a high yield (100 – 150 tons dry substance per hectare – equivalent to 10 times the productivity for corn) and partly by the stated financial synergy with systems that have an excess of CO_2 and heat[74 and 75].

The closed reactors are clearly the most expensive investment – approximately USD 1 million per acre – approximately 25 times more expensive than establishing open basins on land[76]. As a result of the major costs when establishing production on land there is therefore also interest in establishing green algae systems in low water areas. However low water based systems may also be expensive in investment and operation, as major investment will be required in equipment for harvesting and transporting the harvested algae on land.

Cultivation of green algae at sea with a fuel value of approximately 50 PJ – equivalent to approximately 50 % of IDA's Climate Plan's estimated requirement for biomass for transport in 2050 will presumably require an area of approximately 40 km^2 [77]

74. *http://videnskab.dk/content/dk/miljo_natur/alger_skal_satte_skub_i_biogasanlag (29.* juni 2009)

75. *http://ing.dk/artikel/84439-danske-forskere-dyrker-alger-til-biobraendstof-med-kraftvaerksroeg (29.* June 2009)

76. *http://wind-sea-algae.org* (29th June 2009)

77. Gilli Trond and Vilhjamur Nielsen

System for combined production of energy, feed and materials

Based on an area estimate, multifaceted use of some biomass, e.g. the use of straw from corn production for both food and ethanol, will release further areas for energy crops – in addition to approximately 15 % of the current agricultural area that is released upon the stated reduction of animal production. For example, fodder proteins under current animal production is deficient and when selecting replacement and refinement processes this ratio should be taken into consideration when processing crops in order that fodder protein imports can be reduced.

Such multifaceted use in so-called bio refineries will mean that it is not always sensible to form estimates of how much biomass in the form of volume based on weight, volume based on energy content or cultivated areas should remain for energy production and how much may be left aside for chemical substances and products.

Danish projects such as IBUS (Integrated Biomass Utilisation System) and the Lolland biorefinery are extremely focused on converting biomass to biofuels. However, the products resulting from the refining processes can also be used for the production of materials. For example, the Swedish company Xylophane has developed a method for using hemicellulose in the manufacture of bioplastic film.

One example of a potential plant for combined production based on various different forms of biomass is the Lolland biorefinery. The biorefinery provides a physical platform for use of local biomass resources from several different generations of technology and is part of the Lolland local authority's investment in biomass-related projects. Biogas is produced from slurry, straw and other plant waste. In order to ensure that straw and other plant waste can be vaporised, an IBUS plant is set up for pretreatment purposes. Plant waste is cooked under pressure in the IBUS plant, enabling the conversion of the micro-organisms to biogas. Symbiosis between a local district heating plant, agriculture and other local businesses is a prerequisite. This full-scale plant will be the first of its kind in the world.[78]

Calculations of the yield from 1 hectare of winter wheat processed in an IBUS plant indicate that the production of biofuels requires a considerable amount of input energy – equivalent to approx. 50 % of the amount of energy in the products produced.[79] Thus, the production of biofuels requires a good deal of energy. The production of biofuels is thus far from energy free, and it is therefore necessary to calculate net energy dividends when evaluating the potential of biomass based products, as crop selection and the finished product also have a great impact upon yield.

Materials from biomass

It is often pointed out that biomass-based materials may benefit the climate. It would seem that the main advantage is the replacement of non-renewable raw materials with renewable raw materials. As renewable raw materials grow, they bind CO_2 from the air, in contrast to, e.g., oil-based products.

Another advantage could be the fact that less energy is required to produce biomass-based materials than is required to produce the materials they substitute. However paper wool has been demonstrated to be the product that has the least climate impact for bio-based products, whilst flax has the highest climate impact due to the major energy consumption when manufacturing artificial fertilizer. Mineral wool has the least energy consumption[80]. At the same time the example illustrates how important it is for innovation strategies for biomass-based products to also focus on the cultivation strategy itself. Ecological cultivation of flax will thus presumably significantly reduce the climate impact of the product.

When evaluating the climate benefits upon application of biomass-based raw goods, it is necessary to compare the new ground use's absorption of CO_2 from the air compared with that of the previous ground use. The cultivation will have a climatic advantage only if there is greater absorption. For example, this will be the case if the cultivation of annual crops for fodder corn is replaced with a multiannual crop, which may result in approximately 60 % greater greenhouse reduction[81].

One of the main issues is the question of the amounts and acreages that will be required to replace current materials based on non-renewable materials or based on fossil resources. There has been a good deal of research into potential uses for biomass, both virgin biomass and waste products from the processing of foodstuffs etc. However, no research is available indicating the amounts that would be required in Denmark, e.g., to replace fossil-based raw materials in the main Danish industrial sectors. The distinction is made between biomaterials, macro components and micro components.

In the field of *biomaterials*, biotechnological research strategy[82] suggests, among other things, the replacement of synthetic fibres with biofibres, e.g. in light and strong composites. Plants with fibre content, especially flax and hemp, can be cultivated rationally under Danish conditions. The Danish plant fibre crops are particularly well suited for industrial production

78. *www.bass.dk*

79. Claus Felby in 2006: 1 hectare of winter wheat produces 3,670 l ethanol per ha., 2,510 kg of feed and 1,674 kg of biomass for burning. The energy input is 66,000 MJ (i.e. approx. 15,000 MJ for cultivation and approx. 51,000 MJ for processing). This is the equivalent of approx. 50 % of the calorific value of the total output of ethanol, feed and remaining biomass for burning – approx. 134,000 MJ.

80. Schmidt et al: A Comparative Life Cycle Assessment of Building Insulation Products made of Stone Wool, Paper Wool and Flax. Part 2: Comparative Assessment, Int J L, vol. 9, no.2., pp. 122-129

81. Olesen (red.), 2005

82. Biotechnological research strategy..., 2006 of building materials, insulation mats, woven or spun materials, biofilters for oil absorption, paper and fibre composites. Biopolymers can replace the oil-based polymers that are used in traditional plastics.

Macro components are products in themselves but they also form the basis for derivative or combined products. The most important Danish macro components are lipids, proteins, starch, lignin and chitosan. Today, macro components are usually manufactured industrially in large quantities and the kilo price is generally relatively low.

Selective biotechnological methods enable the manufacture of well-defined macro components and value can be added by applying precise processes throughout the entire production cycle. Financial competition and increasing environmental requirements may make it attractive to change industrial production based on the processing of a raw material into a product, e.g. starch or sugar, to production in which several different, high-value products are manufactured from the same raw material. Macro components can be processed from: Brewers' grains and sprouts from beer production, whey from cheese production, remains of beet from sugar production, potato pulp from the production of starch and rapeseed cake, wheat bran, juice residue and pea pods.

Micro components are substances which are chemically pure and are isolated and extracted from a raw material. Examples of micro components are medicines, natural medicines and enzymes for technological and industrial use. It is often maintained that micro components are of financial interest due to the long value chain, which adds value and knowledge and results in a high kilo price.

Plastic is one example that can illustrate the volume and area ratio for biomass-based materials since it is always possible to produce plastic based on biomass instead of fossil resources to a certain extent. At the moment between 4 and 5 % of the world's oil production is used for plastic manufacture.

If we assume that half of the Danish production of plastic products will be based on biomass by 2050, this would amount to approx. 200,000 tons of biomass-based plastic. If we assume that a proportion of this will be produced from cellulose residue or stems from products used in refineries for various different purposes (feeds, energy, other substances and materials) – e.g. 30 % – an additional 140,000 tons of plastic from pure biomass in the form of starch will be needed. This requires between 56,000 and 70,000 ha.[83] of land, which is the equivalent of approx. 20 % of the agricultural acreage that will be freed up according to the biomass scenario described above. A similar assessment of production of insulation matting from hemp to replace the current production of insulation manufactured from glass wool and mineral wool would require approx. 12,000 ha. of land, which is equivalent to approx. 4 % of the released acreage.

Based on these two estimates of the necessary areas, it must be considered difficult to achieve a significant substitution of the current materials based on fossil resources with biomass based material if the change in agricultural production described is only performed with a release of approximately 15 % of the agricultural area in 2050. In other words, it may be necessary to release yet greater areas from fodder production – by achieving synergy effects during combined processing of biomass for food, energy and material purposes and/or with the aid of a more comprehensive reduction of Danish animal production than the reduction of 15 % that is now expected to occur by 2050.

In further work to realize the recommendations of the climate plan concerning production and the use of biomass it will be necessary to perform more in-depth evaluations of social and environmental aspects of production and the use of biomass through research and innovation programmes with the broad participation of interested parties in order that the development of concepts and implementation of these is performed with a broad social legitimacy.

83. 1 ha with starch crops produces 2 to 3 tons of bioplast

Industry

Summary:
Industry

Intermediate objectives, Climate Plan 2050

2015

- Fuel consumption in industry and commerce has been reduced by approx. 27 % compared to 2008.
- Electricity consumption in industry and commerce has been reduced by approx. 32 % compared to 2008.
- Biomass caters for approx. 35 % of fuel consumption in industry and commerce.

2030

- Fuel consumption in industry and commerce has been reduced by approx. 31 % compared to 2008.
- Electricity consumption in industry and commerce has been reduced by approx. 43 % compared to 2008.
- Biomass caters for approx. 75 % of fuel consumption in industry and commerce.

2050

- Fuel consumption in industry and commerce has been reduced by 33 % compared to 2008.
- Electricity consumption in manufacturing companies has been reduced by 45 % compared to 2008.
- Biomass caters for 100 % of fuel consumption in industry and commerce.

MEANS

- Funds to the tune of DKK 800 million per year ought to be earmarked for the promotion of and grants for energy-saving measures in industry. DKK 100 million of this ought to be set aside for research, development, demonstration, market development and verification of new, energy-saving technologies for use in the production industry and technology-based service industries.

- Subsidies ought to be granted when binding agreements on energy management are entered into with individual companies. The agreements ought to relate to specific types of energy and process and, if applicable, to training of staff responsible for planning, purchasing and operation of plants and systems.

- Targets should be established for development in energy consumption and fuel conversion. Financially motivating schemes that promote interest in investing in energy savings and replacements should be created to promote these targets.

- All companies with an annual fuel and electricity consumption of over 5000 MWh ought to perform an energy inspection and process integration study at least once every three years, using external, quality-assured consultants.

- Labelling schemes for products and energy certification of new plants ought to be developed.

Industry and commerce

The IDA Climate Plan 2050 focuses in particular on energy savings in industry and commerce. However, there are a number of topics that are not addressed in the Climate Plan but which are also relevant to the reduction of the impact on climate change. Two factors require specific mention:

1. When we look at the entire flow of goods, from manufacturer to consumer, a certain amount of the gas emissions associated with the product lie outside Denmark. The focus of The IDA Climate Plan 2050 is on national production and, therefore, does not include this perspective. However, from the point of view of the climate, the impact of the product on climate change during its entire life cycle ought to be included in considerations when a manufacturer selects one sub-supplier over another.

2. The second factor relates to the CO_2 that is bound to materials and new materials. The chapter on agriculture addresses the potential related to new materials whereby oil-based plastics are replaced by bio-materials. However, it was not possible to pursue the subject further in the Climate Plan 2050.

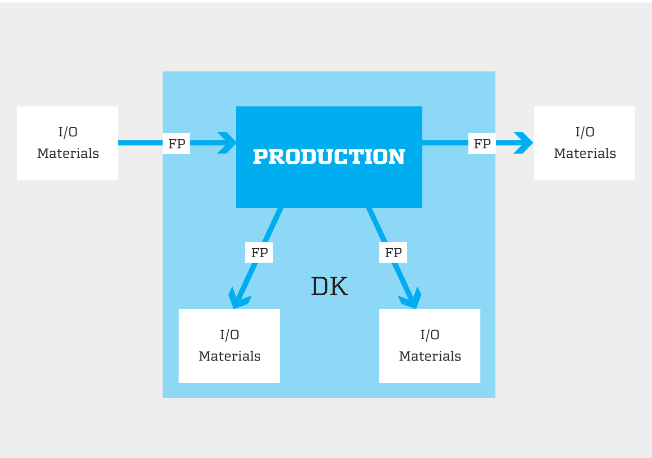


Figure 29: The model applied to CO_2 footprints (FP).

Another significant issue related to products is the issue of energy-saving building components. Due to the consumer perspective, these are dealt with in the chapter on housing and buildings. Finally, with respect to product manufacture, there is the aspect of development and the use of more energy-efficient materials, such as the use of composites instead of metal alloys or use of materials that require less energy during manufacture and processing. It was not possible to address these issues in this report.

The following paragraphs address industry's climate gas emissions and the reduction potential considered achievable for the three intermediate objectives for 2015, 2030 and 2050. In addition, the means considered necessary to achieve these reductions are described. In this report, in addition to manufacturing companies, the term "industry" refers to refineries, construction and civil works companies, wholesale trade, retail trade and private service.

Industry's climate gas emissions 2007

Climate gas emissions from the activities of industry and from existing landfill sites amounted to 25,035,000 tons of CO_2 equivalents[84] in 2007. This is the equivalent of just under 38 % of Denmark's total climate gas emissions. Industry's emissions covered the 6 Kyoto greenhouse gases (CO_2, CH_4, N_2O, PFCs, HFCs and SF_6) as specified in Figure 30.

84. If CO_2 emissions from the combustion of renewable energy sources are included, industry's contribution amounts to a total of 40%.

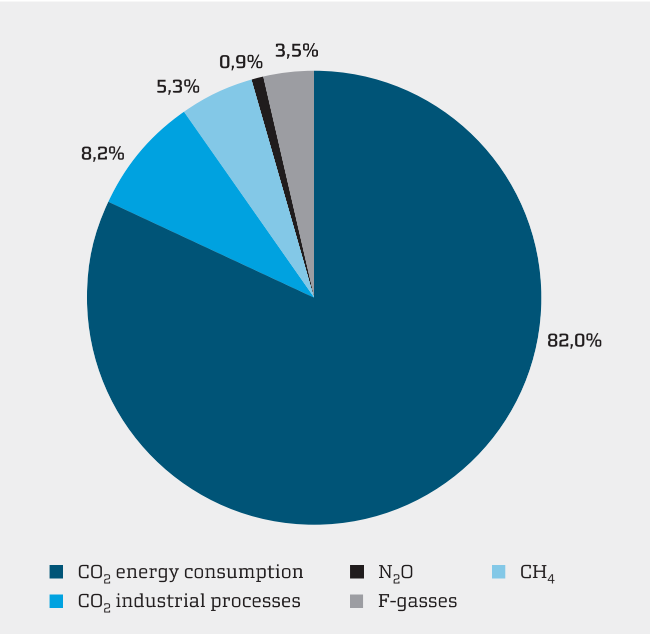


Figure 30: **Industry's climate gas emissions, distributed by type and, in part, source**

CO_2 emissions originating from industry's consumption of energy is by far the largest source of industry's total climate gas emissions. For this reason, The IDA Climate Plan 2050 focuses specifically on energy-efficiency in industry. Emission of CO_2 from other industrial processes originates predominantly from the production of cement (~84 %), lime and limestone (~9 %), tile (~3 %) and metal (~3 %). In general, these CO_2 emissions are directly linked to the production of the products and can only be reduced by reducing the actual production volume or by CCS (carbon capture and storage).

Methane emissions appear partly in connection with the production of energy consumed by industry (7 %), partly in connection with the refining of oil products (7 %) and partly in connection with degasifying of landfill sites (86 %). Methane emissions from Danish landfill sites were considerably reduced when a ban on the disposal of waste suitable for incineration was implemented in 1997. Thus, a number of accumulation facilities for landfill site gases were established on landfill sites with significant gasification up to introduction of this ban. The landfill site gases are either burned off or used as fuel in gas generators that produce electricity.

Use in gas generators peaked in around 2000, at 11,000 extracted tons. However, in line with the decline in gas production, gas generators are becoming increasingly unprofitable to run and new plants are no longer being built in Denmark. Instead, alternative methods are being developed, e.g. at the Technical University of Denmark (DTU), for the breakdown of the gas residues that remain in old depots using the so-called biocover principle; covers are gas-proof but have controlled "windows" which are filled up with a metre-thick layer of compost in which bacteria propagate and break down the methane into CO_2[85].

Development of biogas production will lead to an increased risk of methane emissions from leakages. Therefore, it is important to identify safe methods for both sealing and monitoring. In summary, a 25 % reduction in methane emissions is expected by 2050.

Nitrous oxide emissions ceased in Denmark in 2005 when the fertiliser manufacturer Kemira was closed.

Other emissions of the climate gases PFC, HFC and SF6 (the so-called F-gases or potent greenhouse gases) have been subject to a law controlling use of these since 2000 and this will significantly reduce contributions from these gases within a few years. F-gases are mainly used as coolants in small, stationary cooling systems and in the majority of mobile cooling systems. The use of PFC is forbidden in new systems. In addition, the new legislation includes requirements for monitoring (detection systems) or regular inspection with a view to reducing emissions from cooling systems. To a large extent, HC gases[86], and in some cases CO_2, are used for foam moulding of insulation materials instead of HFC gases. F-gases will be radi-

85. Further details are available in the technical memorandum on climate gases originating from the handling of Danish waste, IDA 2009
86. Cyclopentane and N-pentane

cally phased out up to 2015. It is expected that, by this date, emissions will already have been reduced by almost 80 % compared to 2007. It is not expected that further reductions will be possible by 2050.

The IDA Climate Plan 2050 does not include an assessment of other climate gases such as solvents, NO_x, CO and SO_2. The contribution from emissions of these gases amounts to 0.2 % of total climate gas emissions (The Kyoto Convention).

Industry's energy consumption

Trade and industry accounts for 35 % of Denmark's total energy consumption: 234 PJ in 2007. The largest sectors are manufacturing, which accounts for 49 % of the energy consumption of industry and commerce, and private service and agriculture. Fossil fuels account for 52 % of this energy consumption, renewable energy for 5 %, district heating for 11 % and electricity for 32 %.

The energy consumption of the manufacturing industry has remained fairly constant over the past twenty years. However, the consumption of trade and service industries has increased by approx. 1 % per year. The energy intensity, which is energy consumption relative to gross value added at a fixed DKK rate, is significantly lower today than in 1990 in most sectors

The fact that manufacturing enterprises show reduced energy intensity is particularly due to structural changes whereby sectors that are light consumers of energy, such as the iron and metal industry, grew in proportion to other industries between 1990 and 2006. However, the intensity effect, which is a combination of a wide range of factors such as energy savings and substitution of fuel by, on the one hand, electricity and district heating (which entails savings in conversion loss) and, on the other, increased mechanisation and automation, was almost the same in 2006 as it had been in 1990.

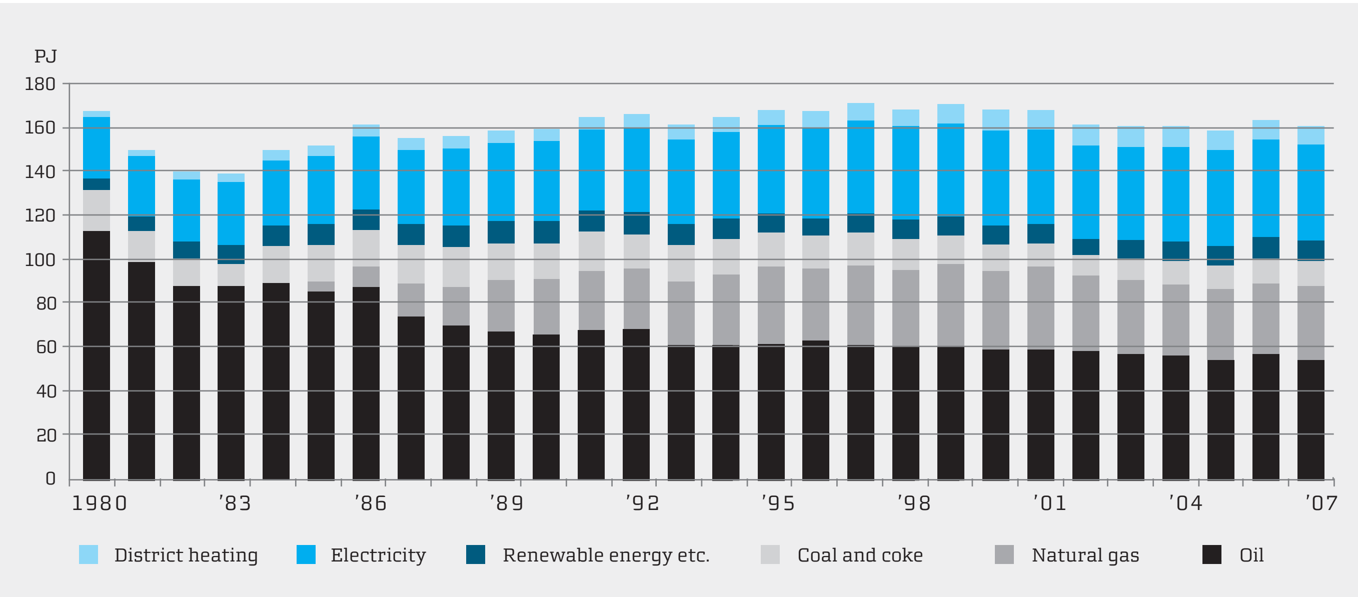


Figure 31: Energy consumption of the manufacturing industry 1980-2007, by energy product (corrected for variations in climate). The figure also includes the energy consumption of agriculture, forestry, horticulture and fisheries.

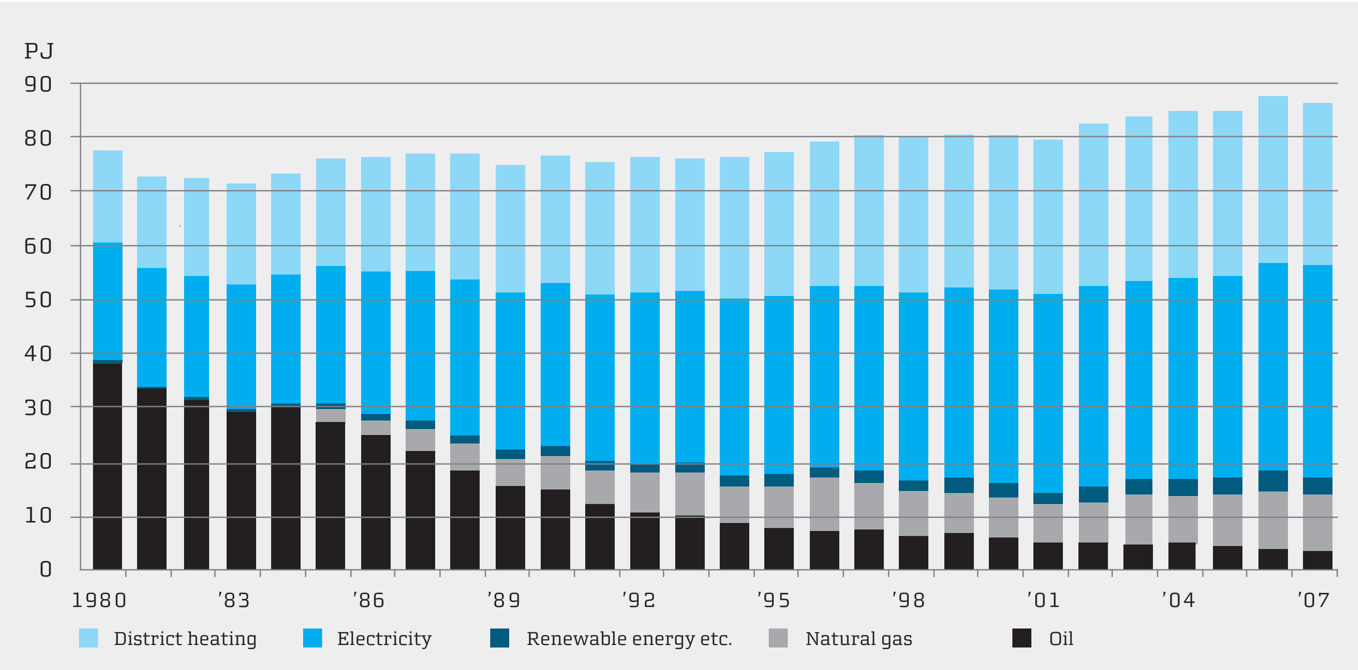


Figure 32: Energy consumption of trade and service industries 1980-2007, by energy product (corrected for variations in climate, including public service)

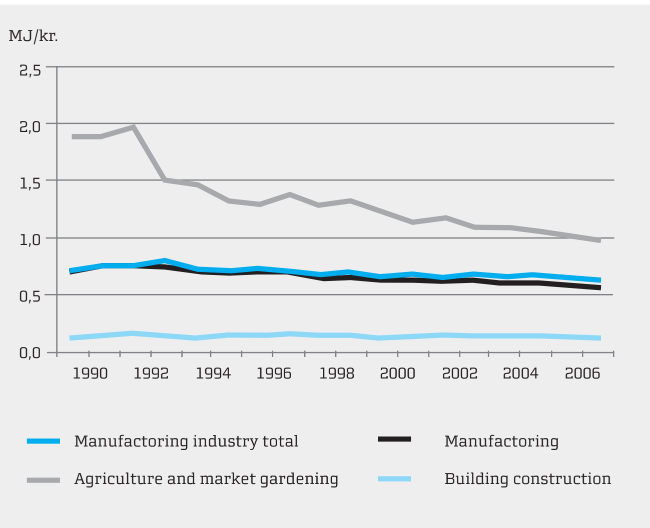


Figure 33: Energy intensity, 1990-2007, in the manufacturing industry (DKK is the gross value added at fixed 2000 prices)

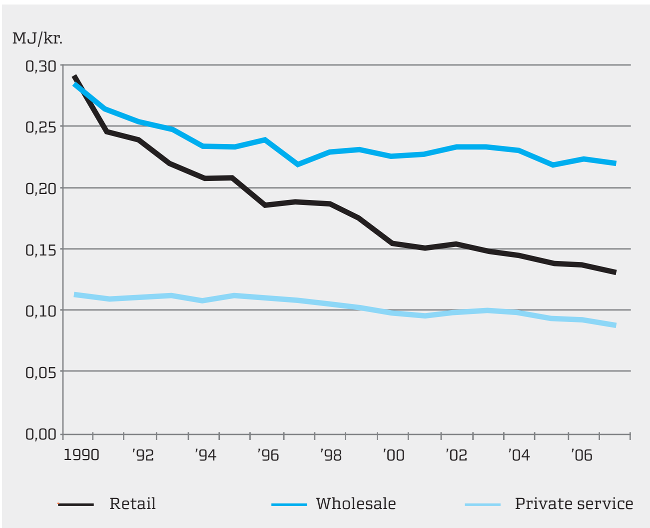


Figure 34: Energy intensity, 1990-2007, in trade and service industries (DKK is the gross value added at fixed 2000 prices)

Energy intensity in wholesale trade more than halved from 1990 to 2007 and it fell by approx. 20 % in retail and private service. The substantial decline in energy intensity in wholesale trade is presumably due to a structural change aimed at creating non-energy intensive wholesale trade. In the case of all three sectors, an increase in the proportion of district heating (replacing oil in particular, which could have produced a loss of 20 – 30 % on conversion) presumably also has an impact on the decline in energy intensity.

However, a study of the manufacturing industry's energy intensity indicates that, since 2000, there has been a small increase in energy intensity if we consider manufacturing companies as a whole and a larger increase if we also take structural development into consideration. Thus, the ten manufacturing sectors used approx. 5 % more energy in 2006 than in 2000 per DKK value added, which indicates that efforts to save energy have not been quite so effective during this decade.

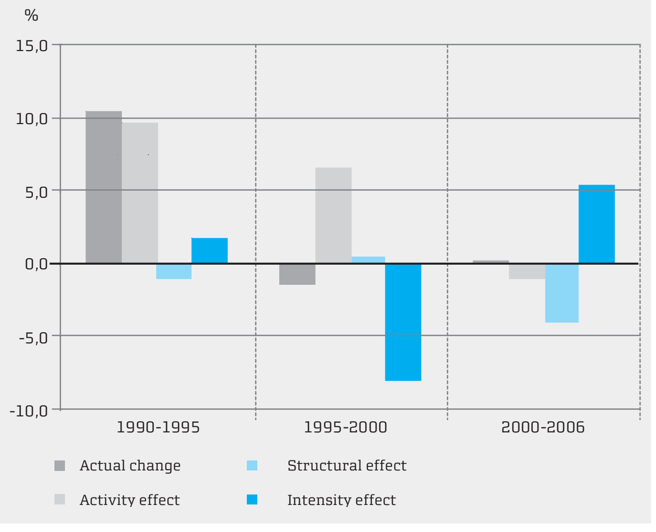


Figure 35: Breakdown of the development of the energy consumption of manufacturing companies, 1990-2006

POTENTIAL FOR SAVINGS

The potential for energy savings on heat consumption (the consumption of fuel and district heating) and on electricity consumption is assessed in the short term (2015) and in the long term (2030 and 2050) with a repayment period of 7,5 years[87]. Energy saving measures in industry would normally only be implemented if the repayment period was significantly shorter (around 2 to 4 years). This is due to the fact that investments in energy savings compete with investments with a strategically higher priority. The reason why this report highlights the energy saving potential of a 7,5 year repayment period is partly due to the benefit to society and partly due to the fact that there is a need to achieve defined climate goals. It is, therefore, quite crucial that endeavours are made to increase enterprises' incentive to make energy savings by various regulatory means.

Great potential in reducing heat consumption

This covers all forms of heat consumption related to either indirect or direct heating with fuels or district heating and electricity. Therefore, heating of the business sector's premises is also included. Industry's total heat requirement amounts to around 159 PJ annually and the heating of premises accounts for 25 % of this.

With respect to industry's heat consumption, it is expected that there will be significant opportunities for savings in all end uses, in process integration and in the use of enzymes in production. Potential savings in fuel consumption with a 7,5 year repayment period are indicated in Table 10.

87. The energy prices applied are the prices used by the Danish Energy Authority in its socio-economic analyses, plus any taxes applicable at the beginning of 2009.

	2015	2030	2050
Saving in %	27	31	33
Saving in TWh	11,8	13,8	14,6

Table 10: Potential savings in fuel consumption, with the 7,5 year repayment period in The IDA Climate Plan 2050
Source: Potential is calculated based on the technical background report; Energy savings in trade and industry, IDA 2009.

Most significant energy savings can be achieved by using thermal pumps, if heat requirements are below 150°C, by converting industry's fuel consumption from fossil fuels to biofuels and by using enzymes for specific types of production. There is currently no thermal pump technology suitable for industry's heat requirements above 150°C (e.g. for the burning of cement and the melting of glass at around 1500 °C).

In addition, there is potential for savings in heat consumption in various different industrial processes[88]. Evaporation processes offer potential in the form of increased preheating, more evaporation steps, thermal and/or mechanical recompression of steam, substitution with reverse osmosis and improved process management.

There is also significant potential for savings in dehumidification processes and the following measures are expected to be implemented: Reduction of water content before thermal dehumidification through, e.g., improved mechanical drainage, preheating of raw materials, indirect dehumidification where possible and increased heat recovery.

In the fields of burning and sintering, potential savings are expected to originate from increased drainage before dehumidification, improved insulation of kilns, increased heat recovery, addition of additives that can reduce the required process temperature. In the case of fusion and moulding processes, savings are expected to come from improvements in insulation, increased heat recovery using thermal recuperators, increased preheating and the use of oxyfuel combustion.

Optimised process management, cascading distillation, other separation technologies such as membranes and additional and more effective column plates are expected to result in energy savings in distillation processes.

As mentioned above, thermal pumps are the source of the greatest savings. It is expected that around a fifth of the achievable reduction in heat consumption can be gained by using thermal pumps (the equivalent of 10 PJ, 16.4 PJ and 17.6 PJ in 2015, 2030 and 2050 respectively). However, a proportion of the savings gained by the use of thermal pumps is offset by an increase in electricity consumption (equivalent to 2.3 and 3.7 PJ in 2015 and 2050 respectively).

Industry's requirement for the heating of premises amounts to 25 % of industry's total heat requirement. According to Climate Plan 2050, it is expected that this requirement will primarily be covered by thermal pumps, excess heat produced by industry and passive as well as active solar heat. If this is to be achieved, heat requirements must be reduced by improving the insulation capabilities of the building shell of both existing buildings and new office buildings. The expected potential for savings on heat for industry's premises is indicated in table 9, which shows total potential savings in industry's heat consumption.

It is expected that around 100 % of industry's consumption of fossil fuels will be able to be replaced by biofuels. However, it should be noted that the conversion to biofuels for industrial combined heat and power will reduce the electricity production of CHP plants to almost one third.

It is assumed that enzymes will be able to be used in processes that represent 5 % of trade and industry's energy consumption (primarily heat) and the savings potential only applies to these processes.

88. Further details are available in the technical background report; Energy savings in trade and industry, IDA 2009.

Industry's electricity consumption must be reduced

Industry's total requirement for electricity amounts to around 75 PJ annually. Potential savings with a repayment period of 7,5 years are indicated in Table 11.

	2015	2030	2050
Savings in %	32	43	45
Savings in TWh	7,2	9,8	10,2

Table 11: Potential savings in electricity consumption, with the 7,5 year repayment period in The IDA Climate Plan 2050.
Source: Potential is calculated based on the technical background report; Energy savings in trade and industry, IDA 2009.

It is assessed that the greatest potential is to be found in pumping, ventilation, cooling and compressed air[89]. These technologies are still the most interesting areas with the greatest potential for energy savings. Even though massive efforts are being made to provide energy labelling for motors, pumps and ventilators, the rollout and implementation/replacement of energy-efficient components and the optimisation of the systems in which these components are incorporated remain outstanding issues.

The most significant potential for savings in the field of lighting is expected to come from LED (light-emitting diodes) and a considerable breakthrough and substantial circulation is expected by 2015. In addition, it is expected that improved management (demand management) will result in potential energy savings in this area.

With respect to pumping, cooling and ventilation, savings potential is expected to arise primarily from the use of highly efficient components, the reduction of requirements, optimised control and an increase in maintenance. In addition, it is expected that the use of Permanent Magnet Synchronous Motors (PMSM) will result in considerable energy savings, particularly in pumping and ventilation. From the point of view of cooling, free cooling, solar protection features and absorption cooling will provide potential for future energy savings.

The use of compressed air shall be replaced wherever possible by direct electrical operation or by the use of highly efficient, oil-free compressors. Furthermore, significant energy savings can be made if loss through leakage is reduced. In the field of industrial electric motors, in addition to the development of more efficient motors, it is expected that reducing the need for an energy service and the optimisation of demand management will provide opportunities for savings.

In the fields of fusion and other process heat based on electricity, it is expected that the optimisation of material consumption (optimisation of feed systems in foundry moulds), minimisation of fusion and shortening of holding and idle times will provide potential for savings. In the field of injection moulding, in particular, the use of all-electric machines will provide significant opportunities for energy savings.

It should be stressed that the savings potential can only partly be realised by the companies themselves in their ongoing efforts to reduce costs and optimise production and by the natural replacement of equipment and processes. In order to achieve great results, a broad range of mechanisms will be required that can motivate and force companies to initiate energy savings.

How do we get energy savings rolling?

To a great extent, energy savings and energy efficiency measures in industry depend on the financial implications. When it comes to short term improvements, it is almost entirely the financial and normative mechanisms that are effective. The coming changes to energy taxation should, in particular, be mentioned here as

89. Further details are available in the technical background report, Energy savings in trade and industry, IDA 2009.

they will cause energy-intensive companies to focus on energy savings. However, the public debate on these taxes underlines the fact that increased taxes can result in the relocation of energy-intensive production.

When compiling a package of mechanisms, it is important to analyse the way in which taxes that will make energy more expensive and investment grants that will make savings cheaper can be combined so that both initiatives promote improvements to the cost-effectiveness of savings. Taxes on energy consumption, in particular the heating of premises, have already been imposed on industry and, all things being equal, increased taxes will increase a company's interest in reducing energy consumption.

Taxes and quota schemes such as CO_2 quotas are tools which are relatively easy to use but which, unfortunately, have some serious side effects. The energy expenses of the greater part of industry only amount to 0.5 – 2 % of turnover whereas, in energy-intensive companies, they account for 10 %. Thus, even the smallest percentage increase in energy expenses has an enormous impact on the competitiveness of these companies (unless their competitors throughout the world are also subject to similar increases).

Subsidies for energy-saving measures do not impair competitive capacity. On the contrary, they will improve it by reducing the level of costs. This can be done by establishing a fund[90] to promote and provide subsidies for energy-saving measures in manufacturing companies. The budget of this type of fund ought to total DKK 800 million per year. As industry's annual energy costs amount to around DKK 15 billion a year, a fund of this size would shorten the repayment time for energy-saving initiatives by 2 to 3 years[91]. This would provide a very significant incentive, which would create great interest in energy efficiency measures in the companies and, presumably, be able to turn the tide of recent years' unfortunate energy intensity trends, cf. (➜ see figure 34). The effect of contribution schemes will be increased if they are directly connected to a business's energy savings, either in connection with changes in existing plant or in relation to benchmarking of new buildings. This will thereby result in a (fund) solution that supports active energy savings – potentially in connection with ESCO businesses as stated below – and which thereby has a direct effect on repayment times.

Financial instruments based on subsidies or loan schemes are generally more positively received by the business sector and a fund for the implementation energy-efficient measures will shorten the repayment period by between two and three years. This is the equivalent of an increase in savings potential of between 8 and 19 percentage points[92].

Energy service companies, or ESCO companies, are another type of financial instrument. These companies can finance a company's savings projects and are paid via the energy savings gained. The prevalence of energy service companies will also result in new players on the market; players who are specialists in energy efficiency measures.

Finally, research and development in the field ought to be given a much higher priority as the immediate gain for society of reducing industry's consumption of fuels and electricity far outweighs the advantages of converting supplies to renewable sources. This research and development shall be followed up by development of the market for new products

90. also proposed in the Danish Society of Engineers' Energy Plan 2030. Main report. The Society of Engineers in Denmark, IDA. December 2006

91. If the fund contributes to savings amounting to 2% of energy consumption (or DKK 300 million) each year, DKK 800 million would reduce the repayment period by 2.7 years.

92. It ought to be mentioned that, to a certain extent, energy companies today "purchase" energy savings from trade and industry. Payment for this typically amounts to DKK 100 – 250 /MWh, which is the equivalent of reducing the repayment period by a few months, or even up to a year. Thus, a fund would be a much more powerful mechanism.

MORE INFORMATION ABOUT EFFICIENCY IMPROVEMENT

Information mechanisms already contain many tools and models that can be used to implement energy efficiency measures. Therefore, what is needed is support for the dissemination of these tools. This can be provided by training designers, sales personnel and consultants. Finally, success stories and methods can be spread via network activities related to energy management and efficiency improvement.

Good tools are important in order to overcome barriers such as a lack of knowledge and ideas and too little time. These tools are intended to support ongoing discussions and information exchange and, in the long term, they will make it easier to act in an energy-conscious manner when purchasing and designing. In the 1990s, a number of tools were developed under the Danish Energy Authority's aid scheme. It would be of benefit to update and develop these tools and make them more easily accessible. It would also be an advantage if good operating instructions for energy-consuming systems were added.

In particular, efforts in and around the company itself, e.g. in relation to employee participation, are highlighted by representatives of trade and industry and in previous research projects (e.g. MIRT[93]) as being important. However, information mechanisms are assessed to have a long term effect and, therefore, are primarily relevant to the potential for 2030.

Tools and models are used by many different players and there is a need to support the existing players' potential and expertise.

One thing that is needed is training of the staff that design, purchase and operate the systems. However, sales personal also need to be trained so that they are aware of the potential for reducing energy consumption and understand the significance of the energy costs seen in relation to the investment and the other costs of the equipment they sell. Finally, an increase in the range of training courses aimed at the consultancy market could promote efforts to introduce energy efficiency measures by increasing the prevalence of competent energy consultants.

Companies may be inspired to get started themselves if they hear others' experiences of energy saving. Experiences can be passed on through brochures, articles, open-house events etc. One particularly efficient way of passing on knowledge is through the participation in groups made up of representatives from like-minded companies. With the aim of benchmarking of energy consumption, they can discuss good and bad experiences of their activities, make a mutual commitment to introduce new initiatives and report on the results. These groups may, for example, discuss one application at a time; they may start by discussing pump systems one year and ventilations systems the next. Thus, this is an activity that can easily be handled by existing company networks and organisations.

LABELLING SCHEMES ON THE AGENDA AGAIN

Energy labelling has helped significantly improve the efficiency of household appliances and could also be used to advantage by industry for appliances that are sold in large quantities. Energy labelling makes it easy to select an energy-efficient solution and no prior training of the purchaser is required.

In other cases, in which equipment is not so simple, projects can be required to be based on energy-conscious design; thus, the need for an energy service is assessed, alternative solutions are identified and overall finances presented. In the same way as companies are required to have environmental approval, a scheme could be envisaged whereby companies receive energy certification. They will be required to document energy-efficient design. Finally, a verifying body may be linked to the process in order to provide certification of the energy-efficient design.

93. Employee participation in environmental efforst, Learning processes in environmental groups, by Børge Lorentzen and Arne Remmen.

In the case of existing systems in energy-intensive companies, energy saving potential can be thoroughly examined every five to ten years. The process may include the participation of experts or persons accredited in the industry in question as well as the processes applied. This will ensure that the energy inspection focuses on the most important and most energy-consuming processes instead of auxiliary equipment.

In companies that consume less energy, an energy inspection can be based on current schemes for energy labelling of buildings and compulsory ventilation inspection, both of which could be extended to include production buildings. At the same time, compulsory schemes could be introduced for several other areas, such as lighting systems, fridge-freezers etc.

The concept of the agreement is to reward energy-intensive companies if they behave in an energy-efficient manner. However, the concept seems to be "losing its shine" and, therefore, it may be necessary to change the scheme and make it voluntary so that all companies that join the scheme are rewarded with a tax reduction and/or with investment grants for energy savings. The requirement could be the same as that of the Dutch scheme which stipulates that a company must be among the top 10 % in the world when benchmarked after a few years.

In connection with the expansion of the circle of players in the field of energy efficiency measures, certification schemes may promote the activities of energy consultants and the introduction of energy management. Thus, international efforts to standardise energy management, ESCO and energy efficiency and simulation will be able to operate together with existing management systems such as ISO 9001, ISO 14001 and others, and this will ensure that energy management is integrated into management systems. Similarly, certification of energy consultants will aid quality assurance and the marketing of energy consultancy.

A RANGE OF OPPORTUNITIES

Both the financial and information mechanisms can operate together with normative mechanisms, such as energy labelling, that both support the involvement of staff in climate change activities and form a basis for subsidy schemes. An increase in control of energy reviews and energy inspections in companies can help increase the focus on energy consumption. However, this is generally met by a negative response from the business sector and ought to be incorporated in government efforts to simplify rules.

It is also assessed that formalised energy management, e.g. in the form of certified management systems, has a positive effect, although this is again dependent on interaction with, primarily, the financial mechanisms. However, the combination of certification options and legal requirements may create greater synergy with the financial incentives so that the long term potential can be realised.

Housing and buildings

Summary:
Housing and buildings

Intermediate objectives – Climate Plan 2050

2015

- In the period up to 2020, 75 % of the most poorly insulated walls, roofs and floors will be renovated and windows replaced. This will result in a saving of 18 PJ in 2015 and 37 PJ in 2020
- Electricity consumption will be reduced by 25 % compared to 2008

2030

- From 2020, new buildings will be "energy producing" according to BOLIG+ (a zero emission building concept) standards.
- Between 2020 and 2030, walls, roofs and floors that are poorly insulated according to current good, average standards will be renovated. This will result in a saving of 21 PJ. Renovation of technical installations between 2010 and 2030 will result in a saving of 20 PJ. Together with activities in the period between 2010 and 2020, by 2030 the total annual saving will amount to 78 PJ.
- Buildings that are not included in the district heating system will be made energy-neutral by promoting the use of renewable energy in buildings.
- The district heating system will be extended and cover approx. 70 % of the total existing building stock.
- Electricity consumption will be reduced by 50 % compared to 2008.

2050

- The energy consumption in buildings has been reduced and buildings outside of the district heating systems are CO_2 neutral. Buildings included in the district heating system will receive energy from renewable energy or waste heat.

MEANS

- Promotion of the development of energy-producing houses, e.g. by making the Bolig+ concept (a zero emission building concept) the final goal for building regulations and by making it a standard from 2020.

- Promotion of the renovation of the existing building stock by stepping up consumer information, providing training, tightening building regulations and creating incentive schemes aimed at consumers. Public authorities shall show the way by imposing special requirements on public buildings.

- Financing of residential renovation must be promoted through a combination of financial incentives including differentiated taxation of residences, favourable real credit financing and public contribution.

- Between 2010 and 2020, DKK 675 million will be set aside annually to support energy savings and integration of renewable energy in building projects. These funds ought to be distributed as follows:

  » DKK 400 million in the form of financial incentives for the promotion of housing renovation.
  » DKK100 million for the integration of renewable energy into buildings.
  » DKK 100 million for special activities related to public buildings.
  » DKK 50 million annually for the training of construction partners and the development of improved instructions on energy-saving construction and components.
  » DKK 25 million annually for information campaigns.

Housing and buildings

Today, the energy consumption of buildings, dwellings and industrial and commercial construction accounts for over 40 % of total Danish energy consumption and costs almost DKK 45 billion a year. Therefore, if we are to ensure a serious reduction of greenhouse gas emissions, it is crucial that we succeed in reducing the energy consumption of buildings.

From a commercial point of view, Denmark would benefit greatly from hefty investment in more energy-efficient construction. Denmark's energy requirements for buildings are currently the strictest in the world and the general opinion is that even stricter requirements for energy consumption – combined with more spearhead development projects, increased research development in energy technologies and communication and learning – may provide Danish engineers, architects, construction companies and energy technologies with an excellent opportunity to move to the forefront of the international market94.

One of the specific challenges facing the construction sector when identifying and assessing focus areas and energy saving potential is that, in 2030, approx. 70 – 75 % of the building stock will consist of housing that already exists today. The energy consumption of the great majority of these buildings is much higher than that of the buildings that are currently being constructed and will be constructed in the future. Thus, the greatest energy savings are to be made on the established building stock.

Energy consumption in older buildings is distributed as follows: Room heating, almost 70 %, heating of hot water, just under 10 % and electricity consumption of electrical appliances and lighting, approx. 20 %. The distribution is quite different in new buildings in which heat consumption accounts for approx. 30 %, heating of hot water approx. 20 % and electricity consumption approx. 50 %.

94. Catalogue of initiatives from the Danish Enterprise & Construction Authority's partnership for lower energy consumption

The government's energy strategy results in an energy saving of 4 % in 2020. The climate plans' target is a saving of 37 PJ in 2020 and the climate plan's total initiatives result in energy savings of 78 PJ and savings of 14 PJ (4TWh) upon integration of renewable energy for hot water and heating. The proposal of the climate plan is thus considerably more ambitious and requires an annual saving of approximately 4.5 PJ. In order to achieve this goal, building owners must perform considerable investments and incentives to promote this development will be required. The total savings amount to 60 % of the total energy consumption, equivalent to an annual saving of DKK 27 billion. The total private investment for the entire climate plan's period is approximately DKK 460 billion of which a significant share will be general maintenance provided that the energy investments are commenced in connection with general renovation.

Targeted efforts and information campaigns could reduce the electricity consumption of buildings by 50 % by 2030.

A significant proportion of the above-mentioned savings stem from renovation of the building shell and it ought to be considered whether energy savings that are not immediately viable should be implemented or whether CO_2 reductions should instead be derived from increasing the proportion of renewable energy and waste heat from the district heating system, or, alternatively, by integrating thermal pumps into buildings.

New construction

Today, there is no technical difficulty in building housing with minimal energy consumption and it is assessed that, with the current technology, it would be financially viable for private house builders to build low-energy dwellings (with the Danish class 1 low energy rating) outside areas with district heating[95]. Low-energy class 1 dwellings can be built at a marginal cost of 10 % of the total construction sum. This can be reduced to approx. 6 % by optimising product solutions and selection of materials etc.

The first dwellings that do not use energy have already been erected, e.g. "Housing for Life" in Aarhus[96], and the first BOLIG+ apartment block[97] is expected to be constructed within the next few years in Aalborg. The marginal cost of changing a building with a class 1 low-energy rating to an energy-producing building depends upon the renewable energy source selected for integration in the building and whether the building belongs to a local, low-temperature district heating area with renewable energy. The marginal cost involved in progressing from the level of low-energy class 1 to BOLIG+ is assessed at around 5 % of the construction sum.

If tomorrow's new buildings are to be energy-neutral, it is important to focus on the design of the building. Buildings must make use of passive solar energy for heating and optimal design is the best way of ensuring this. In addition, it must be ensured that buildings do not require cooling. This also requires focus on the design of the building; the building must be properly shielded on sunny days. These issues provide the engineering profession and architects alike with a challenge that must be met if the industry's problems are to be solved.

If the above initiatives are to be implemented, improved understanding of energy design and an upgrade of the knowledge and expertise of all of the parties involved in construction will be necessary. Furthermore, more stringent requirements for building regulations are another initiative that must be followed up by financial incentives, e.g. in the form of optimal mortgage credit for initiatives that make the buildings of the future more expensive than the standard. The energy costs of buildings should also be made visible to homeowners and be a part of the total costs for new construction. Provided that investments can be financed privately, the cost of new construction will be neutral.

The parties involved in construction ought also to consider new forms of collaboration in order to promote energy-producing dwellings and this is where the engineering profession can take the lead. One example of this is the energy-producing building "Housing for Life", which was developed by engineers, architects, contractors and material manufacturers in collaboration. During the design phase, a number of workshops were held with the aim of identifying issues and developing proposal solutions. During the interdisciplinary collaboration, the team developed the solutions that were subsequently used in the project.

During discussions on the 2008 energy deal, it was decided to impose a requirement for the reduction of the energy consumption of newly built houses by 25 % by 2010 (low-energy class 2), by 50 % by 2015 (low-energy class 1) and by 75 % by 2020. The government's strategy for the reduction of energy consumption in buildings adheres to these targets, the reason being that there is a need to develop knowledge and expertise in the industry. However, it ought to be considered whether it would be advisable to take a decision already now to tighten up building regulations and make BOLIG+ the minimum standard by 2020.

There is also a need for better tools for designers, e.g. simulation programs with improved capacity to calculate and simulate realistic conditions in buildings. The simulation tools can be developed to contain data and costs for operation of the building and this will help to optimise the building. The engineering profession and construction research institutions play a significant role here.

95. SBi 2009:04 More stringent requirements for new construction projects by 2010 and beyond
96. *www.bolig-for-livet.dk*
97. *www.boligplus.org*

The collected commenced construction 1.000 m²	2004	2005	2006	2007	2008	2009
Homes total	**3.375**	**4.100**	**4.625**	**2.850**	**2.375**	**2.075**
Detached- and farmhouses	1.125	2.225	2.625	1.875	1.750	1.500
Row-, linked- and double houses	700	775	825	450	250	200
Apartment blocks	800	950	1.050	450	300	300
Other housings	150	150	125	75	75	75
Business total	**4.175**	**4.600**	**5.725**	**4.350**	**4.325**	**4.150**
Factories etc.	650	700	700	650	775	700
Administration and trade etc.	975	1.050	1.550	1.275	1.425	1.300
Agriculture etc.	2.250	2.425	3.125	2.150	1.900	1.900
Other businesses	300	425	350	275	225	250
Other constructions	**1.875**	**2.000**	**1.825**	**1.300**	**1.225**	**1.225**
Public institutions	400	325	275	175	225	300
Holiday cottages	675	775	675	450	375	325
Garages and out houses	800	900	875	675	625	600
Constructions total	**9.425**	**10.700**	**12.175**	**8.500**	**7.925**	**7.450**

Figure 36: Breakdown of the development of the energy consumption of manufacturing companies, 1990-2006
Source: Statistics Denmark and the Confederation of Danish Industries

Experience from countries such as Austria, Germany and Switzerland indicates that the development of low-energy dwellings and low-energy solutions can be stimulated by providing grants for the upgrade of buildings from standard to low-energy[98]. There is a need to develop incentive schemes which will encourage property owners, between 2010 and 2020, to build houses that are better than low-energy standard 1 and to develop energy-neutral buildings outside the district heating area. An annual sum of DKK 25 million ought to be earmarked to promote the construction of buildings that are better than the legal standard. This corresponds to financial support for approx. 250 new buildings a year.

Between 2004 and 2008, an average of approx. 10 million m² of floor space was constructed, approx. 3.5 million m² of which was for housing. This is the equivalent of approx. 17,000 houses a year. In 2009, it is expected that new developments will account for a

98. SBi 2009:06 Mechanisms for the promotion of energy savings in buildings

significantly smaller proportion[99]. Climate Plan 2050 assumes that the annual increase in new buildings will, on average, be equivalent to the level in 2008.

The cost of new construction is approx. DKK 10,000/m^2 for housing and DKK 13,000/m^2 for offices and other buildings. The energy saving initiatives in the plan can be implemented at an additional cost of approx. 6-10 % up to 2020[100] and, from 2020, energy-neutral buildings can be developed at an additional cost of approx. 10-15 % compared to current prices.

Renovation of existing building stock

BUILDING SHELL 2010-2020

There is great potential for energy savings in the existing building stock. An SBi (Danish Building Research Institute) report[101] has identified potential savings of 37 PJ (approx. 23 % of the energy required for heating and hot water) in dwellings and offices if viable energy-saving initiatives are introduced. The precondition for these savings is that 75 % of the outer walls with a U value of over 0.9 W/mÐK be improved with 100 mm insulation. Similarly 75 % of the walls with a U value over 0.3 W/mÐK must be improved by laying down 200 mm insulation. 25 % of the floors with a U value over 0.5 W/mÐK are expected to be improved with the injection of 100 mm insulation in the beam layer. It is expected that all windows with a total U value over 2.5 W/mÐK, equivalent to all standard 2 layer thermal panes will be improved to today's standard.Thus, it is not a complete renovation of the Danish building mass that is required but rather a dedicated effort to upgrade specific types of building. The total cost of implementing these improvements will be approx. DKK 198 billion. These savings have been identified as viable and, if they are made in connection with ordinary housing renovation and together with planned improvements or replacements, the cost will only amount to approx. DKK 38 billion.

Due to the fact that the investments are viable, a significant proportion of the cost will be able to be covered by mortgage financing. However, incentives must be created in order to ensure that investments are made. This can be done by providing public grants for renovation, favourable loans, differentiated taxation and additional consumer information. The energy labelling scheme for buildings must be further developed and used to identify the most viable renovation solutions. It can also be used as a tool in connection with loans. In order to stimulate energy efficiency renovation, an annual sum of DKK 400 million ought to be earmarked for direct or indirect subsidies for property owners. This is equivalent to 2 % of property owners' total cost of renovation. By comparison, the renovation pool of spring 2009 amounted to DKK 1.5 billion and it appears that private house owners have shown great interest in making use of the scheme to stimulate renovation activity.

Several of the players in the construction industry and building materials manufacturers have conducted demonstration projects related to housing renovation[102]. There are examples of renovation of older detached houses from around 1930, single-family houses from 1960 – 1980 and apartment blocks from 1970. As was the case with the new developments, the projects were carried out by all of the construction industry's parties in strategic collaboration and it is extremely appropriate to assess whether these types of project can be encouraged by creating new types of cooperation in which the engineer plays a significant role.

99. Statistics Denmark and the Building Materials Industry in the Confederation of Danish Industries.
100. SBi 2009:04 More stringent requirements for new construction projects by 2010 and beyond
101. SBi 2009:05 Potential energy savings in the existing building stock
102. Rockwool, Isover, Parvenu, Bjerg Architects, Frandsen & Søndergaard K/S and Rationel Windows, et al

The public sector ought to be a role model when it comes to energy efficiency measures and renovation of the state and local authorities' property ought also to be encouraged. An annual sum of DKK 100 million is earmarked to stimulate the renovation of public buildings.

In order to encourage the renovation of buildings, it is necessary to build up the knowledge and expertise of the building industry and develop instructions and solutions for energy efficiency renovation. A knowledge centre for building renovation has recently been set up. The knowledge centre was established by the Danish Energy Authority and is managed by a consortium consisting of TI, SBI, Viegand & Maagøe and the communication company. Several other parties are subcontractors to the consortium. The centre's main duties are to improve expertise in the building industry, promote consumer information and help develop solutions for energy efficiency renovation. The knowledge centre has a limited budget but it is expected that this will be increased through public/private collaboration in the form of cooperation with companies. In addition to the knowledge centre, there is a need for development of guidelines and instructions for workmen and other parties in the construction industry. It is also necessary to encourage training. These additional efforts ought to be made by the private and the public sector in collaboration and an annual sum of DKK 50 million ought to be earmarked for the activities.

BUILDING SHELL 2020-2030

The SBi report[103] also identified energy savings of 58 PJ which can only be made if all structures that are more poorly insulated than the good, average standard for walls, roofs, floors and windows are replaced so that they meet current renovation requirements. The total investment for this initiative is estimated at DKK 398 billion based on current technology and energy prices. This means that these energy savings are not currently viable.

However, a significant proportion of the energy savings that are not currently viable can be initiated in connection with the viable savings. It is probable that technology and experience of renovation will advance technologies and solutions that, today, are not viable but, with the technologies and energy prices of 2020, will become viable. This means that structures that are not renovated together with the viable renovations will be renovated at a later stage.

The energy-saving measures that are initiated in the buildings that will not be renovated before 2020 will reduce structures to a level that is comparable with requirements that applied to structures in new buildings in 2005. This entails a further energy saving for dwellings and offices of 21 PJ (approx. 14 % of the energy consumption calculated for heating and hot water). Total investment amounts to approx. DKK 200 billion and the additional cost of carrying out the improvements together with improvements that are already planned is estimated at approx. DKK 62 billion. The reason why these savings are more expensive is that the procedures in the remaining structures (that will not be renovated before 2020) are more extensive. As a result of the initiatives that will be launched between now and 2020, new solutions will be developed and the costs will be reduced. Therefore, this is a conservative estimate as current prices have been used as a reference.

The energy savings ought to be assessed in relation to the energy supply system. Thus, energy savings in buildings connected to the district heating system are compared with alternative potential for energy savings in the district heating system and with alternative scenarios whereby the district heating system is converted to renewable energy and CO_2 neutral energy supply. It is particularly important to subject all initiatives that require significant structural procedures[104] to this analysis.

It is assumed that the financial opportunities and incentive schemes will continue beyond 2020.

103. SBi 2009:05 Potential energy savings in the existing building stock

104. Heating Plan for Denmark

BUILDING SHELL 2030-2050

The Climate Plan 2050 presupposes that almost all structures that were erected before 1995 have undergone energy efficiency renovation before 2030 and that only a few additional initiatives are required.

Building components with a life span of less than 20 – 25 years, such as insulated window panes, will be replaced continually. Components will be replaced in connection with ordinary maintenance and will reduce energy consumption further.

TECHNICAL INSTALLATIONS 2010-2030

The SBi report[105] identified energy savings that could be made if the building stock's technical installations were improved. Potential savings amount to approx. 20 PJ, which is approx. 13 % of the energy consumption calculated for heating and hot water in dwellings and offices. The total cost of improvements to the building stock's technical installations amounts to approx. DKK 34 billion. It has not been possible to obtain exact information about the extent to which the cost of improvements to technical installations could be reduced if these improvements were carried out together with planned improvements or maintenance.

Energy efficiency renovation of the technical installations ought to be carried out together with renovation of the other building stock and should be stimulated, in exactly the same way, by financial incentive schemes for property owners, as mentioned in previous paragraphs.

ECONOMY AND FINANCING IN RESIDENTIAL RENOVATION

The total costs connected with the performance of improvements in the period until 2020 is approximately DKK 198 billion. If the investments are performed in connection with general residential renovation and together with planned improvements or replacements, the marginal cost will be only approximately DKK 38 billion.

The total building and construction investments amount to approximately DKK 180 billion. Investments in residential building are approximately DKK 100 billion, of which approximately DKK 65 billion is new build and DKK 35 billion concerns renovation[106]. Renovation is primarily additions to existing buildings, new kitchens and bathrooms. Energy renovation is limited and it is estimated that financial benefits must be formed in order to promote energy renovation.

The climate plan therefore establishes annual support of DKK 400 million for building renovation in the period 2010-2020, equivalent to approximately 2 percent of the costs of building owners in the period. As stated, this investment together with the other initiatives will promote renovation.

The total investments for residential renovation in the period 2020-2030 are approximately DKK 200 billion, where the extra costs for performing the improvements together with previously planned improvements are estimated to be approximately DKK 62 billion. The climate plan presumes that these investments can be implemented without direct public support, however they will be commenced through long-term planning that will also include discussions on energy charges and residential taxation.

There is therefore a need for other initiatives that can promote incentives for building owners to renovate buildings. It is recommended that differentiated taxation and building loans be considered so that the building owners who make savings also achieve special benefits. It should be evaluated whether property taxation can be based on energy consumption. For example, energy neutral buildings in the RESIDENTIAL+ standard may be entirely or partially exempt

105. SBi 2009:05 Potential energy savings in the existing building stock

106. DI construction materials building prognosis for 2008 and 2009

from property taxation, which will promote the development of this type of residence.

It is recommended that particularly favourable loans be created, which have been demonstrated to be a very valuable incentive in promoting energy savings. Examples from Austria and German have demonstrated that favourable lending promotes energy savings and the integration of renewable energy.

The German climate target to reduce the emission of greenhouse gases by 40 percent in 2020 (basis year 1990) has led the federal government to inject extra funds that are targeted at making existing building mass more energy efficient. The federal government has thus quadrupled the support for energy redevelopment of buildings since 2005. In addition to the federal government's support schemes, individual states have implemented their own energy efficiency programmes.

In Germany support is given through the German regeneration bank Kreditanstalt für Wiederaufbau (KfW), i.e. through the KfW Förderbank (deposit bank). The bank is a public institution with an annual turnover of DKK 4,000 billion. Via KfW Förderbank the German government provides cheap loans, direct contributions and tax relief for trade duties for energy efficient renovation. The framework limit in the years 2006-2009 is euros 1.4 billion a year. The overarching goal is to reach householders who otherwise would not have considered energy savings when repairing their buildings. The target is an annual CO_2 redevelopment of five percent of buildings that are more than 30 years old. Support is given in the form of a 30-year loan at low interest with the potential for five repayment free years.[107]

There are examples of the financial sector working on financing packages for housing renovation and there is a need to encourage this development more.

For example, on 1 April 2009, Spar Nord Bank launched a consultancy concept entitled: "Energy-Efficient Housing Consultancy". The philosophy behind the concept is to calculate the total cost of the individual family's housing investments. There are two dimensions to the consultancy. One of the aims is to reduce the household's consumption costs. The other, significant objective is to ensure the value of the house on an energy market on which consumption costs are expected to constitute an ever increasing proportion of the family's housing costs.

Energy-Efficient Housing Consultancy is based on collaboration between Spar Nord and Energi Nord. Spar Nord collects a range of key data on the individual home and Energi Nord prepares a screening of the potential for energy savings in the house in question – an energy report. This report compares the technical and financial potential in the individual home and provides homeowners with a well-planned foundation on which to base their decisions. This helps prepare them for action or to look for further information.

It can be difficult to perform energy savings in the non-profit residential sector. There is therefore a need to evaluate how this sector can be made more energy efficient. There are several reasons to indicate bringing the National Building Fund's assets into play and this should be included in future considerations. One report from the Ministry of Social Affairs indicates that DKK 161 billion should be spent over the coming 20 years. The paradox arises here that residential policy in recent years and the use of the National Building Fund's assets for financing new old age and nursing residences have resulted in the National Building Fund only having limited potential to provide support for renovation projects. It is recommended that political measures be taken to promote energy savings in the public sector.

107. SBi report 2009.06 Means for promoting energy savings in buildings

ELECTRICITY SAVINGS IN BUILDINGS, WITH THE EXCEPTION OF INDUSTRIAL BUILDINGS

Electricity consumption in buildings will increase as the number of appliances increases if independent initiatives are not introduced. However, it is assessed that, by 2030, we will be able to reduce electricity consumption in households to a level equivalent to 50 % of current consumption if we introduce mechanisms that promote the most energy-efficient solutions and phase out the worst.

Thus, the Danish Electricity Saving Trust assesses that electricity consumption in buildings can be halved if we merely replace current appliances with the best low-energy appliances[108]. In addition, if appliances are replaced on a continual basis, there will be no additional cost involved.

The Danish Electricity Saving Trust's initiatives and campaigns have had a significant impact on the reduction of electricity consumption and it is important to continue to focus on consumer information.

In order to encourage the use of the most energy-efficient products, it is necessary to boost consumer information, consumer campaigns and labelling. It is assessed that the Danish Electricity Saving Trust's funds ought to be doubled from DKK 90 million per year to DKK 180 million per year. The Climate Plan 2050 recommends that all energy-saving activities be assembled in a common trust so that the various different activities can be coordinated.

The EU is in the process of introducing a wide range of standards for the maximum energy consumption of appliances. The introduction of these types of requirement is, presumably, the most efficient way of achieving reductions. Thus, Danish politicians and EU parliamentarians have an important task ahead of them; ambitious standards for electricity consumers' appliances must be defined under the auspices of the EU.

Integration of renewable energy technologies in buildings

Renewable energy can be integrated into buildings that are not connected to the district heating system or that are connected to the part of the district heating system that is based on fossil fuels.

In order to encourage the use of renewable energy forms, building regulations must require that renewable energy be integrated into all buildings outside the district heating system when renovation activities are carried out. The long-term goal for 2050 ought to be that 100 % of all energy supplied to these buildings must be renewable energy.

As a supplement to legislative requirements, the integration of renewable energy can be increased by initiating incentive schemes equivalent to the schemes initiated in connection with energy efficiency renovation.

An annual sum of DKK 100 million ought to be earmarked to encourage renewable energy in buildings outside the district heating system.

INTEGRATION OF SOLAR THERMAL SYSTEMS

Solar thermal technology is a simple technology that has been tried and tested over the course of many years and has now reached the stage of its development at which solutions become standard solutions. It is estimated[109] that solar thermal systems can produce 4 TWh to cover energy consumption for hot water and room heating. This is equivalent to the output from 6 million m^2 of thermal solar panels installed on buildings in Denmark.

Half of this goal can be achieved by 2020 and three quarters by 2030, which is equivalent to the installation of 4 million m^2 of solar panels by 2030. A system that heats hot water costs approx. DKK 25,000 and a system that provides hot water and room heating

108. The Danish Society of Engineers' Energy Plan 2030

109. Danish Solar Thermal Association costs approx. DKK 40,000. The simple energy price for solar thermal energy is DKK 0.5 /kWh.

USE OF THERMAL PUMPS

Thermal pumps are not renewable energy; they change the form of the energy. Heat is produced by electricity at a high rate of efficiency.

One example of this particular development is a solar thermal pump, developed jointly by Danfoss and Sonnenkraft. Solar heat is the primary energy form which is supplemented by a thermal pump, and solar energy is used to increase the utilisation coefficient in the thermal pump. The solar thermal pump can be used for heating and hot water in dwellings.

Thermal pumps and solar thermal pumps can replace traditional heating systems, such as oil-fired central heating or natural gas, in energy-efficient buildings outside the district heating system.

The advantage of using thermal pumps in existing buildings is that fossil fuels are superseded by electricity that can be produced by renewable energy sources.

INTERACTION BETWEEN RENEWABLE ENERGY IN BUILDINGS AND THE DISTRICT HEATING SYSTEM

In connection with the expansion of the district heating system to cover 70 % of the total building stock, it is appropriate to consider whether renewable energy technologies can be integrated into buildings that are located a long way from the district heating station. The advantage of this solution is that energy is produced close to where it will be used, which minimises loss from the supply network, e.g. in summer months.

Demonstration projects are currently underway which show ways in which renewable energy can be integrated, both in the form of large systems in district heating stations and in small systems closer to buildings, ➜ see figure 19 in the paragraph on the energy system.

USE OF SOLAR CELLS IN EXISTING BUILDINGS

The Danish Society of Engineers' Energy Plan 2030 identified that 2 % of the electricity consumption in 2030 can be covered by solar cells integrated into buildings. The price for this initiative would be DKK 7,500/kW in 2016 and DKK 3000/kW in 2030.

Climate Plan 2050 assumes that this development will increase up to 2050 so that 5 % of the electricity consumption of buildings is covered by solar cells integrated into buildings by 2050.

EMPLOYMENT

The number of persons employed in the building sector in recent years has been historically high and in the second quarter of 2008 amounted to approximately 177,000 within building and construction. With an average annual investment in the building sector of approximately DKK 20 billion for residential renovation in the period 2010-2030, the investments in residential renovation will be increased by 50 % and increase employment in the sector by approximately 20,000 workplaces/year.

It is necessary to strengthen the building sector's competences within energy renovation. There is therefore a need to develop guidelines and training of players in the construction industry so that knowledge of energy efficient solutions will become standard. In connection with this it will be necessary to establish further education, and the climate plan will result in the investment of DKK 50 million per year in the period 2010-2020 for further education of construction workers as well as the development of better guidelines and information on energy saving building and components.

This initiative will mean that the Danish building industry will obtain many special competences that can also be used in relation to the export of building materials, competences and knowledge. The value of this increased export potential and its social value is not included in the climate plan

Transport

Summary:
Transport

Intermediate objectives, Climate Plan 2050

2015

- Energy consumption of road transport will be approx. 0.4 % more efficient per year
- Transport initiatives have been launched, otherwise it will not be possible to meet targets by 2030 and 2050

2030

- Energy consumption of the transport sector reduced by 21 % compared to 2008.
- Total vehicle traffic reduced by 18 % due to focus on physical planning, urban densification and restructuring of the taxation system.
- 45 % of passenger car and goods vehicle traffic are electric.
- Half of the growth in goods traffic by road can be transferred to rail and sea by 2030.
- 95 % of all rail transport covered by electrically driven trains.
- Domestic air traffic is reduced by 95 %
- Energy-efficiency of the shipping industry improved by 40 %.

2050

- Energy consumption of the transport sector reduced by 38 %.
- 80 % of passenger car and goods vehicle traffic is electric.
- 20 % of traffic is driven by alternative fuels (hydrogen, DME etc.).
- Air traffic to destinations that can be reached by train within three hours no longer exists.
- Energy-efficiency of the shipping industry improved by 60 %.
- Biomass to the equivalent of 75 PJ in calorific value is used in the transport sector.

MEANS

- Regional town and country planning must contribute to the limitation of energy consumption by transport by increasing the use of regional plans. New residential areas will be centred on railway stations and the location of large residential areas, commerce and shopping facilities in the same local neighbourhood will be supported. Permission will be given for larger plot ratios around stations and, in addition, the taxation system shall aim to support urban densification.

- The vehicle registration fee will be restructured on a proceeds neutral basis in order to encourage people to buy more efficient and safer cars. Within a ten-year period, the vehicle registration fee will be converted to a road pricing system which supports the goals for low emissions. Electric cars ought still to be given special advantages.

- Over the next 30 years, DKK 200 billion ought to be invested in the extension of light railways and the metro. The rail network ought also to be developed and improved so that it becomes a real alternative to the car.

- All Danish towns ought to be given the opportunity to introduce environmental zones that gradually increase emission requirements for vehicles crossing the city boundary. The ultimate goal is to prevent all vehicles apart from emission-free vehicles from entering towns.

- The Ministry for Traffic and Energy and local authorities ought to take the initiative to prepare an action plan detailing the best ways in which to encourage purchase and use of electric vehicles.

- Tight regulation of short routes by air.

Transport

Transport accounts for 19 % of all Danish emissions of climate gases and 23 % of CO_2 emissions alone[110]. Thus, it is particularly difficult to reduce climate emissions in the transport sector. This is due to several factors. On the one hand, transport activities have increased over the past many years and are expected to grow in the coming years. On the other, fuels required for traffic must be able to be transported in a safe manner and, at the same time, be of a high energy variety. Thus, there is currently no real alternative to fossil fuels that can be used for all transport activities.

Therefore, if we are to achieve a significant reduction in climate emissions, society must put all known mechanisms into operation. These include:

- Reduction of the climate emissions of the individual transport forms.
- Transfer of transport activities to the forms of transport with the lowest climate emissions.
- Physical planning and urban densification that can reduce transport activities.

This development presupposes considerable developments in technology up to 2030 and 2050. However, technological development rarely appears of its own accord and, therefore, it is of crucial importance that the social environment supports the technological development. One example of this is the electric car. It appears that there is significant potential for the development of workable concepts for electric cars. However, in order for these to be a success, they must be supported by a suitable tax system.

It must be stressed that technological development is not enough on its own. Other, cleverer ways of handling our means of transportation must be developed concurrently. Thus, it should not be taken for granted that every family should own a car to be used for a wide range of different purposes. Car sharing schemes and various rental and leasing concepts will enable consumers to use one type of car for their daily transport to work and another type of car for holidays or larger transport needs.

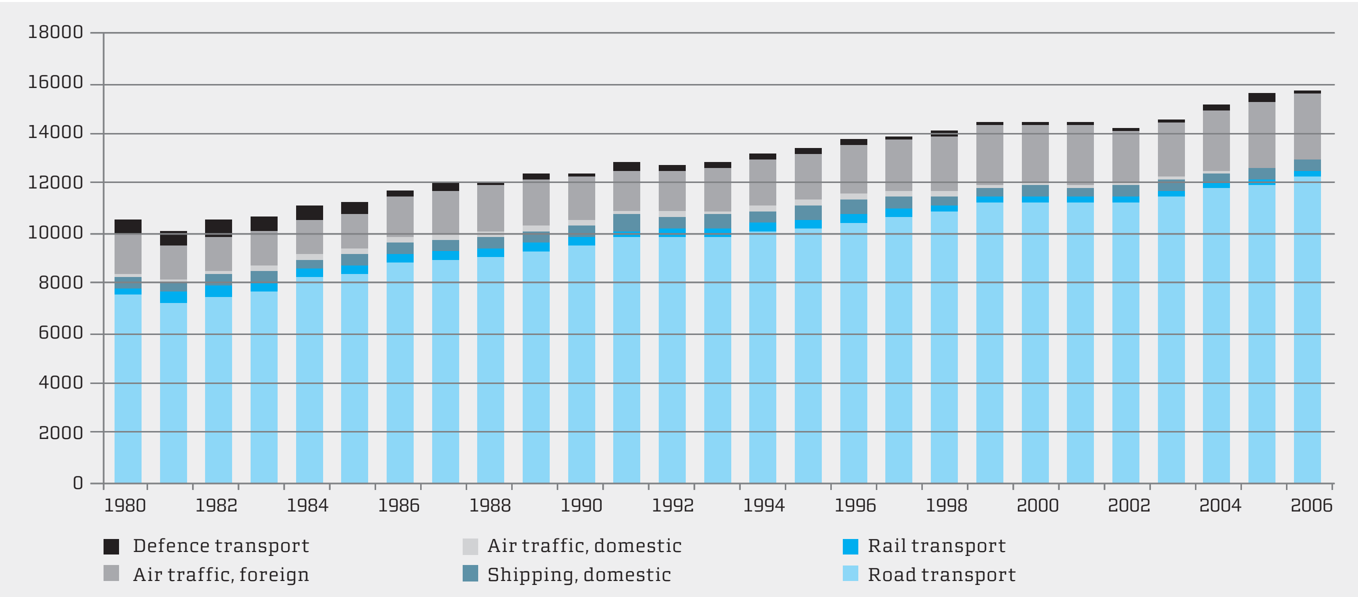


Figure 37: Development in transport's CO_2 emissions, by sub-sector and in 1000 tons

110. Denmark's national inventory 2008

More consistent physical planning that concentrates on ensuring that all new dwellings and industrial areas are constructed close to stations will also be of crucial importance and improved integration between walking/cycling, cars and public transport will also be of great significance.

Urban planning – limits the need for transport

The current, dominant form of urban planning with increasingly segregated residential areas, industrial areas, shopping areas etc. increases the general need for mobility and transport. This is further supported by several current taxes and duties, e.g. the transport allowance and the high duty on the purchase of cars but no tax on mileage.

In order to reduce daily private transport activities it is absolutely necessary that people living in and around towns are able to meet their transport needs with limited requirement for transport by car. This can be done by ensuring a varied selection of attractive business opportunities and shopping facilities in the local area, preferably within cycling distance of people's homes as well as easy access to attractive public rail transport – also preferably within cycling distance.

A reduction in daily private transport activities further requires that, to an increasing extent, people live in and around towns. If people move from scattered, rural areas to towns or suburbs, it will be much easier for them to cycle and to serve them with public transport. Similarly, they will be closer to shops, schools and leisure activities.

This requires long-term management, a range of general planning principles and planning authorities with the competence and power to implement the plan. It is important that the Ministry of Environment, which after the structural reform was made responsible for regional planning, assumes responsibility for this project together with regions and local authorities. The tax system must also contribute to this development, e.g. through differentiated property taxes, reduction of or abolition of mileage allowance etc

The increase in road traffic must be stopped

Restructuring of the Danish tax on private cars would be a key factor in reducing road traffic.

One option is to convert the vehicle registration fee to a mileage tax, thus taxing consumption rather than car purchase. From a technical point of view, a mileage tax could be introduced with the help of a GPS-based road pricing system. A restructure of this kind could be implemented over a 10-year period on a proceeds neutral basis.

Complete phase-out of the vehicle registration fee and conversion to a mileage tax corresponds to an average tax of DKK 0.75 per kilometre. It is assessed that this will reduce the total number of kilometres driven in private cars by 15 %[111]. The mileage tax ought to be set up such that safe and energy-efficient cars pay less tax than large, heavy petrol guzzlers. A gradual phasing out of the mileage allowance ought also to be seriously considered.

However, financial mechanisms alone will probably not curb the growth in the use of private cars. Apart from the practical advantages, there are many other reasons for wanting to own and use a car, e.g. culture, habit and the sense of freedom. Even the waiting time in the traffic jam on the motorway on the way to work in the morning can be perceived as welcome leisure time (perhaps the only time of the day), a good excuse to relax and listen to the radio. It is impor-

111. All things considered, an assumed price elasticity of -0,3 would mean a reduction of 15 % in the number of kilometres driven in private cars. Based on an assessment by Per Homann Jespersen, Roskilde University Centre

tant to understand this if we wish to change people's transport behaviour. Therefore, additional research in this area will also be important.

Extension of the car share concept will have a dampening effect on the use of the private car as all expenses associated with purchase and use are related to the actual driving of the car. Today, there is a large initial expense when the car is purchased but, after that, use of a private car is relatively cheap. An extension of the car share concept can be encouraged by providing shared cars with free parking in towns, as is already the case in Copenhagen. In addition, more flexible leasing and rental agreements could support more differentiated use of cars, e.g. the car that is used for the daily commute is not necessarily the car that is used for the family holiday.

Urban traffic based on collective solutions and bicycles

The need to be able to get around easily, particularly in the largest cities and the need to reduce energy consumption are powerful reasons for making significant changes, moving from the car to public transport and providing bicycles with a more central role in towns and suburbs.

The issue of congestion around the largest cities is a self-perpetuating problem. More and larger approach roads often increase congestion in the cities, and buses, in particular, are hard hit by the increase in traffic intensity. As a result, more and more people choose the car. This vicious circle could be broken by limiting the volume of traffic in several different ways. Congestion tax could be introduced, initially in Copenhagen. It is assessed that road pricing in the capital could reduce road traffic in Copenhagen by almost 15 %. This is approximately equivalent to the traffic during the summer period.

If we are to encourage a change from the private car to other forms of transport, it is just as important to create attractive alternatives to the car and to improve opportunities for switching between the different forms of transport. For example, good parking conditions (park and ride facilities) at stations make it more attractive to switch between car and rail transport. For shorter distances, extensions to stations with more access roads and safe, fast cycle paths combined with taxes on the use of cars in cities encourage commuters to replace their car with a bicycle.

Isolation of cycle paths from other traffic and partial cover of the paths will increase the speed of cycle traffic and make it more comfortable and competitive. The diffusion of electrical bicycles can also contribute to this development.

Modern light railways in and around the larger cities would also provide an alternative to the car, as would an increase in the capacity of the commuter trains in Copenhagen. Greater capacity and new light railways are efficient and inexpensive ways of increasing mobility around town.

Buses also play a decisive role in the transfer from car transport to public transport. Buses must first and foremost bring people from their home to stations from where their journeys can continue by train, light railway or metro. In areas where railways systems have not been built, buses can also function as the backbone of the collective transport system. In the coming year there should be further work on the construction of demand controlled transport systems that integrate a special routes (medical transports, school runs, etc.) into general public transport. This will strengthen public transport's overall competitive ability. Similarly more buses must be able to convey bicycles – this is particularly important for regional bus traffic.

INVEST MORE IN RAIL TRANSPORT

If the railways are to be a real and attractive alternative to road transport, an extensive renovation and expansion will be necessary. If the train is to be an attractive alternative to the car, it must provide comfort; transport time is quality time that can be used efficiently on, e.g., work. There must be frequent departures, coordinated timetables and, perhaps most important of all, trains must run on time.

From the perspective of renewable energy and reliability of supply, it will be important to ensure that large parts of the railway network run on electricity. The government's traffic plan contains this element but does not state a precise deadline. Away from the main lines, electrification could, perhaps, be concentrated around the stations where trains accelerate and decelerate. This could be combined with the introduction of hybrid trains whose batteries are charged by brake energy on the stretches that are electrified.

All train types equipped with hybrid technology will provide CO_2 and emissions benefits. These hybrid benefits will become even more important in the future, for example when legislation further limits the use of internal combustion engines at stations and in inner city areas. It is expected that use of the whole spectrum of hybrid functions (automatic start-stop, regeneration of brake energy, support during acceleration (boost), electric ignition and distribution of load) will result in a reduction in energy consumption of up to 30 %. The greatest saving can be made on stretches with many starts and stops. Furthermore, the hybrid system means that, to a large extent, it will not be necessary to start the internal combustion engine when a train stops at a station. The additional cost of cables, batteries and cooling systems is moderate and is almost completely offset by the savings that can be made (by cutting back on internal combustion engines, cutting out 24V batteries and start measures). If suitable hybrid technology is used, due to the auxiliary power in the train, the IC engine will only need to be started when there is a real need for energy (power on demand).

The government's traffic plan also specifies implementation of the so-called time schedule, i.e. travel time of one hour between Copenhagen and Odense, between Odense and Aarhus and between Aarhus and Aalborg. This requires investment in new tracks between Copenhagen and Ringsted and a further upgrade of infrastructure.

The government's traffic plan also includes replacement of the existing signal system with a new system based on the common European ERTMS. This will enable greater speeds and greater distance between trains[112] and will permit the implementation of high-speed traffic where track and rails allow.

A modern traffic management system for the railway will provide CO_2 reductions due to the potential for "smoother operation" which prevents additional stops at signals, e.g. if there are delays to the trains in front etc. There is increasing international interest in activities that are able to ensure this. In some countries, this is referred to as ECO controlling and it can be compared to the intelligent traffic management system that is used for road traffic.

In order to be able to compete with air traffic, it is vitally important that Denmark join the European high-speed network via a new connection over Zealand to Femern and beyond into Germany. The new stretch of railway between Copenhagen and Ringsted ought to be part of this connection and, therefore, ought to be prepared for high speed trains – preferably 350 km/hour. However, it is crucial if this is to succeed that the German network south of Puttgarden is significantly extended and upgraded.

It is assessed that it will be necessary to invest approx. DKK 200 billion[113] over the next 30 years in an extensive renovation of the Danish rail network and signal systems, electrification of the main network, addition of high-speed trains and light railways and extension of the metro in Copenhagen[114]. DKK 200 billion over

112. Higher frequency or better regularity
113. This sum was also highlighted in the Energy Plan 2030. Since then, the government has introduced the green investment plan but this only defines a price and deadline for the signal project. Therefore, there is still a need for large investment in this area.
114. Based on an assessment by Professor Otto Anker Nielsen, DTU.

25 years is a large investment but, seen in relation to the cost of congestion on the roads in the capital alone (almost DKK 5.7 billion a year) and the fact that the investment will help solve a number of energy-related problems, it holds economic benefits for society.

This will be able to create a real and attractive alternative to car transport and it is expected that an expansion of this magnitude will be able to handle a doubling of rail transport's proportion of private transport activities, at the expense of private motoring[115]. In addition, a good deal of domestic air traffic will be rerouted to the railways. If the future Danish high-speed network is connected to the Swedish and German high-speed networks, experience of extension of high-speed networks in other countries shows that rail transport will be able to compete with flights over distances equivalent to the route between Stockholm and Berlin. In addition, a reduction in the price of public transport may be considered in order to make this more attractive.

Addition of high-speed tracks for high-speed trains will also create much better conditions for goods transport. Other tracks will be freed up for goods transport and goods trains will no longer interfere with faster trains. Goods traffic will be able to be more frequent and faster than today and this is a vital if we are to convince the business community to move their goods transport to the railways. It is also important to develop efficient systems for loading between trains and lorries so that goods can be transferred quickly and easily.

As an incentive to transfer a proportion of the goods transport from road to rail, Denmark ought to introduce a tax on goods transport by road similar to the German MAUT[116]. If this is done together with the proposed expansion, as will be the case with private transport, we will be able to expect a doubling of the proportion of goods transported by rail instead of road

115. Based on an assessment by Alex Landex, lecturer at DTU.

116. MAUT is a tax imposed on vehicles in Germany, Austria and Switzerland. In these countries, all vehicles over 3.5 tons are required to pay an additional tax to use the motorways and some highways.

ENERGY EFFICIENCY OF THE PRIVATE CAR MUST BE IMPROVED – THE ELECTRIC CAR IS THRIVING

The internal combustion engine is today by far the dominant technology in the field of road transport. There is currently good potential for increasing its energy efficiency but, when we look at its development history, we can see that there have only been small improvements to its efficiency over the past many decades.

The average CO_2 emission is currently 200g CO_2 per kilometre. However, there are a number of cars on the market that have significantly lower CO_2 emissions and that can be promoted at neutral cost by combining changes to vehicle registration fees with a further increase in green owner taxes. Thus, a new taxation system ought to provide energy-efficient and safe cars with further benefits. The EU Commission is working to reduce the CO_2 emission of new cars to 100g per km by 2020. Denmark ought to put pressure on the EU to impose even stricter requirements for energy efficiency and, thus, CO_2 emissions on car manufacturers.

Fuel cell-based cars, hybrid cars and electric cars are all alternatives which carry a promise of significantly improved efficiency compared to traditional cars. Of the three technologies, it is assessed that the hybrid and electric cars will be the first to break through onto the market. The hybrid vehicle that is a combination of an IC engine and an electric engine is already available in a number of versions and, due to developments in battery technology there is considerable potential for both the hybrid and the electric car.

From a technological point of view, the hybrid cars provide an excellent platform for the development of fuel cell vehicles and purely electric vehicles with batteries. The fuel cell-based car will probably not see a breakthrough for some years yet. Today, fuel cell-based cars can be developed based on PEM (Polymer Electrolyte Membrane) technology with hydrogen as the energy carrier. However, from a financial point of view, these cars are far from viable. The Climate Plan's target is for 20 % of private and goods transport to be powered by hydrogen, DME or similar by 2050.

The greatest hindrance to the widespread circulation of the electric car has always been the battery. However, development has taken off over the past 10 years and batteries now have adequate technical features. In addition, new, inexpensive battery technologies continue to be developed. Today, the best lithium-polymer batteries have an energy density of 0.2 kWh/kg and can be recharged in less than an hour. With the electric car's high efficiency rate (70 – 80 %), consumption of approx. 0.2 kWh/kg in the case of a car for 4 people plus baggage and a top speed of over 100 km/hour, the operating radius of a fully loaded car with a battery of 40 – 50 kWh and a weight of 200 – 300 kg is 200 to 300 km. By comparison, a car with an IC engine will use 0.5-0.6 kWh/km[117].

Thus, the efficiency of the electric car is two to three times better than that of the IC engine. As 70 % of all electricity production in the Climate Plan 2050 is based on wind power, electric cars will be extremely advantageous, both from the point of view of supply and with respect to the reduction of CO_2 emissions.

In addition to this, when they are connected to the electric system, the batteries of electric cars will help increase the flexibility of the electric system significantly, and this flexibility is necessary when there is a high proportion of fluctuating renewable energy in the system. The cars' intelligent charging systems purchase electricity from the mains supply when there is an excess of electricity in the system and electricity is inexpensive. They sell electricity to the mains supply when there is a shortage and electricity is expensive. Thus, electric cars combined with wind power will be able to provide a renewable energy solution for a good deal of transport activities. This is the basis for several of the projects currently in progress at DONG.

117. Per Jørgensen Møller, chairman of the Danish Society for the Promotion of Electric Cars.

It is assessed that, during the course of the next 10 years, the electric car can become an attractive option for certain transport activities and, in the long term, can make a considerable contribution to transport activities in general. In the future, and after the product has matured and is being mass produced, it is expected that the electric car will cost the same as a car with an IC engine and efficiency will reach 90 %. According to The IDA Climate Plan 2050, 45 % of private and goods transport will have been transferred to electric vehicles by 2030 and, by 2050, 80 % of all private and goods traffic will be electric.

In cities in particular, electric cars will be an extremely attractive alternative and will help reduce particle pollution. As electric cars are most suited to short trips, due to their limited operation radius, an obvious choice will be to support the circulation of electric cars in environments close to cities. Widespread circulation of the electric car is an important task for local authorities in their endeavours to improve the urban environment. Therefore, local authorities and the Ministry of Transport are encouraged to take the initiative to prepare an action plan detailing the best ways in which to promote the electric car.

In the longer term, environmental zones in cities, in which only emission-free cars may travel, could be an option. In order to kick start this development, it will be worthwhile to implement a pilot project in the near future in a specific area, with limited distances and an excess of electricity (e.g. the island of Samsø).

ITS (intelligent traffic systems) provide excellent potential for improving the efficiency of traffic in general. For example, they supply constantly updated information to citizens about traffic conditions, options for changing between forms of public transport and they support improved traffic management that will ensure more uniform speeds in cities and, thus, minimise idle time that creates pollution and consumes more energy. Intelligent traffic systems are not an independent point on the Climate Plan's agenda but help limit general transport activities and transfer between various different forms of transport.

Stop the increase in air traffic

The development in the effect of air travel on the climate greatly depends on international development. Air travel is therefore an area in which it is difficult to regulate at a national level. In the section below it is expected that development in Danish air travel will occur in line with international development. However regional regulation of short routes that are difficult to perform by train is expected.

Air traffic subjects the global climate to more than CO_2, i.e. NO_x, H_2O, SO_x, carbon and condensation clouds. The most recent assessment report from the IPCC[118] calculates that the impact on the climate by air traffic is 1.2 to 2.7 times greater than the actual CO_2 emissions of air traffic as a whole[119]. There is no "best estimate"[120]. Short routes, e.g. Danish domestic routes, during which aircraft do not reach the high altitudes of the longer routes, will of course have less impact on the climate than average. On the other hand, long routes will, on average, have more impact on the climate. If several of the short routes are replaced by rail transport in the future, the proportion of long routes will increase and the resulting multiplication factor will be greater.

	Domestic	International	Total
Tons of CO_2	175 000	2 701 000	2 876 000
Tons of CO_2-eq.	350 000	5 403 000	5 753 000

Table 12: CO_2 emissions and total impact on the climate by Danish air traffic in 2007 (multiplication factor 2)

Improvements to fuel efficiency in air traffic activities can be divided into two categories. The first category relates to *traffic management and operational improvements*, i.e. coordination and control of the air space, removal of excess weight, optimisation of the speed of aircraft, limited use of auxiliary generators when the aircraft is on the ground, better cabin factors and exploitation of loading potential etc. The second category relates to *technical improvements to aircraft.* Average fuel economy is improved when new, more efficient aircraft are introduced. New aircraft are improved, e.g., by making improvements to the engines and implementing aerodynamic (airframe) improvements.

Up to 2020, the efficiency of new types of aircraft will be determined based on the manufacturers' own specifications of the aircraft on the drawing board, e.g. the Airbus A350 and the Boeing B787 are expected to be 20 % more efficient that their closest predecessors from the beginning of this century. The Airbus A380 will be 12 % more efficient that the Boeing 747-400[121]. Smaller jet aircraft are also expected to be more efficient than their closest predecessors.

The development of and switch to new types of aircraft takes a long time. It is probable that aircraft types that are not currently on the drawing board will be introduced before 2030. The target of the European aircraft manufacturing industry is for new aircraft to be 50 % more energy-efficient by 2020 compared to 2000[122]. Table 12 indicates expected fuel improvements for the total fleet and a total improvement in efficiency of 30 % between 2005 and 2030.

118. IPCC Fourth Assessment Report, Working Group I Report "The Physical Science Basis", chapter 2.6

119. This value is based on the Radiative Forcing Index (RFI). The assessment report also calculates the Emission Weighting Factor (EWT) at between 1.2 and 2.7. The EWT has a built-in delay, therefore the RFI is a more appropriate matrix for political decisions on climate for the coming decade.

120. A multiplication factor of 2 is used in The IDA Klimaplan 2050

121. UK Air Passenger Demand and CO_2 Forecasts, November 2007, *http://www.dft.gov.uk/pgr/aviation/atf/ukairdemandandco2forecasts/airpassdemandfullreport.pdf*

122. 2008 Addendum to the Strategic Research Agenda, Advisory Council for Aeronautics Research in Europe (ACARE), http://www.acare4europe.com/docs/ACARE_2008_Addendum.pdf

Year	Average annual improvements in fuel efficiency	
	Dept. for Transport 2007	IPCC 1999
2005-2010	0,8 %	1,30 %
2010-2020	1,6 %	1,00 %
2020-2030	0,6 %	0,50 %
2005-2010	0,8 %	1,30 %
2005-2030	1,0 %	0,90 %
Samlet 2005-2030	29,7 %	33,00 %

Table 13: Average annual improvements in fuel efficiency up to 2030. Source: Department for Transport's report[123]

Projections for fuel efficiency specifically relating to the period after 2030 are not yet available. The IPCC assesses that efficiency will improve by 0.5 % per year after 2021 and the Department for Transport expects an efficiency improvement of 0.75 %. Fleet efficiency will be improved by 15.3 % between 2030 and 2050 based on the Department for Transport's forecast

TECHNOLOGIES BEHIND EFFICIENCY IMPROVEMENTS

There is a wide range of improvements with the potential to improve the efficiency of fuel for air traffic. One example is the propeller aircraft (turbo fan). These aircraft use significantly less fuel than jet aircraft. However, they are slower due to the limited speed of the propeller tips and they are very noisy.

The technical challenge of developing and manufacturing alternative fuels that are suitable for aircraft is great. It is not easy to determine whether conventional jet fuel is better than an alternative. One aspect that ought to be examined is the life cycle of emissions of CO_2, NO_x, CH_4, CO, SO_x, UHC, carbon etc. In addition, the impact of these substances on the climate in connection with air traffic must be considered, e.g. whether condensation clouds and cirrus clouds are becoming thicker[124]. Thus, the impact on the climate of aircraft that use alternative fuels as a propellant will depend, among other things, on our ability to design the alternative fuels. If it is not possible to design an alternative fuel that is better than fossil aircraft fuel, it would perhaps be better to use biofuel elsewhere.

TAKING THE TRAIN FROM COPENHAGEN TO AARHUS

By 2030, we can expect clear, unpleasant signs of climate change. Therefore, there will be international, political interest in halting the growth in air traffic, and possibly especially in air traffic due to the fact that its short term impact on climate change is great. It is assumed that growth will be reduced to a level equivalent to energy efficiency measures so that CO_2 emissions can be held constant.

In the case of domestic air traffic, it is appropriate to consider the potential for transferring all passengers to trains if the transport time by train is less than three hours. If the plan to keep travel time between the cities on the Copenhagen-Odense-Aarhus-Aalborg line to one hour at most is implemented, the journey from Copenhagen to Aalborg will take three hours. It is also possible to envisage an improvement of the routes between Hamburg and Copenhagen and between Aarhus and Hamburg so that the journey can be made by train in less than three hours. In addition to this, Sweden wishes to reduce the travel time between Stockholm and Copenhagen to three hours.

Today, it takes around three hours to travel between Aarhus and Copenhagen by train. In spite of this, many choose to fly. This poses a great challenge, as the Climate Plan proposes that domestic air traffic has been reduced to 5 % of the present level in 2030. Realistically, this will require strict regulation. Furthermore,

123. UK Air Passenger Demand and CO_2 Forecasts, November 2007,

124. Aircraft fuelled by hydrogen produce 2.6 times more water vapour, IPCC assessment report, Working Group III Report "Mitigation of Climate Change", chapter 5.3.3

the plan presupposes that all air travel between cities such as Hamburg and Stockholm will be replaced by train travel from 2030. It is assumed that the saving to be made by avoiding air travel when the train journey takes less than three hours will provide a reduction in CO_2 equivalent to the current national emission.

	Domestic	Internat	Total
2005	350 000	5 403 000	5 753 000
2030	175 000	7 609 000	7 784 000
2050	-	7 259 000	7 259 000

Table 14: Impact on the climate of Danish air traffic (Tons CO_2 equiv.)

CO_2 emissions by shipping

The proportion of CO_2 emissions for which shipping is responsible is indicated in Table 14[125]. According to the list, shipping is divided into international shipping, between two ports in two different countries, and domestic shipping, between two ports in the same country. Figures for CO_2 emissions by international shipping are based on an estimate of the total number of voyages (by type and size of ship) combined with international statistics for oil used to power ships.

	Lower limit	Consensus estimate	Upper limit	Proportion of total, global CO_2 emissions
Total domestic and international CO_2 emissions by ship*	854 mill. tons	1019 mill. tons	1224 mill. tons	3.3 %
International CO_2 emissions by ship**	685 mill. tons	843 mill. tons	1030 mill. tons	2.7 %

Table 15: IMO consensus estimates of total CO_2 emissions by shipping

* Activity based figures including domestic shipping and the fishing industry, but excluding oil for military vessels.
** Activity based international figures, excluding domestic shipping (defined by the sale of oil to domestic shipping) and excluding the fishing industry

125. In recent years, due to the drastic growth in global shipping, there has been some uncertainty as to the total volume of energy consumption of shipping worldwide. As a result of this uncertainty and the increased focus on the environmental conditions of ships, including their emission of CO_2, the UN's international maritime organisation (IMO) set up a working group to define, among other things, total oil consumption for shipping and associated CO_2 emissions. The results are presented in BLG 12/INF.10 (28 December 2007), REVISION OF MARPOL ANNEX VI AND THE NOx TECHNICAL CODE, Input from the four subgroups and individual experts to the final report of the Informal Cross Government/Industry Scientific Group of Experts and MEPC 58/INF.6 (1 September 2008): Prevention of Air Pollution from Ships. Updated 2000 Study on Greenhouse Gas Emissions from Ships. This review is largely based on the IMO's most recent report and an analysis of current global initiatives to improve the energy efficiency of shipping and, thus, to reduce their CO_2 emissions.

Based on the assumptions of the Intergovernmental Panel on Climate Change (IPCC) for continued global growth and IPCC scenarios for the climate of the future, the IMO has estimated CO_2 emissions in 2020 and 2050.

Figure 38 shows a calculation of total CO_2 emissions for the scenarios described including an absolute minimum scenario and a maximum scenario. The latter is based on “business as usual” and no energy efficiency measures. This scenario presumes low energy prices, which must be considered unrealistic. None of the projections indicate a significant reduction in CO_2 emissions up to 2050, which is partly due to the fact that development is motivated by an expected growth in international trade which results in an increase in the transport of both finished goods and raw materials.

The forecasts incorporated traditional assumptions about the correlation between financial growth and transport. However, regional differences in transport patterns and the emergence of new transport corridors were also taken into account. Growth in the pattern of transport will also give rise to a need for larger ships and energy efficiency will increase as the size of the ships increases. These factors are also included in the IMO’s predictions.

Scenarios for CO_2 emissions from International Shipping from 2007 to 2050 in the absence of climate policies

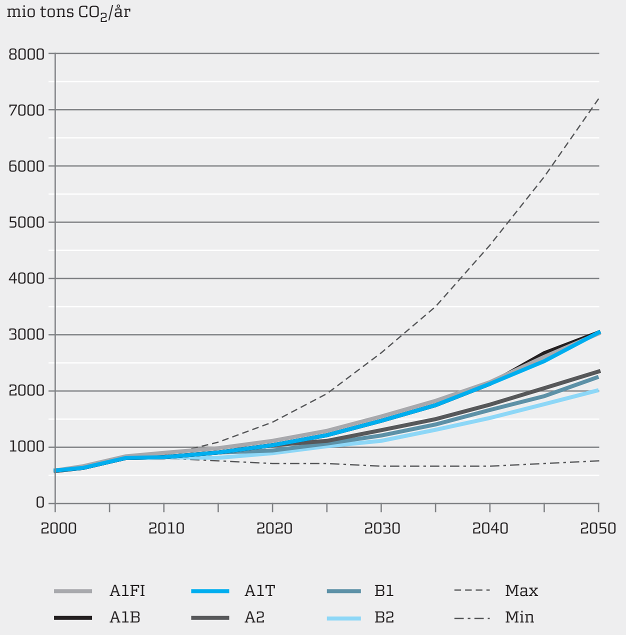


Figure 38: CO_2 emissions for international shipping, estimated for various different IPCC development scenarios [2]

TOMORROW’S GREEN SHIPPING

If oil prices increase, the speed that is financially most advantageous will be reduced as energy consumption is highly dependent on speed[126]. Naturally, more ships will be needed to maintain the flow of goods if speeds are lower. Even if we make corrections for this, a reduction in speed will reduce the CO_2 emission per transport unit. However, reductions in speed will continue to be based on a range of economic calculations.

Technical initiatives will be able to improve the energy efficiency of ships in the coming years and the incentive to do so will be provided by energy prices. However, the issue of whether legislation will be introduced that will put pressure on technological developments to produce more energy-efficient ships will be vitally important. The UN’s maritime organisation is working at full speed to define requirements for thresholds for CO_2 emissions per transport unit. This threshold value, which has already been named the *Energy Efficiency Design Index* (EEDI), is only intended to apply to new ships, hence the name.

Table 16 shows a list of potential improvements over the coming years. The improvements are assessed based on our current knowledge of modern shipping technology. It is assumed that the technological im-

126. More details are available in the technical memorandum on shipping

provements indicated in the table will be used in the described development scenarios, apart from in the scenario based on the assumption of "business as usual".

Technical solution for the reduction of energy consumption	Potential saving in percent
Better use of waste heat from propulsion machinery (WHR = Waste Heat Recovery)	5 – 10
Optimisation of air conditioning and pump systems	1 – 3
Improved paint types for hulls	5 – 8
Increased optimisation of hull design using CFD (computational fluid dynamics)	2 – 5
Use of Kappel propellers	3 – 5
Use of contra-rotating propellers	5 – 10
Extension of the ship's "duck tail"	1 – 3
Use of fuel saving devices (twisted rudder, "Costa bulb", local fins in front of the propeller)	2 – 4
Trim optimisation	2 – 10

Table 16: List of potential technical initiatives that can reduce a ship's energy consumption compared to the standard scenario – "business as usual"

If, over the next 20 years, it is possible to improve efficiency by a total of approx. 30 % through technical initiatives, the total average improvement of the energy efficiency of the global merchant fleet (taking older tonnage into account) will amount to 25 % in 2030 and approx. 40 % in 2050 compared to today. If operational initiatives are also included (a general reduction in speed is one of the options), an additional 15 % could be achieved by 2030 and a further 5 % from 2030 to 2050. Thus, total improvement in efficiency (technology and operation) will amount to 40 % by 2030 and 60 % by 2050.

In general the collected CO_2 emissions from shipping will not only depend on improved energy efficiency but also on the development in the global trade.

Adapting to climate change

Summary:
Adapting to climate change

The IDA Climate Plan 2050 only addresses adaptation to climate change generally. It was not possible to make an overall assessment of the needs, necessary initiatives and price here. Therefore, issues relating to adaptation to climate change in The IDA Climate Plan 2050 have not been broken down into sub-goals as is the case for the other issues addressed in the plan.

Climate Plan 2050

- The administrative framework for solid strategies for adaptation to climate change is in place. Denmark has a national strategy in this area which provides all of the relevant players with indicators, guidelines and focus areas. The distribution of burden within society has been defined and the distribution of responsibility between local authorities, state and citizen has been clarified.
- A coherent national plan for development of the coast has been implemented.
- Activities relating to adaptation to climate change are rooted in the local authorities as this provides the best opportunity for development of interdisciplinary and sustainable solutions based on national indicators.
- Solutions for adapting to climate change are assessed based on their sustainability and it is ensured that they do not lead to increased emissions of greenhouse gases.
- In general, Danes recognise both the significance of climate change for Denmark and their own accountability.
- Denmark is a market leader in technologies and expertise relating to solutions for adapting to climate change.

MEANS

The current Danish strategy for adapting to climate change is an ad hoc strategy. It is recommended that the government evaluates as soon as possible whether local authorities, utilities companies, citizens and other main players are actually aware of their responsibility for Danish adaptation to climate change.

- Denmark ought to introduce systematic monitoring of initiatives for adaptation to climate change.

- Local authorities/utilities ought to be motivated to begin the process of adapting to climate change, e.g. by making it an obligatory element of local planning.

- A coherent national plan for coast development ought to be implemented. This requires a break with existing traditions for management of this issue whereby individual landowners are responsible for protection of their own stretch of coast.

- Denmark ought to make use of and develop export potential for solutions relating to adaptation to climate change. In order to do this, it is important to create the right conditions for conversion of knowledge and expertise in the field of climate change to services that can be exported to the rest of the world.

THE CONSEQUENCE OF CO_2 EMISSIONS

In order to provide society with the best possible solutions, importance shall be attached to sustainable solutions that ensure that initiatives related to adaptation to climate change do not result in increased emissions of greenhouse gases and, thus, have an adverse impact on the balance.

Adapting to climate change

The main reason for including adaptation to climate change in The IDA Climate Plan 2050 was to obtain an overview of the need for adaptation to climate change and to assess the best technical and social initiatives in the field.

It was not possible to include the aspect of the cost of adaptation to climate change. This aspect could have been included in the comparison of preventive costs. However, as this would have required further discussion of our expectations for the rest of the world, it was not possible this time. Therefore, issues relating to adaptation to climate change in The IDA Climate Plan 2050 have not been broken down into sub-goals as is the case for the other issues addressed in the plan.

Based on the work with the Climate Plan 2050, it is assessed that Denmark's greatest challenges when it comes to adapting to climate change relate to ensuring that the administrative framework is in place. The technical tools are available but we still lack clarity on the distribution of responsibility between citizen, local authority and state: Who shall pay the extra cost of adapting to climate change – the state, the local authorities or private citizens?

Knowledge exchange is a vital issue and the government has taken the initiative to collect knowledge of adaptation to climate change at www.klimatilpasning.dk. It is very important that this knowledge bank is used actively by the involved parties.

THE IMPACT OF CLIMATE CHANGE

The earth's climate is changing and research in the field indicates that we can expect climate change to increase in severity for many years to come, regardless of the initiatives we take to reduce the emission of CO_2 and other greenhouse gases.

In Denmark over the next 20 years, we can expect longer periods of drought, heavier and more extreme downpours, more powerful storms and, to a certain extent, higher sea levels. This development will continue until the turn of the next century, regardless of whether we succeed in reducing greenhouse gas emissions.

More specific assessments of the consequences for Denmark are made based on scenarios. The Danish climate strategy is based on the IPCC's A2 and B2 scenarios[127] and a scenario that applies the EU's 2-degree objective, modelled according to Danish conditions (➜ see table 17). Consequences for the individual sectors and areas are addressed based on the scenarios.

In 2007, a Danish project aimed at diagnosing the impact of climate change on fresh water resources was carried out. The report is based on IPCC's A2 and B2 scenarios. The conclusions of the report[128] were as follows: Both scenarios would result in a significant increase in average annual precipitation. In the case of scenario A2, the increase would be 12 % and in the case of scenario B2 20 %. The increase in precipitation will result in a rise in the water table and the rate of flow in water courses will also increase. At the same time, seasonal variations will increase and, therefore, a reduction in flow rate is expected in late summer. The B2 scenario produces the largest annual rate of flow, whereas A2 gives the driest summer periods. The sea level is expected to rise by approx. 1 metre, which will have an impact on coastal protection and coastal aquifers up to 10 km inland. Similarly, other disciplines have assessed the consequences for their own fields[129].

127. The scenarios are described on the IPCC website, www.ipcc.ch.

128. In 2007, DANVA (The Danish Water and Wastewater Association) and Copenhagen Energy carried out a diagnosis of the impact of climate change on fresh water resources in Denmark.

129. Further information is available at www.klimatilpasning.dk

Scenario	A2		B2		EU2C	
Year	**2006-2035**	**2071-2100**	**2006-2035**	**2071-2100**	**2006-2035**	**2071-2100**
Winter temperature	+0.6 °C	+3.1 °C	+0.7 °C	+2.1 °C	+1.0 °C	+2.0 °C
Summer temperature	+0.5 °C	+2.8 °C	+0.6 °C	+2.0 °C	+0.7 °C	+1.3 °C
Winter precipitation	+8 %	+43 %	+6 %	+18 %	0 %	+1 %
Summer precipitation	-3 %	–15 %	-2 %	–7 %	-2 %	–3 %
Maximum daily precipitation	+4 %	+21 %	+5 %	+20 %	+11 %	+22 %
Max. storm strength	+2 %	+10 %	0 %	+1 %	+1 %	+1 %

Table 17: Estimated Danish climate change compared to the period between 1961 and 1990 based on the IPCC's A2 and B2 scenarios and the EU2C climate target, according to which the increase in global average temperature will remain below 2 ºC (Source: DMI).

The traditional view of nature conservation can hinder the management of climate change. Nature is not static. Therefore, we must accept that nature is continually changing. It is important for us to take an active approach to the way in which we wish nature to develop within the constraints established by climate change. We must make specific decisions about the way in which we will handle the changes to available water resources. This entails consideration of water supply, water courses, wetlands and lakes, the risk of flooding of built-up areas etc.

ACTIVITIES RELATED TO ADAPTATION TO CLIMATE CHANGES IN DENMARK

A significant proportion of the activities related to adaptation to climate change originate in the local authorities. However, there is no cumulative assessment of the status in Denmark. In order to gain an impression of the activities relating to adaptation to climate change in Denmark, the IDA asked 400 of its members who work in the field on a daily basis to give their opinion of the activities that are in progress today.

15 % of the respondents feel that the population is sufficiently aware of climate changes and 17 % believe that politicians focus sufficiently on the consequences of climate change (➜ see table 18). With respect to knowledge about adaptation to climate change, 17 % of IDA's technical experts believe that there is sufficient knowledge about the consequences of climate change, whereas only 8 % feel that there is sufficient knowledge of the financial consequences. 76 % point out that increased coordination of the Danish climate activities by the government is of vital importance.

From this point of view, it seems that the government's timing was good when it launched its strategy for adaptation to climate change in March 2008[130]. However, only 3 % of the experts believe that the strategy equips Denmark to adapt to the challenges of the future. A further 28 % only feel that the government's strategy equips Denmark for future climate change to some extent.

130. Strategy for adapting to climate changes in Denmark, The Danish Government, March 2008.

The Danish strategy for adapting to climate change is an ad hoc strategy. This means that the relevant players must act when they feel it is necessary. The experts' assessments do not indicate that the main players in the field of Danish adaptation to climate change are ready for this type of approach. Therefore, it is recommended that the government assesses as soon as possible whether local authorities, utilities companies, citizens and other main players are actually aware of their responsibility with regard to adaptation to climate change in Denmark and that the government initiates systematic monitoring of the field.

Wastewater – a challenge both now and in the future

Climate changes will have a range of consequences for wastewater[131]. Extreme downpours subject the drainage system to enormous pressure. This means that basements and low-lying areas become flooded with wastewater. Increased wastewater flooding results in poorer water quality in rivers and lakes, which in turn results in poorer bathing water quality. Flooded basements are bad for houses in general and have an impact on house prices as well as the ability to insure the house in the long term.

	To a great extent/to a very large extent	To some extent	Only slightly/ not at all	Don't know	Total
There is sufficient awareness in the population of the consequences of climate change for Denmark	15 %	44 %	42 %	0 %	100 %
There is sufficient awareness among politicians of the consequences of climate change for Denmark	17 %	42 %	41 %	0 %	100 %
There is sufficient awareness in the media of the consequences of climate change for Denmark	26 %	51 %	23 %	0 %	100 %
In Denmark, we have sufficient knowledge of the consequences of climate change	17 %	37 %	46 %	1 %	100 %
In Denmark, we have sufficient knowledge of the financial cost of adaptation to climate change	8 %	24 %	68 %	1 %	100 %
The government's strategy for adaptation to climate change equips Denmark to adapt to the challenges of the future	3 %	28 %	65 %	4 %	100 %
There is a need for increased government coordination of the Danish activities related to adaptation to climate change	76 %	15 %	6 %	4 %	100 %

Table 18: To what extent do you agree with the following statements on climate change?

131. Wastewater includes both drainage systems and treatment plants. The drainage system in Denmark consists of both joint systems (rainwater and wastewater are transported in the same system) and separate systems (rainwater and wastewater are transported in two separate systems).

If the general water level rises, flooding of e.g. technical systems, such as water treatment plants, pumping stations and pipes, will result. This also means that it will be more difficult to get rid of wastewater and even the smaller rain showers will become more difficult to manage. In addition, temperature changes will lead to an increase in processing speed and the composition of wastewater will change.

TOTAL SOLUTION FOR WATER

The solution lies in a holistic approach to water in local authorities. Activities must be integrated with initiatives in e.g. the Water Framework Directive, the Bathing Water Directive and the Flooding Directive and initiatives related to the general service level and renovation of wastewater systems.

One possible adaptation scenario for the area of water as a whole is shown in Figure 39.

BARRIERS TO ADAPTATION

In practice, the solutions in the field of wastewater contain a number of barriers to adaptation. For example, there is no proposal by the government that clarifies expectations for local authorities and utilities companies. Thus, it is not clear how the financing of adaptation to climate change will be put into effect, nor who is responsible for which areas.

The adaptation of wastewater systems to meet the challenges of climate change is closely linked to other municipal areas, e.g. activities in regulatory departments relating to future water plans, activities in urban planning departments relating to land development and parcelling, activities relating to municipal contingency etc. Wastewater is linked to almost all other municipal activities as drainage is essential to planning and the infrastructure of the local authority in general.

In addition, a holistic approach to wastewater solutions requires interdisciplinary collaboration within local authorities and across municipal borders. This poses a number of challenges for most local authorities.

Summary – status

- Create an overview of the whole water circuit. Existing tools – 3D terrain models, drainage models and hydro-geological models can be used. Analyse and prioritise areas based on rises in water levels (recipients) and flooding associated with extreme downpours. Designation of hot spots in which the risk profile of climate change is high. Calculate the cost benefit of selected initiatives in order to assess the extent to which an adjustment would be best now or later. The analysis shall be general to begin with and then provide details for selected areas.

Make a climate adaptation stategy

- Analyse potential solutions
  - » E.g. make use of rainwater locally
  - » Use existing wastewater systems optimally, e.g. management and control
  - » Invest in new systems that have been subjected to interdisciplinary considerations and are robust.
  - » Prepare a contingency plan
- Include preventive measures (energy reduction) in the strategy

Prioritise activities and include initiatives in the local authority's planning tools

- Interdisciplinary coordination within the local authority and, if applicable, across municipal borders if local authorities have recipients in common
- Draw up a prioritisation model to help the local authority
- Initiatives must be integrated into municipal plans, wastewater plans, water plans etc.

Circulate information about adaptation to climate change

- What should citizens do themselves?
- What does the local authority do?
- What do the utilities companies do?

Implement selected initiatives over time

Figure 39: Scenario for a total solution for water

Local authorities are currently in the process of forming companies. The responsibility for wastewater activities will be removed from the local authority and taken over by separate, but municipally owned, companies. The utilities companies have set a target via DANVA and the Danish Electricity Saving Trust to reduce energy consumption in the water industry by 25 %. It is important that this initiative is combined with preventive measures so that energy reduction and, thus, a reduction in CO_2 are included in future adaptation solutions.

IDA's study among its members who work with adaptation to climate change[132] indicated that only every fourth technical expert believes that the issue of drainage and wastewater is adequately addressed in municipal planning for adaptation to climate change. Results are even worse when it comes to the question of whether there is sufficient awareness of adaptation to climate change when municipal projects are put out to tender. Only 8 % feel that there is sufficient awareness of the challenges associated with adaptation to climate change. This suggests that local authorities in Denmark are not sufficiently focused on this issue.

Therefore, the IDA Climate Plan 2050 recommends that local authorities/utilities companies initiate the process of adapting to climate change and consider adaptation to climate change in all projects related to the management of wastewater systems in order to ensure that they are geared to the future.

Citizens also play a part in local authorities' activities in the area of adaptation to climate change. Financial incentives could be considered in order to encourage citizens to take their share of the responsibility. For example, rainwater could be separated from wastewater in areas where this is an option.

132. IDA Study on Adaptation to Climate Change, May 2009

The drinking water supply

Denmark's water supply is essentially based on the extraction of groundwater. The significance of climate change for water supplies will vary greatly, depending on the local geological conditions[133].

On the face of it, the increase in annual precipitation should provide more water resources. However, in areas in which the water level is the factor that limits water resources, increased seasonal variation in extraction will pose a problem for water supplies in the summer period when water courses and lakes are at risk of drying out. In other areas, groundwater extraction will have a positive effect as it can relieve problems with flooding due to increased precipitation.

BARRIERS TO ADAPTATION OF THE DRINKING WATER SUPPLY

Before the utilities companies can begin working actively on initiatives for adaptation to climate change, there are a number of general conditions that must be clarified. Water supply planning is pending implementation of the Water Framework Directive and the new water plans.

Changes to water supply systems often entail large investment. Denmark has opted for a decentralised water supply structure with a large number of small water works. Therefore, if water extraction activities need to be restructured, the individual water works can find themselves facing an enormous financial burden. The study carried out by the IDA[134] among engineers indicated that almost 80 % of respondents felt that there was a need to adapt the water supply to meet the challenges of climate change.

133. The available resource is often limited due to the impact of extraction on rate of flow in water courses and other surface recipients. In addition, limits can be imposed by the in-rush of sea water, the release of heavy metals due to oxidation or pollution by xenobiotics.

134. IDA Study on Adaptation to Climate Change, May 2009

In addition, there is a clear tendency that members do not believe that there is sufficient focus on adaptation to climate change – particularly among private waterworks.

Due to the fact that changes to the water supply often require hefty investment, changes will often be implemented in connection with technical wear and tear or pollution of drilling sites. Therefore, The IDA Climate Plan 2050 recommends that expected climate changes are incorporated into water supply planning and adaptation to climate change is included in water planning, otherwise adaptation of the drinking water supply to climate change will happen too late.

Construction and civil works

Future weather changes must be taken into account when new projects such as the renovation of existing dwellings are being planned. The most significant challenges are expected to be the warmer and wetter winters in addition to generally more frequent and heavier rainfall, more intense heat waves and more violent storms.

The above projections all impose new demands on future buildings and renovation. With the increased volume of precipitation, there is a greater risk of flooding in certain low-lying areas. Therefore, it is important to be able to conduct water away from the houses and to stop water from entering buildings. The milder winters provide better conditions for biological activity, promoting the growth of harmful fungi such as mould that can be detrimental to the indoor climate.

According to the IPCC's most recent report, the longest heat waves will increase from the current 5 days to 14 days and the number of warm summer nights will increase from 10 to 30. Warmer summers will result in a demand for cooling.

The anticipated increase in groundwater level, higher water levels in water courses and greater risk of storm water in coastal areas make it important to protect buildings against seepage of water and flooding. More violent storms make it important to protect dwellings and buildings against storm damage. On the other hand, climate change can be used constructively as heavier rain showers in the future will promote fertile soil and water "green roofs"

BARRIERS TO ADAPTATION

National awareness – the interest of the wider public in adaptation to climate change in general – is a barrier that must be overcome. As indicated by the table with the results of the survey among engineers who work in the field of adaptation to climate change, there is broad consensus on the need to take adaptation to climate change into account in new building projects as well as renovation projects. This applies to an even greater extent to sewerage projects.

Engineers who work in the field of adaptation to climate change were asked to indicate the construction initiatives they felt ought to be prioritised. 95 % feel that drains and drainage conditions ought to be prioritised. In addition, protection against storms is considered to be a significant focus area.

	High priority/ very high priority	Average priority	Low/very low priority	Don't know	Total
Drains and drainage conditions	86 %	9 %	2 %	4 %	100 %
New standards for protection against storms	55 %	30 %	7 %	8 %	100 %
Increased need for cooling in the summer	21 %	38 %	35 %	6 %	100 %
New standards for snow load	17 %	32 %	39 %	12 %	100 %
Less need for heating in the winter	16 %	37 %	42 %	5 %	100 %

Table 19: What ought to be prioritised in building projects in order to ensure protection against climate change?

One way of adapting new buildings to climate change is to incorporate separation of rain water from other waste water. There are other options that incorporate increased volumes of precipitation, e.g. grass roofs. The roofs absorb rainwater and create a green environment in the town. As, in general, we expect our new houses to live up to 100 years, the IDA Climate Plan recommends putting adaptation to climate change on the agenda when new buildings are constructed and when private households make extensions and changes to their houses.

Coastal zone management

Climate changes will lead to a general increase in erosion of coasts and reduced protection against flooding in low-lying areas of Denmark, most of which are, today, protected by dykes. The increase in erosion is a result of both the increase in the water level and the stronger winds that subject coastal zones to larger waves during storms. This will cause an increase in retrogradation of the coast compared to the situation today. Due to the fact that the violent storms come from the west, not all of the country's coasts will be subjected to the same increase in impact.

The Danish Coastal Authority has assessed the impact of climate change on Danish coastal zones[135] based on the IPCC's A2 scenario. The Danish Coastal Authority used the IPCC benchmark for expected mean global increase in water level, i.e. a global increase in water level of 42cm was applied. Added to this is the increase in water level caused by changes in wind conditions. The main message about future rises in sea level to come from the international scientists' conference in Copenhagen in March 2009 was that the sea level will probably rise more than the IPCC has predicted[136].

The Danish Coastal Authority's calculations indicate that, according to the A2 scenario – which is optimistic – coastal retrogradation in protected coastal zones and on coastal stretches that are only moderately exposed will be relatively modest up to 2050. After 2050, coastal retrogradation will increase significantly so that, by 2100, average retrogradation will be approx. 14 m. The Danish Coastal Authority also estimates that problems may arise behind the dykes when sea levels rise due to the fact that it will be more difficult for the increased volume of precipitation to drain into the sea, and this will cause greater flooding along the water courses behind the dykes.

In addition, coastal protection activities must take extreme events into account. With the current climate, we can expect a maximum water level of 1.8 m above the normal water level once every 100 years. By 2096, a similar 10-yearly event is expected to result in a water level of between 2.37 and 3.13 m above normal[137].

ADAPTING COASTAL ZONE MANAGEMENT TO CLIMATE CHANGE

According to Danish law, it is up to individual landowners whether they choose to protect themselves against flooding or coastal erosion. Therefore, there are no laws or regulations that determine whether protection should be carried out or the extent to which landowners are required to protect themselves. The relatively modest retrogradation up to 2050 means that the Coastal Authority is working on building the height of dykes, extending groynes in line with retrogradation and heightening breakwaters in line with the rise in the water level. In order to avoid over-investment and more maintenance than necessary, the Coastal Authority proposes a strategy of gradual adaptation whereby initiatives and changes to flood hazard prevention are not implemented before actual changes due to climate change have been ascertained.

135. The impact of climate change on coastal zones, the Danish Coastal Authority, March 2008
136. http://www.climatecongress.ku.dk

137. Adapting drainage systems to climate change and scientific tests, financial analysis. Environmental project no.1187, 2007

Climate changes bring the Coastal Authority's dilemma of finding a balance between coastal protection and the natural dynamics of the coast into sharper focus. On the one hand, coastal protection is required to protect values such as towns, infrastructure, farming land and existing natural values and landscape. On the other hand, the nature of the coastal landscape in Denmark is some of the most original, untouched and diverse nature we have to offer.

Therefore, it requires good planning to ensure a balance between protection of our coasts and free coastal dynamics. Future installations and buildings ought to be situated in areas in which there is no great risk of flooding or coastal erosion, and it would probably be most sensible in the long term to give up summer cottage areas close to the coast.

Future coastal protection activities ought to be based on an overall strategy for all coastal areas. A strategy of this type, that takes all of the different interests into consideration, is a qualified alternative to coastal zone management whereby the height of dykes is gradually built up, water courses are supplied – one by one – with high water level closure systems and whole fiord systems are closed off with protective embankments out of consideration for a limited number of urban areas. Therefore, The IDA Climate Plan 2050 recommends the implementation of a coherent national plan for coastal development. This requires a break with existing regulations according to which the individual landowner is responsible for protection of the coast

Nature and production in a changed climate

Climate changes will result in changes to nature reserves in Denmark. In general, it is expected that the growing season will be prolonged, that primary production will be increased, the turnover rate will increase and the conditions for competition among species will change.

WATER AND TEMPERATURE – CHALLENGES FACING AGRICULTURE

Climate changes will have an impact on farming land. Turnover of organic substances will be affected as they are dependent on temperature, and erosion and wash-out of nitrogen are affected by precipitation conditions and volume of rainfall. Increased precipitation and rises in sea and groundwater levels will result in flooding and water-logged land in some areas. In some locations, the impact can be rectified by treating the soil more carefully. However, in other areas, it many mean that the soil can no longer be used for agriculture.

In general, higher temperatures and a prolonged growing season will have a positive impact on crop yield and, therefore, production will be expected to increase. It may become more common to cultivate crops suited to warmer climates, such as winter corn and maize, whereas spring-sown cereals and, perhaps, potatoes may become less common. A warmer climate means better growing conditions for forage crops. Therefore, it will be possible to cultivate new forage crops to replace some of the imported crops.

However, with climate change comes the risk of introducing new livestock diseases and more of the diseases we have today will have better conditions in which to develop. In addition, it is expected that there will be an increase in new species of weed and better growing conditions for fungi, plant diseases and insects (including harmful organisms). This can lead to an increased need for pesticides in tomorrow's agriculture.

FORESTRY – THE VULNERABLE CONIFERS

Trees are long-living organisms and, thus, have a relatively high ability to adapt. However, this ability varies from species to species and depends on the specific climate change. Due to the fact that many species of tree in Denmark are close to their northernmost limit for propagation, and as this limit is particularly due to too low temperatures, they will be relatively unsusceptible to a slight increase in temperature. However, a reduction in the volume of summer precipitation, and in particular, the probability of longer periods of drought, will generally weaken all tree species. Conifers, and especially those with relatively superficial root systems, will be most vulnerable.

An increase in the strength and frequency of storms must be taken particularly seriously in forestry strategies for adaptation to climate change. As most storms occur during the winter months, when deciduous trees have shed their leaves, conifers are again the most susceptible to storms. Finally, the balance between the trees and their pests can be affected by changes to climate conditions, particularly due to the fact that growing conditions for certain types of pest improve in a warmer climate.

When we consider forestry's long production horizon and uncertainties as to the precise type of climate change, tree species ought not to be phased out completely but ought to be grown on a monoculture basis. As we do not yet know precisely which climate changes to expect, mixed forests with deciduous trees provide the safest form of adaptation.

Forestry initiatives that provide forests with the best protection against possible and unforeseen climate change are, to a great extent, identical to the principles for nature-based forestry, which is aimed among other things at the omission of clear cutting, active forest improvement through frequent and light felling and the establishment of an uneven aged, mixed forest stand of tree species that have been adapted to local conditions.

FISHING FOR NEW SPECIES

As temperatures increase, populations of the species living at the southernmost limit for propagation will either perish or move north whereas species that are now living at their northernmost limit will proliferate, particularly if they are able to make use of the same organic niche vacated by the northern species. Temperature changes will affect the diet of the fish as they have an impact on the oceans' eco-systems.

Populations of cod and herring are expected to decrease further due to climate change whereas southern species such as sprat, anchovies and sardines will gain ground. Therefore, the fishing industry must adapt and begin to catch sprat, anchovies and sardines.

The new species pose a challenge for the management of the fishing industry as it lacks a reference for the size of a sustainable population and knowledge of the impact the new species will have on the existing eco-system. Therefore, there is an increased need for new surveillance technology in order to be able to monitor the changes in the eco-systems and fish populations.

Mussel fishing and breeding will also be affected by changes in temperature. Shellfish populations are already changing, presumably due to changes in temperature. Furthermore, acidification of the oceans may have an impact on certain species of mussel and plankton and, thus, on the availability of food for all species of fish, including the species of greatest importance to the fishing industry. Higher temperatures may also promote new species of pathogenic bacteria and poisonous algae which may threaten wild fish and shellfish populations as well as fish that are bred in marine farms.

NATURE CONSERVATION – A BALANCE BETWEEN PRESERVATION AND CHANGE

Climate changes will result in changes in Danish nature reserves. Expected changes include prolongation of the growing season; an increase in primary production; an increase in turnover rate; a change in the conditions for competition among species; potential changes in behavioural patterns with an increased of imbalance in food chains and eco-systems; a decrease in species with poor mobility; low genetic diversity etc, an increase in robust and more common species resulting in a reduction in diversity of species; replacement of northern species with more southern species and an increase in invasive species from the south; an increase in erosion; an increase in summer droughts with the associated consequences for animals and plants; more frequent and more prolonged flooding; higher eutrophication of lakes, water courses and Danish waters; a fall in salinity levels in Danish waters and the Baltic Sea; more widespread and a higher frequency of deoxygenation; impact on /loss of currently low-tide eco-systems; a reduction in marine, benthic fauna with resulting loss of basic diet.

In general, the adaptation of nature conservation activities to climate change involves the mitigation of stress factors, protection of genetic diversity and development of expertise, e.g. nature rehabilitation; establishment of large, coherent nature reserves and links with broad corridors for the passage of wildlife; extension of buffer zones between nature and agriculture in order to reduce eutrophication and the effects of pesticides; rehabilitation of alternative acreage with natural habitats that could disappear if sea levels rise; reestablishment of better physical conditions in water courses; prevention of the introduction and spread of invasive species; monitoring of changed compounds of species and general nature surveillance.

Socio-economic aspects of adapting to climate change

The key issue with regard to adaptation to climate change is deciding which initiatives are worth implementing. The decision is complicated by a number of factors: the uncertainty attached to our knowledge of our needs in the next 20 to 100 years; and the general economic development over the same period. What will generate the greatest socio-economic benefits?

Economist Nicholas Stern believes that our failure to price CO_2 emissions is the greatest market-related mistake the world has seen to date.

When fossil fuels such as oil, coal or gas are burned, pollution is emitted – with negative consequences. These consequences are not included in the price of the fuel. An additional charge on carbon in the form of a price for CO_2 emission will provide us with a tool to work with when we consider the value of prevention versus adaptation. In his report, Stern calculates that the price of refraining from prevention will amount to around 5 % of GNP per year, and if we see more violent climate changes it could be up to 20 % of GNP[138]. Naturally, this will be spread unevenly around the world depending on the climate changes experienced by specific countries or regions.

DECISIONS BASED ON COST BENEFIT

No overall study of the field has been conducted in Denmark and, therefore, it can be difficult for both private citizens and local authorities to take decisions. However, there are some studies available in certain areas.

With regard to extreme events, financial risk assessment also plays a major role. With the current climate, we can expect a maximum water level of 1.8 m above the normal water level once every 10 years. By 2096, a similar 10-yearly event is expected to result in a water level of between 2.37 and 3.13 m above normal[139]. The resulting flooding will have very different impacts depending on the stretch of coast in question. In the case of the area around Roskilde, the socio-economic cost of an extreme rise in water levels following a storm is estimated at DKK 200 – 300 million.[140]

The cost of protecting ourselves against this will be extremely high as it will require very large investment. In addition, dramatic events such as storm flooding can have a long-term impact which is not easy to include in a financial, cost-benefit model. Particu-

138. The Stern Review, Nicolas Stern 2006.
139. Adapting drainage systems to climate change and scientific tests, financial analysis. Environmental project no. 1187, 2007
140. Adapting drainage systems to climate change and scientific tests, financial analysis. Environmental project no. 1187, 2007

larly if several towns in the same area are affected, the financial impact on commercial life, tourism etc. will be of significance for many years. This illustrates how difficult it will be for local authorities to take decisions on extreme situations. There is a need for further studies on ways in which local authorities ought to address the risk of extreme weather conditions.

The financial consequences of extreme rain have been estimated for Roskilde local authority and it is clear that the risk of extreme rain will increase to such an extent that it will be worth boosting the civil works budget by 10 to 20 %. This will ensure citizens a wastewater system that takes the risk of basement flooding etc. into account and can provide the same service in 2096 as they receive today.

Cost-benefit analyses for local authorities for adaptation to climate change are of vital importance when decisions are to be made. Therefore, The IDA Climate Plan 2050 recommends that local authorities and the government join forces to prepare guidelines and methods for a uniform cost-benefit calculation model for adaptation to climate change.

Adaptation to climate change as a business

Another angle to adaptation to climate change is the business potential that lies in the expertise that Denmark is developing in the field. 80 % of the experts who took part in IDA's study believe that the technologies being developed have the potential to become export products. However, only 24 % feel that there is sufficient focus on adaptation to climate change when funds are allocated to research and innovation. At the same time, only 12 % feel that Denmark exploits its potential for export of its expertise and technologies related to adaptation to climate change.

This view is shared by the Business Panel on Climate Change[141], which has accumulated a number of assessments of the rate of growth of export for the various different business areas in the field of adaptation to climate change, e.g. water filtration/desalination where growth rates of between 6 and 23 % are expected and infrastructure which is expected to increase by 7.6 %. By comparison, the general growth rate for export is expected to be 4.4 %.

Thus, the government faces a significant challenge to create an environment that enables the conversion of expertise and experience in adaptation to climate change to services that can be exported to the rest of the world. In these times of financial crisis, when there is a need for increased public investment, we ought to focus on investing in projects on climate change.

141. Danish positions of strength in the field of climate change, The Business Panel on Climate Change 2008