IDA´s klimaplan 2050

Tekniske energisystemanalyser og samfundsøkonomisk konsekvensvurdering - Baggrundsrapport

Mathiesen, Brian Vad; Lund, Henrik; Karlsson, Kenneth

Future Climate

Engineering Solutions

The IDA Climate Plan **2050**

Technical energy system analysis, effects on fuel consumption and emissions of greenhouse gases, socio-economic consequences, commercial potentials, employment effects and health costs

BACKGROUND REPORT

IDA

STRENGTH THROUGH KNOWLEDGE

IDA's Climate Plan 2050
Background Report

Authors:
Brian Vad Mathiesen, Aalborg University
Henrik Lund, Aalborg University
Kenneth Karlsson, RISØ - DTU

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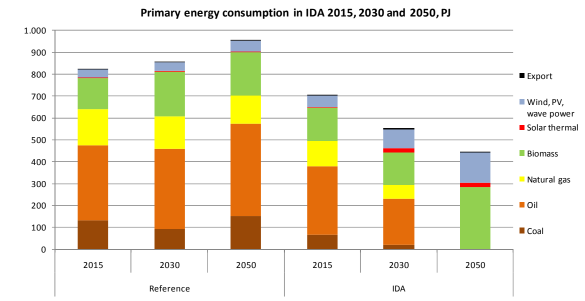
Kalvebod Brygge 31-33
1780 Copenhagen V.
Telephone 33 18 48 48
Fax 33 18 48 99
E-mail: ida@ida.dk

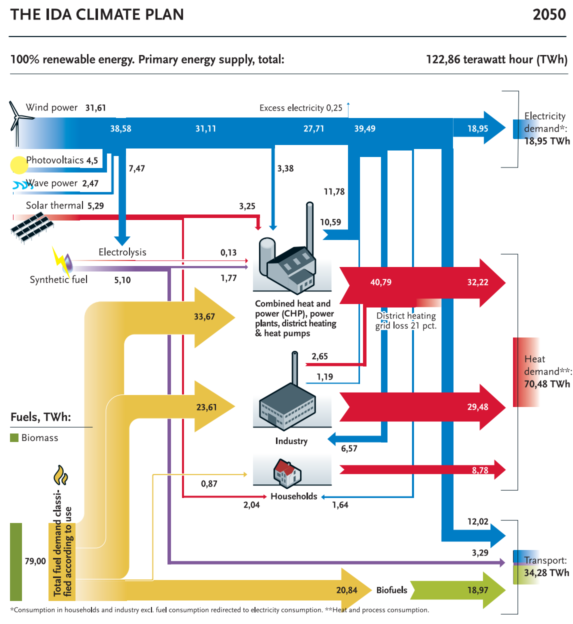
The technical energy system analyses and estimations of economic consequences for IDA's Climate Plan 2050 are presented in the Background Report. This Plan is the Danish contribution to the international project Future Climate. The Report has been completed during the period December 2008 to July 2009. IDA's Climate Plan 2050 was released on 11 May 2009 as a public consultation draft. Adjustments have been done after the public consultation period. The final results of the analyses in IDA's Climate Plan 2050 are presented in this Report, and along with a description of both the assumptions and the analyses in the Climate Plan.

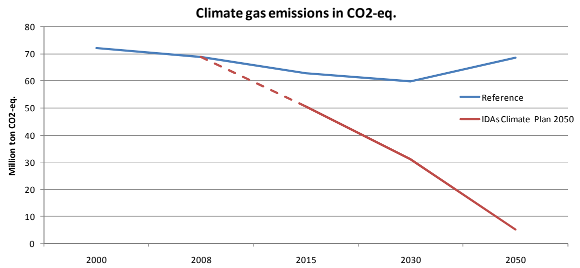
Background Report to

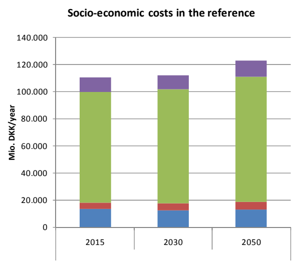
IDA's Climate Plan 2050

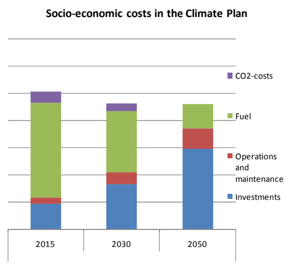
Technical energy system analysis, effects on fuel consumption and emissions of greenhouse gases, socio-economic consequences, commercial potentials, employment effects, and health costs

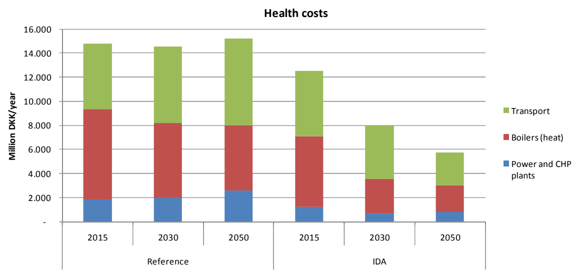


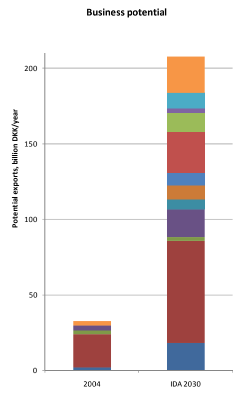


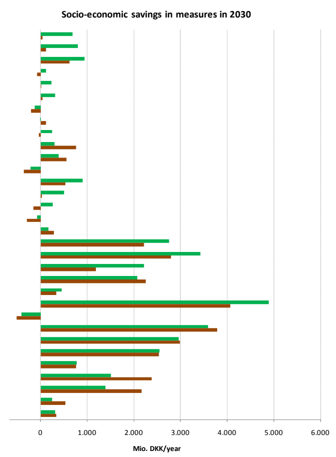












Brian Vad Mathiesen, Aalborg University
Henrik Lund, Aalborg University and
Kenneth Karlsson, Risø-DTU

August 2009

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1 Preface

It has been a great challenge to assemble the threads in this climate plan and to perform the collected analyses of the energy systems on behalf of The Danish Society of Engineers, IDA. Not least because it looks at the energy system in the short term in 2015, in the medium term in 2030, and in the long term in 2050. The vision in this plan is a 100 per cent renewable energy system. It was not possible to assemble an integrated plan without those active in IDA's technical specialist societies and groups, the IDA employees, and the project coordinators for the themes into which the project has been divided. There has also been invaluable support for the work from large parts of the Danish energy sector. Therefore, all of these deserve a personal thank you. During the development of the Background Report we have drawn especially upon a range of specialists from universities and firms. They have contributed directly with various inputs and we owe them a special thank you. Together with these people it has been possible to procure the large amount of data necessary for the analyses:

Niclas Scott Bentsen, PhD Student	Forest and Landscape, Copenhagen University
Helge Bach Christiansen, Engineer	IDA Energi
Anders Dyrelund, Director Marketing	Rambøll A/S
Claus Felby, Professor	Forest and Landscape, Copenhagen University
Peter Frigaard, Head of Department	Aalborg University, Department of Civil Engineering
John Bøgild Hansen, Director Systems Development	Topsoe Fuel Cell A/S
Mogens Weel Hansen, Engineer	Weel & Sandvig A/S
Helge Holm-Larsen, Director Business Development	Topsoe Fuel Cell A/S
Jacob Ilsøe, Energy Consultant	Birch & Krogboe A/S
John Tang Jensen, Technical Consultant	Dansk Fjernvarme (Danish District Heating Association)
Lotte Jensen-Holm, Business Development Manager	Topsoe Fuel Cell A/S
Per Homann Jespersen, Senior Lecturer	Roskilde University
Kaj Jørgensen, Senior Scientist	Risø-DTU, System Analysis Division
Betina Kamuk, Project Leader	Rambøll A/S
Peter Karnøe, Professor	Copenhagen Business School
Alex Landex, Lecturer	DTU Transport
Jesper Magtengaard, Engineer	Dong Energy
Allan Mahler, Technical Manager	Dong Energy
Otto Anker Nielsen, Professor	DTU Transport
Jan Erik Nielsen, Engineer	Dansk solvarme (Danish Solar Thermal Association)
Lars Henrik Nielsen, Senior Scientist	Risø-DTU, System Analysis Division
Per Nielsen, Managing Director	EMD A/S
Jan Runager, Managing Director	ARCON solvarme
Svend Svendsen, Professor	BYG-DTU
Henrik Tommerup, Senior Lecturer	BYG-DTU
Per Alex Sørensen, Engineer	PlanEnergi s/i
Göran Wilke, Managing Director	The Danish Electricity Saving Trust
Kim Winther, Environmental Economist	DONG Energy

Finally we owe a thank you to our closest colleagues, who have helped with specialist inputs and corrections: Frede Hvelplund, Poul A. Østergaard, Marie Münster, Morten Boje Blarke and Mette Reiche Sørensen, all from Aalborg University, Denmark and David Connolly, University of Limerick, Ireland.

Brian Vad Mathiesen, Henrik Lund and Kenneth Karlsson
August 24, 2009

2 Summary

The central technical and economic results of the Background Report are described in this chapter. Please note that the results are based on assumptions, subjective analyses, etc., which are described in the following chapters.

2.1 100% Renewable Energy and Large Reductions in fuel consumption

The current primary energy supply in Denmark, i.e. fuel consumption and renewable energy for production of electricity and heat for households, transport and industry, is approx. 800 PJ. If new initiatives are not taken, it is expected that energy consumption will decrease marginally until 2015, but then increase gradually until 2050 to about 950 PJ. Initiatives are proposed in IDA's Climate Plan 2050 which can reduce primary energy supply to 707 PJ in 2015, 556 PJ in 2030, and 442 PJ in 2050. At the same time, the share of renewable energy from wind turbines, photovoltaic, solar thermal, wave energy, and biomass will be increased. The share of renewable energy in the reference energy systems increases from about 16 per cent in 2008 to 22 per cent in 2015 and to about 25-29 per cent in 2030 and 2050. The share of renewable energy in the Climate Plan increases to 30 per cent in 2015 and 47 per cent in 2030. ***In 2050 the entire Danish energy system, incl. transport, is based on 100 per cent renewable energy.*** The primary energy supply is illustrated in Fig. 1. The energy flows for the reference energy system in 2030, IDA 2030 and IDA 2050, are illustrated in **Fig. 2** to Fig. 4.

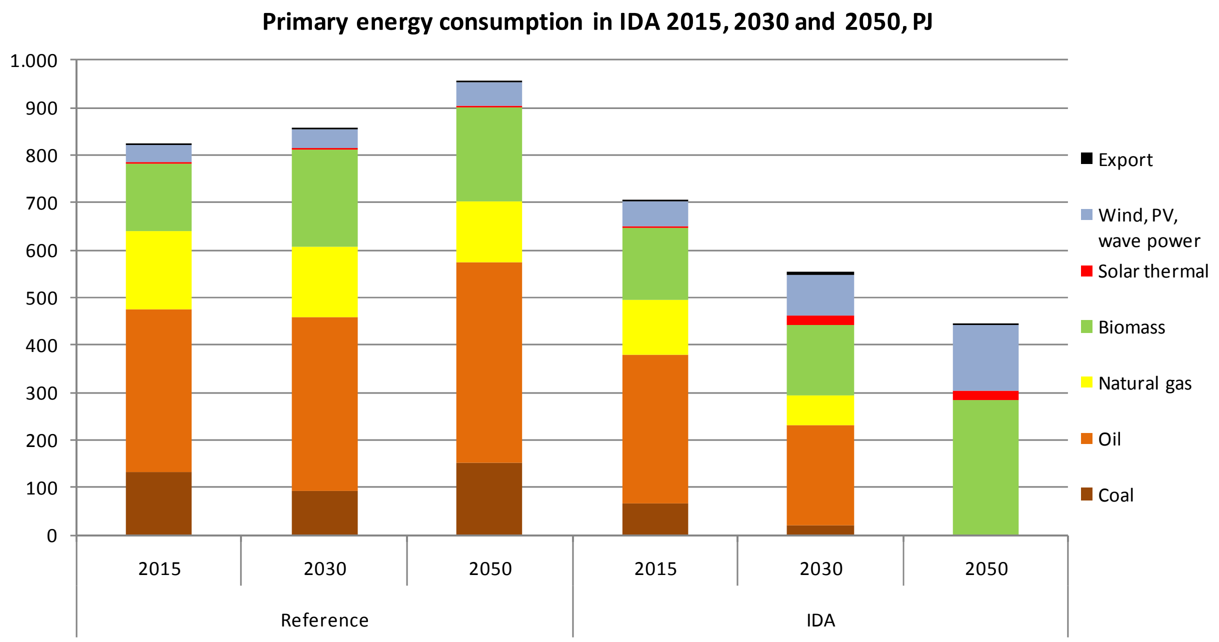
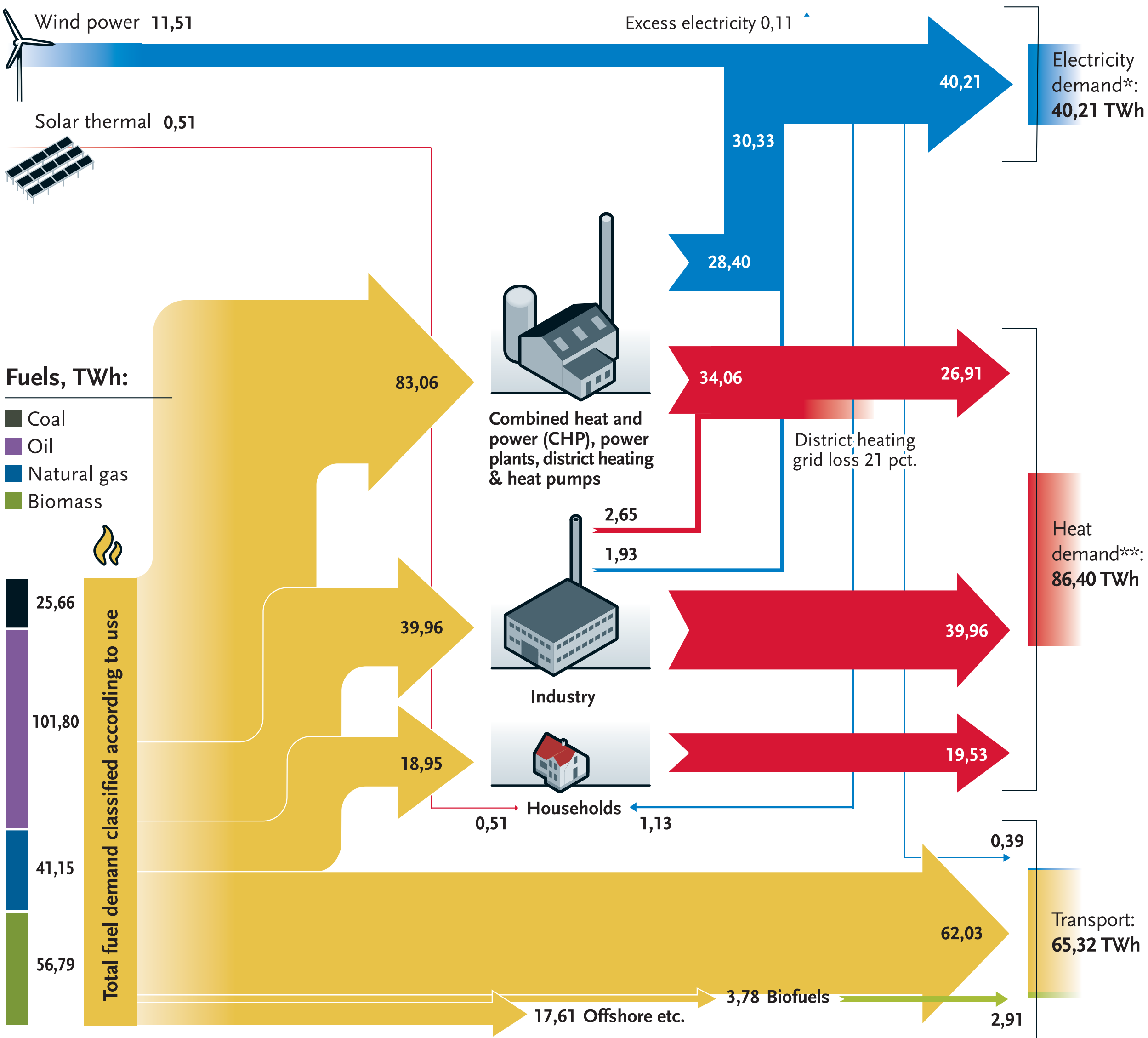


Fig. 1, Primary Energy Supply in IDA's Climate Plan 2050.

The energy system in IDA 2015 is based on measures which can be realised with current technology. Although some of the measures in IDA 2015 plan must be implemented over a period from 2010 to 2020, they are considered as fully implemented by 2015 for the analyses. In IDA 2030 large parts of the transport system are changed, district heating systems are heavily expanded, there are more efficient power plants, more mature and new renewable energy technologies are introduced, and further energy savings implemented. In general large parts of the fossil fuel consumption are replaced by electricity demands, especially within transport, with battery electric vehicles and electrically powered trains.

DANISH REFERENCE 2030

29% renewable energy. Primary energy supply, total: 237,42 terawatt hour (TWh)



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

Fig. 2, Sankey diagram of the reference energy system for 2030.

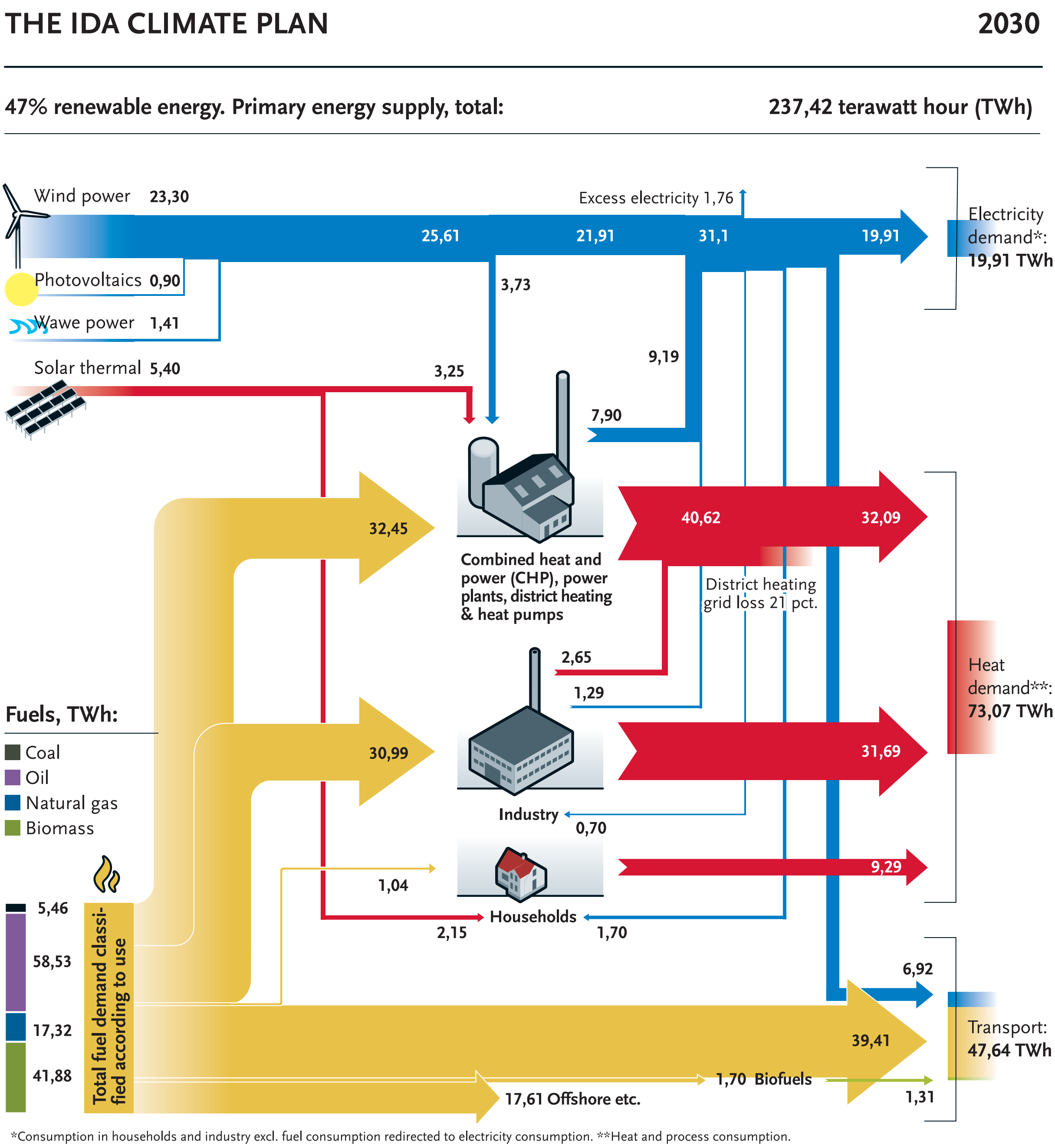


Fig. 3, Sankey diagram of IDA 2030 in IDA's Climate Plan 2050.

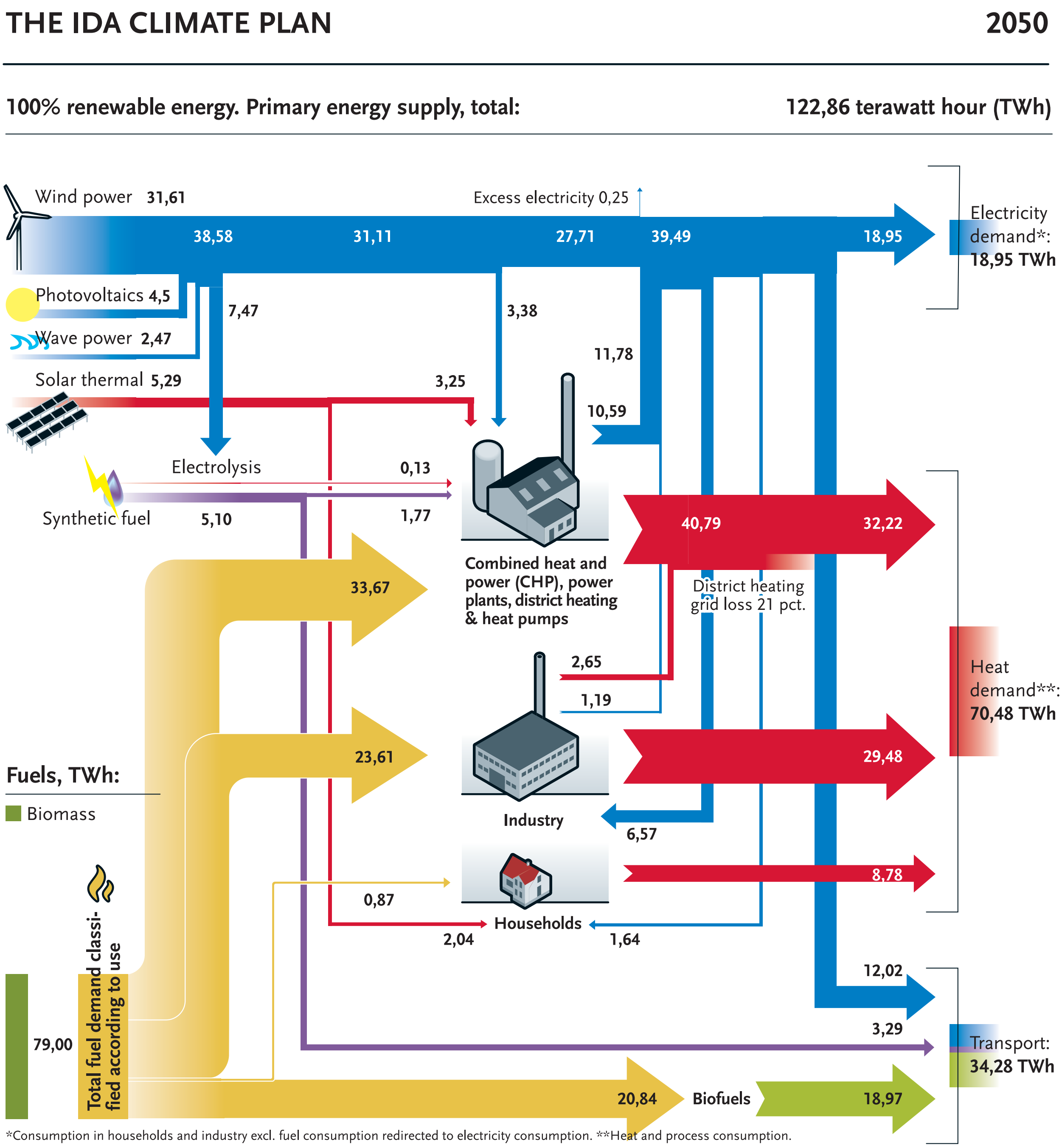


Fig. 4, Sankey diagram of IDA 2050 in IDA's Climate Plan 2050.

In IDA's Climate Plan 2050, an energy system is designed which is based on 100 per cent renewable energy, starting from the initiatives proposed in IDA 2015 and IDA 2030. This is partly to ensure that these energy systems do not stand in the way of this objective and partly because of the Danish Government's objective that Denmark shall be 100 per cent independent of fossil fuels and nuclear power, when the oil and natural gas resources stop. The result is that this is possible, but there is a key issue surrounding the consumption of biomass: should biomass be used to generate electricity for direct use or should it be used for the production of synthetic fuels. A balance must be met between these two requirements to utilise the biomass resource effectively and therefore, an estimate is presented in this report for this balance.

Further savings are presented and more renewable energy is introduced in IDA 2030 toward a 100 per cent renewable energy system. There are sufficient domestic biomass resources to meet demand for both the IDA 2015 and IDA 2030 scenarios. However, there are additional challenges in the 2050 energy system when 284 PJ of biomass is used in the Climate Plan. This can potentially be supplied with domestic resources, but conversely it will not leave many resources for producing other material goods, if this is to be based on biomass as well. Therefore, due to these limitations on domestic biomass, there is a further challenge in the future regarding the fuel consumption in industry and aviation. It is uncertain if these demands can be met using direct or indirect electricity production (i.e. electrolysis), or whether further savings must be introduced.

A 100 per cent renewable energy system has been designed which potentially can be maintained by domestic biomass resources. It must however be emphasised that there is no objective in the Climate Plan not to do international trade with biomass. However the Climate Plan ensures that Denmark does not merely become dependent on imports of biomass, instead of being dependent on imports of oil, natural gas and coal which is the case in the reference scenario, once Denmark does not have any resources left in the North Sea.

2.2 *Large reductions in greenhouse gas emissions*

The initiatives in the Climate Plan reduce the emission of greenhouse gases by about 90 per cent in 2050 in comparison to 2000. The energy system constitutes only a part of the greenhouse gases emissions. For the Climate Plan this part will be reduced to 34 million tonnes CO_2 in 2015, 19 million tonnes CO_2 in 2030, and is completely removed in 2050. Beyond this, reductions in greenhouse gas emissions from industrial processes and from agriculture are proposed. Considering these, the emissions of green house gasses in 2050 can be reduced to 7.2 per cent of the emissions in 2000. However, if an extra contribution from aircraft due to discharges at high altitudes is also included, the reduction in 2050 is 10.2 per cent of the emission in 2000.

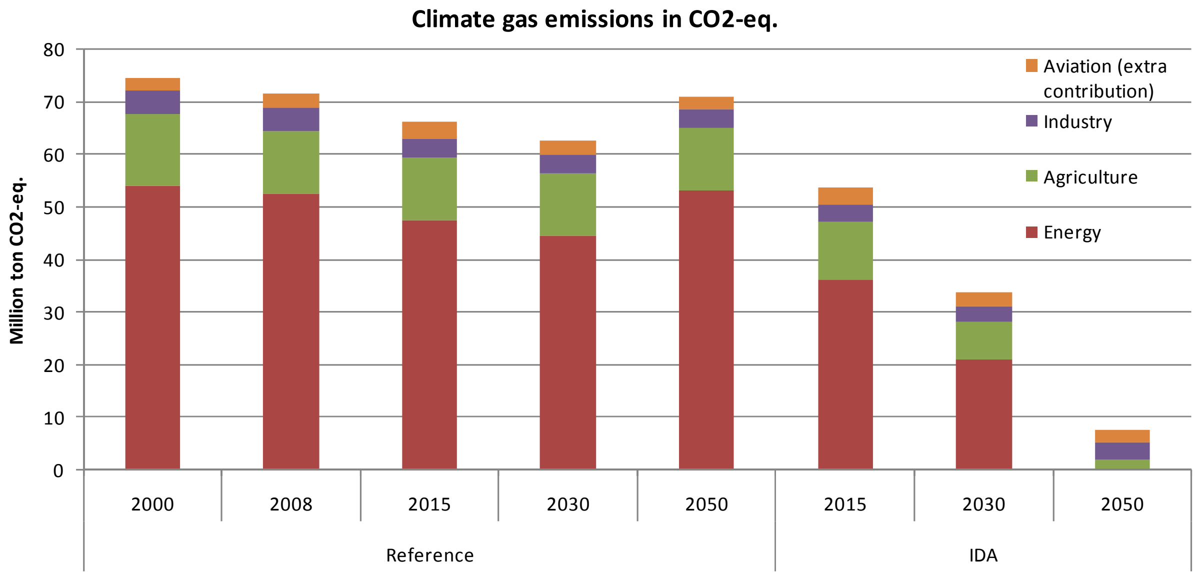


Fig. 5, Emissions of greenhouse gases in IDA's Climate Plan 2050.

2.3 Better socio-economic solutions with more renewable energy

The Climate Plan will be implemented over a period from now until 2050 by continuously replacing worn-out facilities when their lifetime expires, meaning they need to be replaced regardless of implementing the Climate Plan. Therefore, as a point of departure for this study, the expenses are calculated as extra expenses through investing in better facilities in comparison to the reference energy system. There are however exceptions to this.

The socio-economic costs are calculated as annual expenses in each of the years 2015, 2030, and 2050. The annual costs in the Climate Plan's energy systems are compared with the payments in the reference in each of the applicable years. The costs are categorised under fuel costs, operations and maintenance costs, and investment costs. A real interest rate of 3 per cent is used in depreciation investments. The economic analyses are based on the latest assumptions regarding fuel prices and CO_2 quota costs, which were defined by The Danish Energy Authority in May 2009 [1].

Three fuel price levels are used. The middle price level is based on current fuel prices which corresponds to an oil price of $122/barrel according to the Danish Energy Authority. The high fuel price is based on those that occurred in the spring/summer of 2008 and correspond to an oil price of $132/barrel [2]. The low price level is based on assumptions which The Danish Energy Authority used in its forecast in July 2008 and corresponds to an oil price of $60/barrel [3]. Calculations are also done with long-term CO_2 quota costs of 229 DKK/tonne and 458 DKK/tonne for 2030 and 2050 respectively. The CO_2 quota costs do not include all costs to the economy, such as flooding for example, but are only anticipated quota costs. If these types of effects are included in the calculation, there will be an economic advantage for the energy systems in the Climate Plan.

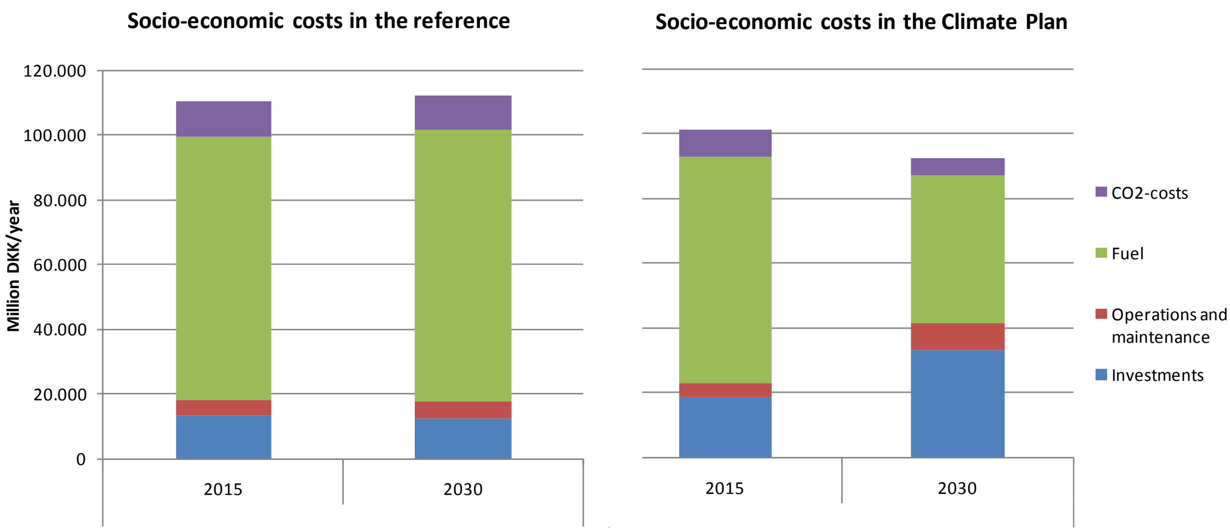


Fig. 6, Socio-economic costs in 2015 and 2030.

After analysing the implications of these various fuel and CO_2 costs, the general picture is that Denmark will achieve a significantly better economy with both IDA 2015 and IDA 2030, than with the reference scenarios. ***In 2015 and 2030 the difference with the middle fuel and CO_2 price assumptions is 9 and 20***

billion DKK/year respectively, as displayed in Fig. 6. In IDA 2015 it is important however to note that a part of the measures are undertaken in the period 2010 to 2020. On top of this there are advantages regarding saved health costs, commercial potentials, and employment effects.

In addition a more robust situation is reached with the IDA Climate Plan as the combined costs for energy are less sensitive to fluctuations in oil prices and CO_2 costs. There will be a gain even with fuel prices half as high as The Danish Energy Authority recommends at the moment. It is worth noting that between 50 and 95 billion DKK/year will be used for fuels from now until 2030, depending on the fuel prices. It is proposed in the Climate Plan that these expenditures be reduced to between 29 and 51 billion DKK/year, again depending on the fuel prices.

Two advantages can be obtained from the IDA 2015 and 2030 proposals. Firstly, they are less expensive than the reference energy systems, and secondly, these systems are significantly less sensitive to fluctuations in the fuel prices. In the future one must however expect that the world will continue to experience fluctuating fuel prices and neither constantly high nor constantly low oil prices.

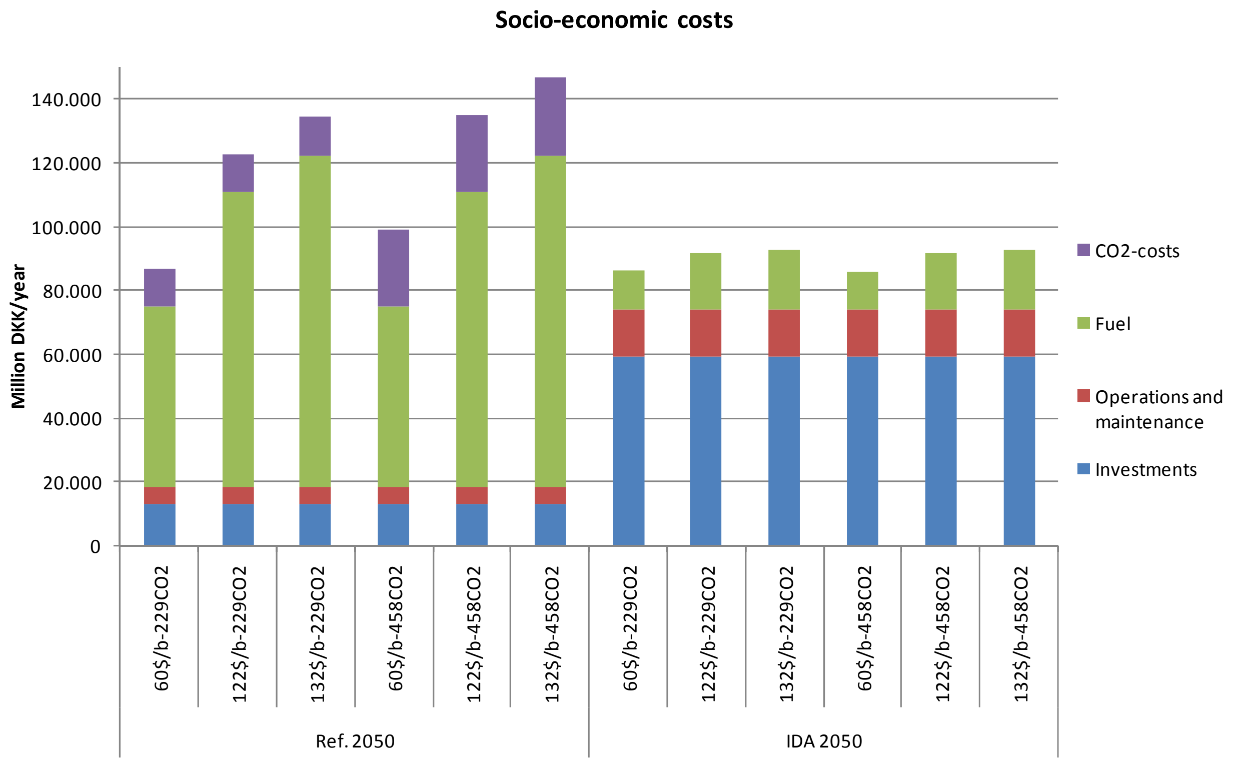


Fig. 7, Socio-economy costs in 2050 at different fuel and CO_2 prices.

IDA 2050 is based on 100 per cent renewable energy. The costs in this study should be seen as a first attempt to estimate the costs of the economy in such a system. Such estimates are however associated with significant uncertainties. In 2050 there is a wide range of measures, such as the electricity and heat savings, which are altered only marginally in relation to the measures in IDA 2030. The most important changes are that the share of renewable energy is raised significantly in the electrical system, the power plants are more efficient, synthetic fuels from electrolysis have replaced some of the biomass demand,

and the transport sector utilises more rail transportation and includes more battery electrical vehicles. It must be emphasised that the results are dependent on the fuel price assumptions, as well as the significant structural societal changes that are proposed in IDA 2050. IDA 2050 is robust even with larger changes in the biomass prices than analysed here. The results indicate that there are potential savings of over 25 billion DKK/year in the middle fuel price scenario for IDA 2050 compared to the reference, as illustrated in Fig. 7.

The above-mentioned estimation of costs to the economy is in a closed system without international electricity market exchange. Analyses of the consequences of international electricity exchange on the Nord Pool have also been conducted (The North European Power Exchange). The analyses are started using electricity prices from a normal year in the Nord Pool area and with fluctuating fuel and CO_2 quota costs. The net income is a combined calculation of import/export incomes including bottleneck incomes, as well as various CO_2 quota and fuel costs when there is electricity market exchange with the surrounding countries. The results indicate that in situations with low fuel prices and low CO_2 quota prices, income is primarily through electricity exports, while in the case of high fuel prices income is primarily through imports (i.e. money can be earnt by export or it is less costly to import than to produce electricity domestically). Therefore, there is also a difference in the earnings from electricity market exchange in the reference and IDA scenarios. The IDA energy systems provide higher incomes, primarily because of more efficient power plants combined with available capacity when the consumption is covered by wind turbines, etc. This will however result in larger CO_2 emissions in Denmark and increased coal or biomass consumption.

All in all, the economic benefits of the IDA Climate Plan due to the international exchange of electricity is insignificant compared to the economic benefits due to the annual costs of the system itself, which amounts to several billion DKK/year to the advantage of IDA 2015 and IDA 2030 as presented previously. In the references for both 2015 and 2030, as well as in IDA 2015 and IDA 2030, an increase in the transmission capacity to other countries from 2,500 MW to 5,000 MW only provides an opportunity for marginal extra incomes which are insignificant in comparison to the costs associated with this extra capacity. The conclusions of the electricity exchange analyses of the 2050 energy systems are estimated to be in keeping with the above results. It must be emphasised that the results for the electricity market exchange analyses for 2050 are simply an estimate and are based on The Danish Energy Authority's expected electricity price in 2030 and not 2050. It must also be emphasised that the analyses of a closed energy system without electricity market exchange are not an expression that international trade of electricity should not be the case in the future. This is only done in order to ensure that the energy systems in the Climate Plan are not dependent on this, or dependent on curtailing fluctuating renewable energy in certain situations as the energy systems in the Climate Plan can avoid this.

Even large changes in assumptions regarding international electricity trade in the means for electricity market exchange are not critical for the comparison. The large difference in costs between the various systems can be summed up by stating that the Climate Plan has large investments, while the reference has large fuel costs. Hence the cost comparison completed here is especially sensitive to both changes in the fuel prices and changes in the interest rate and investment requirements. Therefore, analyses have been done at three fuel levels and two CO_2 offset price levels. However, none of results change the general picture that the Climate Plan has lower costs than the reference. Nor are the results changed when the investment levels are increased by 50 per cent, although the earnings do become lower. The same is the case if the real interest rate is at 6 per cent instead of 3 per cent. It must be pointed out however that this applies to the combined package. With an altered interest rate or scope of investment, several of the individual measures will then have a negative economic result.

2.4 Health costs

The health costs have been estimated on the basis of six different emissions to the air: SO_2, NO_x, CO, particulates (PM2.5), mercury, and lead. In IDA's Climate Plan 2050 the highest reductions are in the emissions of NO_x, CO, and small particulates, while there are smaller reductions in the other emissions. The reduced emissions are primarily caused by lower coal demands for the power plants, less diesel and petrol in the transport sector, reduced demand for oil in industry, and a reduced demand for wood in individual household heating-systems. On the other hand, the emissions increase marginally because of more straw, wood, biogas, etc.

The health costs calculated here are based on the latest published data for costs connected to different technologies in different point sources. The costs are based on enumerated lost work days, hospital admissions, health damage, deaths, etc. The combined health costs estimated for the reference energy systems for 2015, 2030, and 2050 are approximately 14 to 15 billion DKK/year, which fit well with other studies. In Fig. 8 the health costs have been estimated by sector. It is important to emphasise that the total health costs presented here only give an indication of the total costs because of health effects. For a more precise measure of the health costs, the energy system scenarios would need to be analysed with the new preconditions in air-pollution analyses modelling tools.

In IDA 2015 and IDA 2030 these costs have been reduced to approximately 13 and 8 billion DKK respectively. ***Thus there are savings in the health costs of approx. 2 billion DKK in 2015 and approximately 7 billion DKK in 2030***, if the measures in the climate plan are implemented. Approx. 0.9 billion DKK of the saved costs in 2015 are located in Denmark and about 2.3 billion DKK in 2030. The rest of the savings in health costs are placed in the neighbouring countries. The health costs included are based exclusively on the six emissions and do not include environmental costs due to damage to nature and animal life, nor costs from extraction of fuels and materials abroad, e.g., from a coal mine in South Africa. Thus it is a conservative evaluation of externality costs. If the socioeconomic environmental and health costs due to the CO_2 emissions on top of the six emissions analysed here are included, a conservative estimate shows that the above-mentioned savings are approximately twice as large. The health costs have also been analysed for 2050. Here the potential savings in health costs are 9.5 billion DKK, out of which 2.4 billion DKK is saved in Denmark.

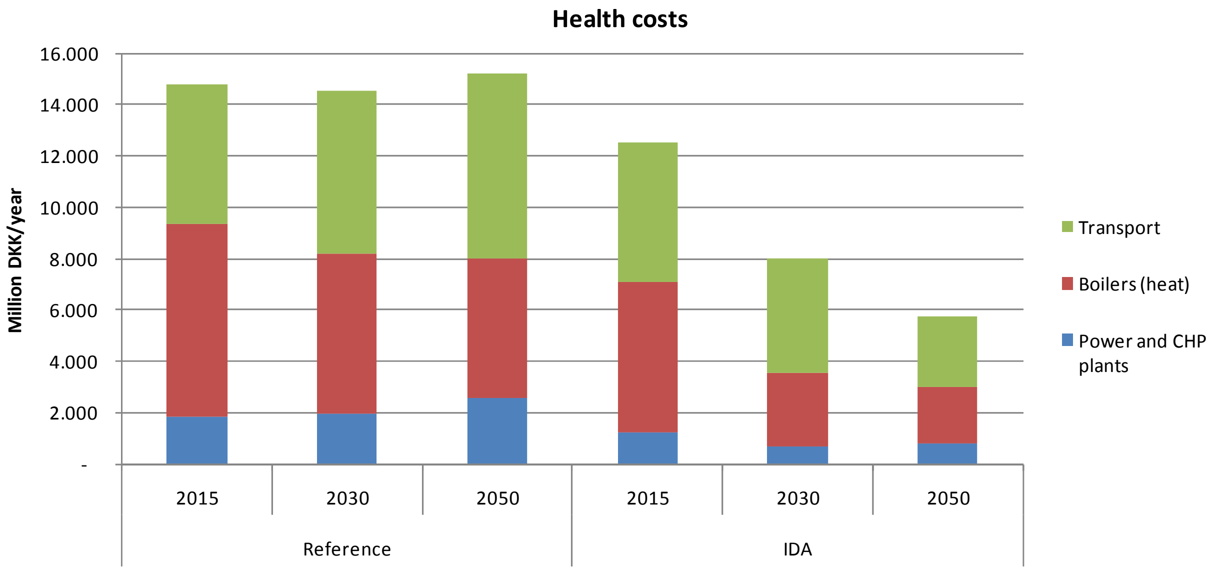


Fig. 8, Combined health costs from the energy systems divided by sector.

2.5 Commercial potentials

A systematic implementation of the technologies that are included in IDA's Climate Plan 2050 will include significant opportunities to increase exports. These commercial potentials are evaluated for the Climate Plan with a starting point in the current and historic export of energy technologies in Denmark. It is estimated that IDA's Climate Plan 2050 can create a potential export of energy technology that climbs from the present approx. 64 billion Danish crowns in 2008 to ***approx. 200 billion DKK/year*** going forward to 2030.

It must be emphasised that this type of quantification is associated with significant uncertainties and must be considered an estimate. However the rough estimate provides a good overview of the technologies which can be exploited if the Climate Plan is implemented. It must also be emphasised that these potential earnings come on top of the earnings that are shown through the changed operation and structure in the energy system itself. The results are illustrated in Fig. 9.

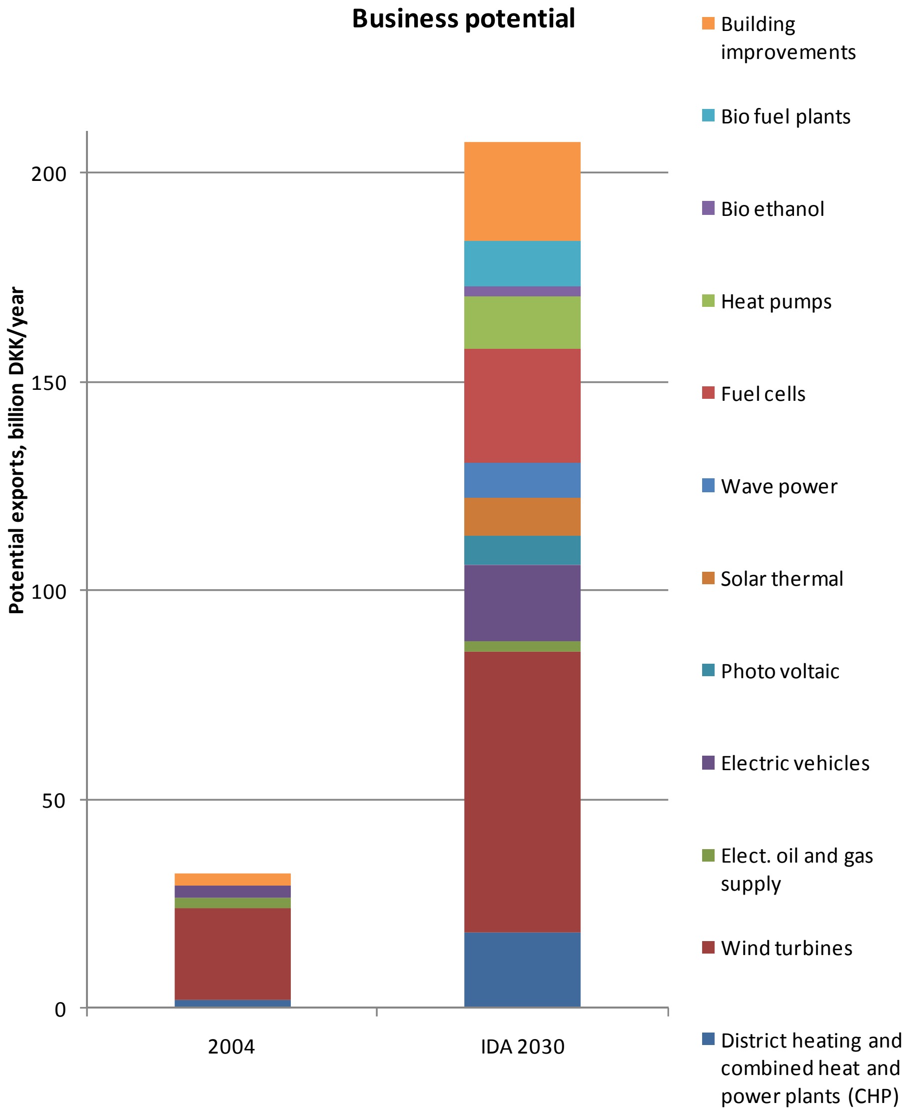


Fig. 9, Commercial potentials per year through implementation of IDA's Climate Plan 2050

2.6 Employment effects

The starting point for the estimation of the employment effect is the division in annual costs for the Climate Plan compared with that in the reference. To begin estimating the employment effects, the annual costs for both the Climate Plan and the reference were broken down into investments and operations. An implementation of the Climate Plan 2050 includes a change in the costs for fuel to expenditures for investments and hence, the Danish society will not be burdened with extra costs for energy. Such changes will include higher Danish employment while also improving the balance of payments. This effect is increased further if the above-mentioned commercial potentials in the form of increased exports are also realised.

In the Climate Plan, expenditures for fuels are reduced while expenditures for operations and maintenance are increased. In addition, an extra investment of just below 1 trillion DKK is made in the Climate Plan compared to the reference, which is spread out over the period going forward to 2050. For each cost type, an import share has been estimated based on experiences from previous collections of foreign exchange and employment data for investment in energy facilities. In relation to the previous data, a general upward adjustment of the import share has been done, as from experience these are increasing.

For the share that is left after removing the import share, two jobs are created for each million DKK. This includes derived jobs in the finance and service sector. It should be emphasised that these estimates are subject to uncertainties and again it is emphasised that they are based on adjusted numbers from previously collected data. The extra employment created in Denmark by the Climate Plan compared with the reference has been estimated with these methods and assumptions to be ***approximately 30-40,000 jobs***. Jobs will be lost in the handling of fossil fuels, but jobs will be created through investments in energy technology. In the long term, the employment will settle down as investments reduce and the transition to a 100 per cent renewable energy system is complete, so that there are about 15,000 extra jobs in the IDA Climate Plan compared to the reference for 2050. In practice this reduction will probably spread over a period of years.

It is important for a number of reasons to place the large employment effort as early as possible in the period. The first reason is that the labour force as a share of the total population is falling in the entire period going forward to about 2040 and therefore, the largest labour capacity to undertake a change of the energy system is in the beginning of the period. The second reason is that the Danish North Sea resources will run out during the next 20 years. Hence it is important to develop such energy systems and changes as early as possible in the period. Finally, the potential increase in the export of energy technologies which can replace the oil and natural gas exports will be reduced and could disappear entirely in the course of 10-20 years.

The above-mentioned effects on the employment do not include the job creation as a result of increased export of energy technology, i.e. the commercial potentials described above. These advantages will be an additional benefit of the Climate Plan. With an assumption of a 50 per cent import share, an annual export of 200 billion DKK will generate in the order of up to 200,000 jobs, depending on where the exports would have been without the Climate Plan, the extent of unemployment, and the potential for these people to be employed in other export trades. In relation to this, it should be noted that everything else being the same, a share of Danish labour will be made available as the oil and gas extraction in the North Sea comes to an end.