IDA's Energy Vision 2050

A Smart Energy System strategy for 100% renewable Denmark

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Update of "IDA's Energy Vision 2050" scenarios

Since the release of "IDA's Energy Vision 2050" in 2015 the used energy system analyses tool, EnergyPLAN, has been updated from version 12.4. Due to the updates of the tool, the original EnergyPLAN models made for "IDA's Energy Vision 2050" do not work in newer versions of EnergyPLAN. Due to this, and that the "IDA's Energy Vision 2050" scenarios are used for other currently ongoing research projects, and the newer versions of EnergyPLAN provide a more realistic hourly simulation of the energy system than the version of EnergyPLAN used in 2015, it was found relevant to update the "IDA's Energy Vision 2050" scenarios. As such, this note covers adjustments made to the DEA and IDA scenarios from "IDA's Energy Vision 2050".

The note is divided into; adjustments due to changes made to EnergyPLAN between version 12.4 and version 13.x, and other adjustments made to the EnergyPLAN models. Lastly, updated figures from the executive summary from the original "IDA's Energy Vision 2050" report.

As can be seen from the updated figures in the end of this document, the updated EnergyPLAN models do not affect the overall conclusions made in the original "IDA's Energy Vision 2050" from 2015.

1 Adjustments made due to changes in EnergyPLAN version 13.x

- As of EnergyPLAN version 13.0 electrolysers are categorised and operated differently than in earlier versions of EnergyPLAN , see [1] for more information. To make the models work in EnergyPLAN v13.x, the electrolyser capacities are combined into one category and the investment costs are adjusted accordingly. The total installed capacity of electrolysers is not changed, but the electrolysers operate more flexible.
- As of EnergyPLAN version 13.1 an option was added to change how EnergyPLAN operates compared with the external electricity market, see [1] for more details. This option has been used for the market open scenarios in the update, as it provides an operation of the energy system that more correctly reflects the interaction with the surrounding electricity markets.

2 Other adjustments made to the EnergyPLAN models

- The distribution for the cooling demand has been changed to instead use an hourly district cooling distribution from 2015.
- In the IDA scenarios, the electricity transmission capacity to surrounding countries has been changed to be the actual capacity in 2015 plus any new transmission capacity already decided to be build (Kriegers Flak of 0.4 GW and the COBRAcable of 0.7 GW).
- The capacity factor of wave power has been changed to from 0.05 to 0.4 in 2035 and from 0.05 to 0.51 in 2050.
- The investment, lifetime and fixed O&M has been clarified for certain technologies. The following table provides an overview of the numbers used in the updated versions of the models. Technologies not shown and data marked with "-" in the table remain unchanged compared with the original "IDA's Energy Vision 2050" report.

Technology	Investment [MEUR/unit]		Lifetime [Years]		Fixed O&M [% of inv.]	
	2035	2050	2035	2050	2035	2050
CHP2	1.2	1.2	-	-	3.75	-
CHP3	1.395	0.8	32	-	3.3	-
Heat storage CHP	-	-	20	-	-	-
PP1	1.395	0.9	32	27	3.3	3.26
Offshore wind power	-	-	-	-	2.94	-
Geothermal heat	250	250	25	25	2.45	2.45
Individual boilers	5.8	6.75	21	20	2.6	0.37
Individual heat pumps	11.5	11.5	20	-	0.98	0.98
Individual solar thermal	-	-	30	-	1.35	-

Table 1 – New investment, lifetime and fixed O&M used in the update of "IDA's Energy Vision 2050"

- To reflect the current investments in biomass CHP units in large district heating areas in Denmark, the IDA2035 scenario has been adjusted so that the central CHP units and power plants use 50% gas and 50% biomass. The efficiencies and costs (see Table 1) have been adjusted accordingly.
- The sensitivity analyses with low and high fuel price now use the fuel price levels shown in the original "IDA's Energy Vision 2050" report.
- In the IDA scenarios, the district heating boilers are for the most part used as backup boilers, as such, they have been changed to wood pellet boilers. The extra fuel cost for using wood pellets has been added in the EnergyPLAN models as an increased cost for variable OM.
- The capacity of the district heating storage has been changed to 112 GWh in both 2035 and 2050.
- A minor error in the calculation of upgraded biogas in the IDA scenarios was found. The correct amounts of upgraded biogas are 9.31 TWh in IDA2035 and 15.12 TWh in IDA2050.
- The distributions for onshore and offshore wind power have been changed from being based on actual production data in 2013 to instead be production of the share of wind power capacity installed in Denmark with production in 2013, using the stamdata register from the Danish Energy Agency [2] to estimate this capacity in each hour. The annual production for both onshore and offshore wind power is unchanged compared with the original DEA and IDA scenarios.

3 Comparison between original and adjusted scenarios

The figures shown below are updated versions of the figures from the Executive Summary of the original "IDA's Energy Vision 2050" report. Only figures that have changed due to the update are included. The figure numbers used below corresponds to the figure number for the corresponding figure in the IDA report. The most significant differences between the original figures from the original "IDA's Energy Vision 2050" report, and the new figures using the updated EnergyPLAN models are:

- In the updated IDA scenario for 2035 the gas consumption has increased by about 25 TWh/year, and the biomass consumption for the same scenario has decreased by about 30 TWh/year, resulting in a small decrease in primary energy supply of about 5 TWh. The lower consumption is especially due to a lower electricity production from power plants.
- In the updated IDA scenario for 2050 the CHP units are operating less, and instead the power plants are operating more, resulting in a minor increase in fuel consumption costs and O&M costs, which also results in a decrease in Electricity exchange costs. This also results in an increased biomass consumption for scenarios where there is an exchange of electricity with surrounding countries.
- In the updated DEA wind 2050 scenario the power plant is operating less, resulting in a small reduction in fuel consumption costs and O&M costs, this also results in an increase in Electricity exchange costs. Also, the DEA wind 2050 scenario has a biomass consumption that is about 5 TWh lower.
- The difference in total annual costs are larger between the three fuel cost scenarios for the 2035 scenarios and the DEA fossil 2050 scenario.
- Electricity consumption capacity for "Smart transport", as shown in Figure 13, are based on peak hourly electricity consumption in the simulation. Due to the changed hourly simulation in EnergyPLAN, electricity consumption capacity for "Smart transport" has changed in the updated scenarios, which is especially visible in the IDA 2050 scenario, where the electricity consumption capacity goes from about 4.6 GW to about 7.4 GW. Also, the shown electric boiler capacities are different in the new Figure 13, which is due to a correction of minor error in the original Figure 13.

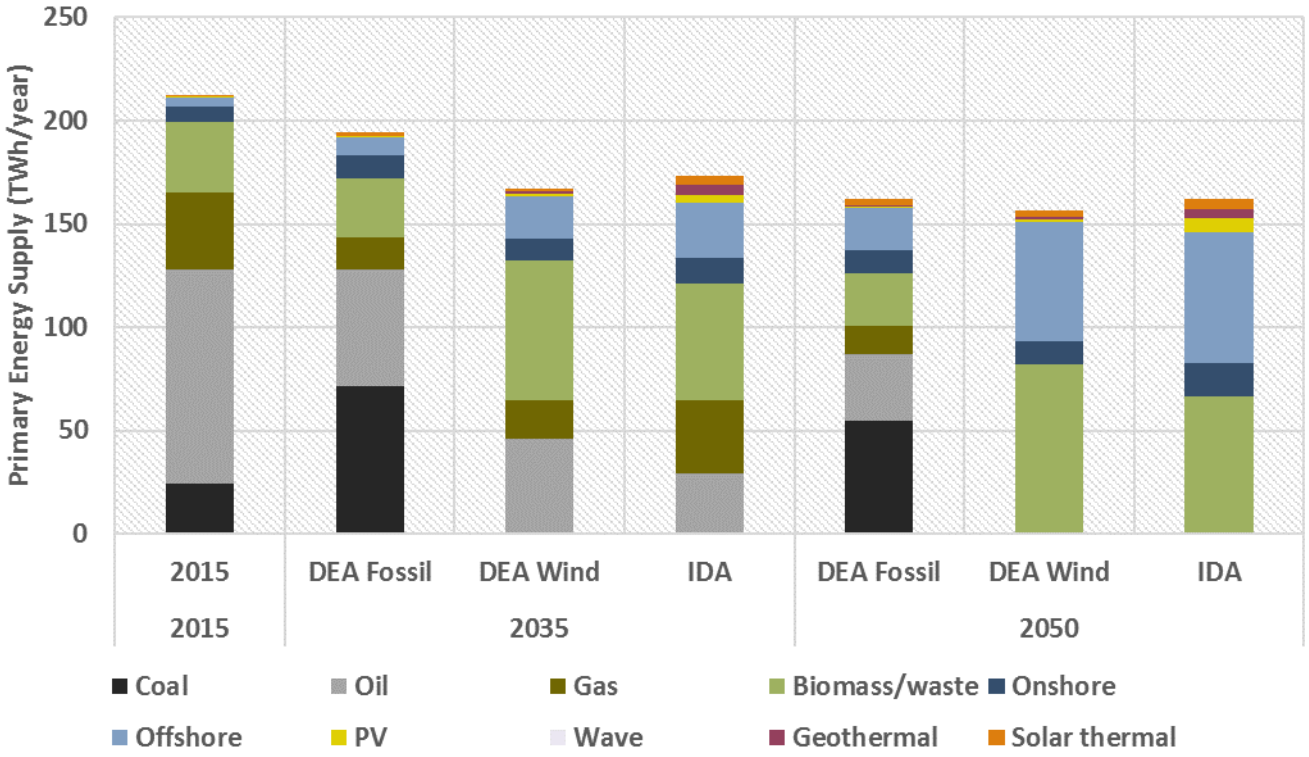

Figure 3: Primary Energy supply in 2035 and 2050 in the IDA Energy Vision, in 2015 and in the DEA scenarios

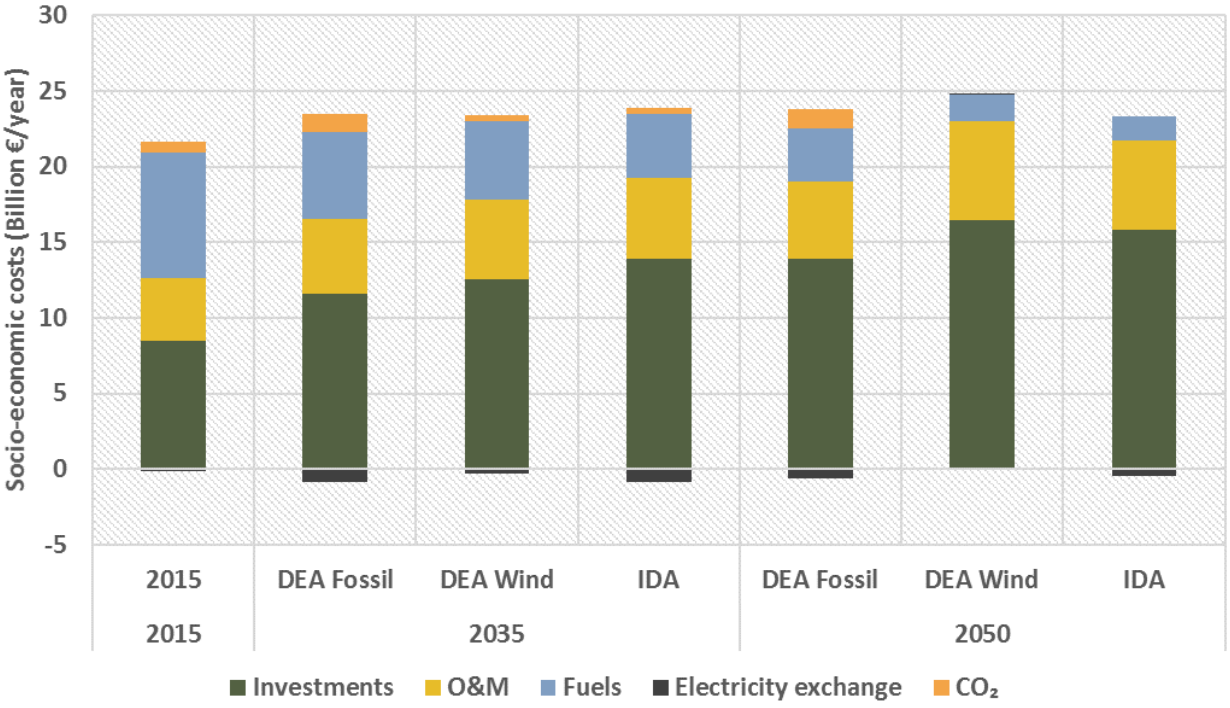

Figure 4: Socio-economic costs of the energy systems analysed including transport. Net earnings on international electricity markets are illustrated as a negative and should be subtracted to get the total costs of the systems

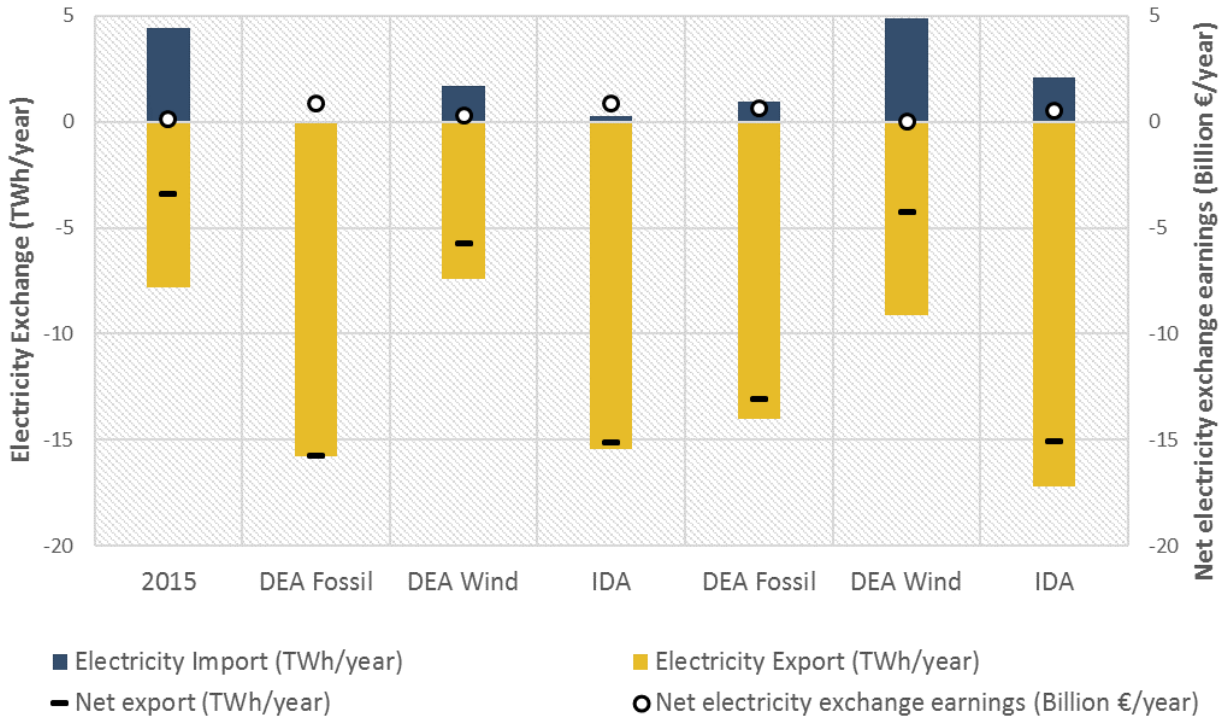

Figure 5: Electricity exchange and earnings on electricity import and export assuming three levels of fuel price assumptions for 2015 as well as the IDA and DEA scenarios

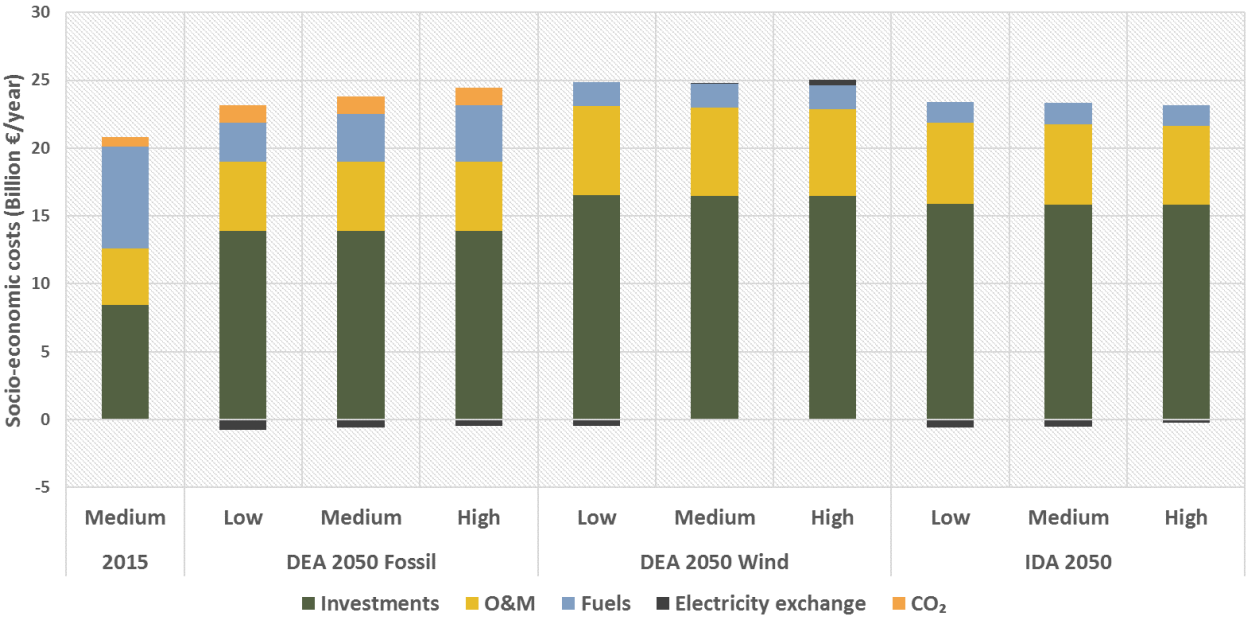

Figure 6: Socio-economic costs of the energy systems analysed including transport for the three different fuel price levels (oil prices equivalent to 62, 105 and 148 $/barrel and 77 €/MWh on the international electricity markets). Net earnings on international electricity markets are illustrated as a negative and should be subtracted to get the total costs of the systems

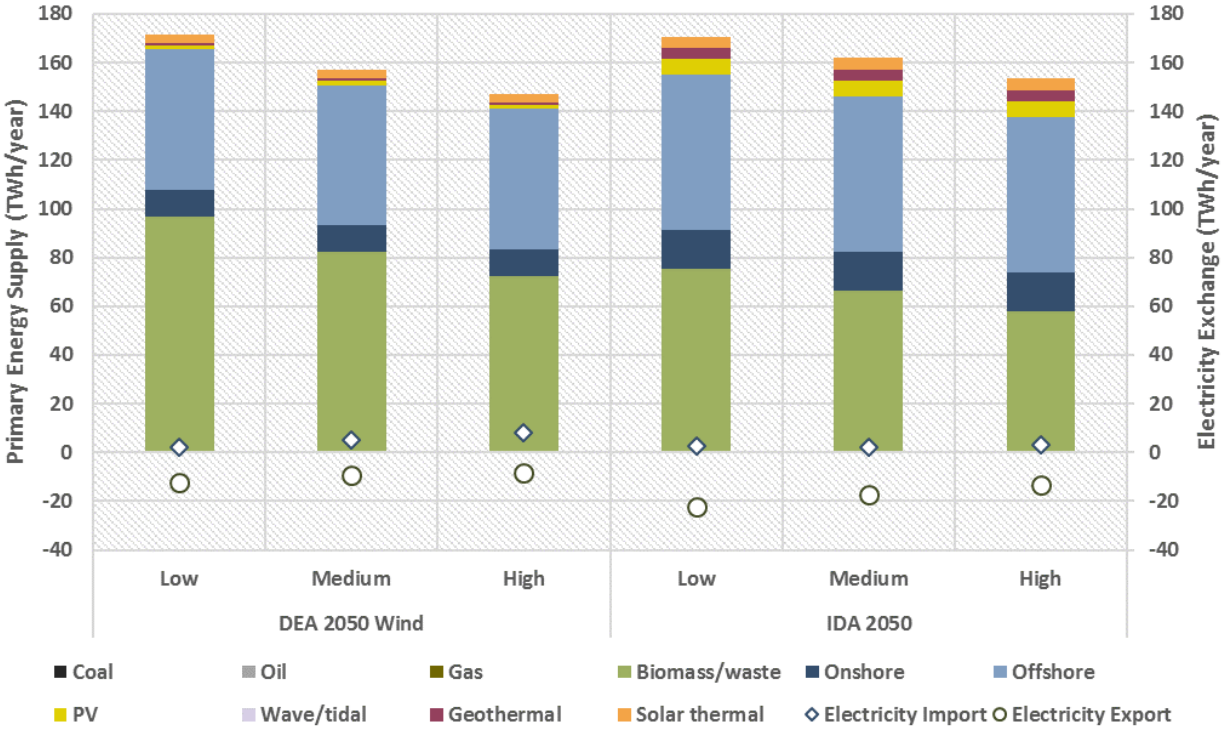

Figure 7: Resulting primary fuel production assuming three different fuel price levels (oil prices equivalent to low: 62, medium: 105 and high: 148 $/barrel and 77 €/MWh on the international electricity markets)

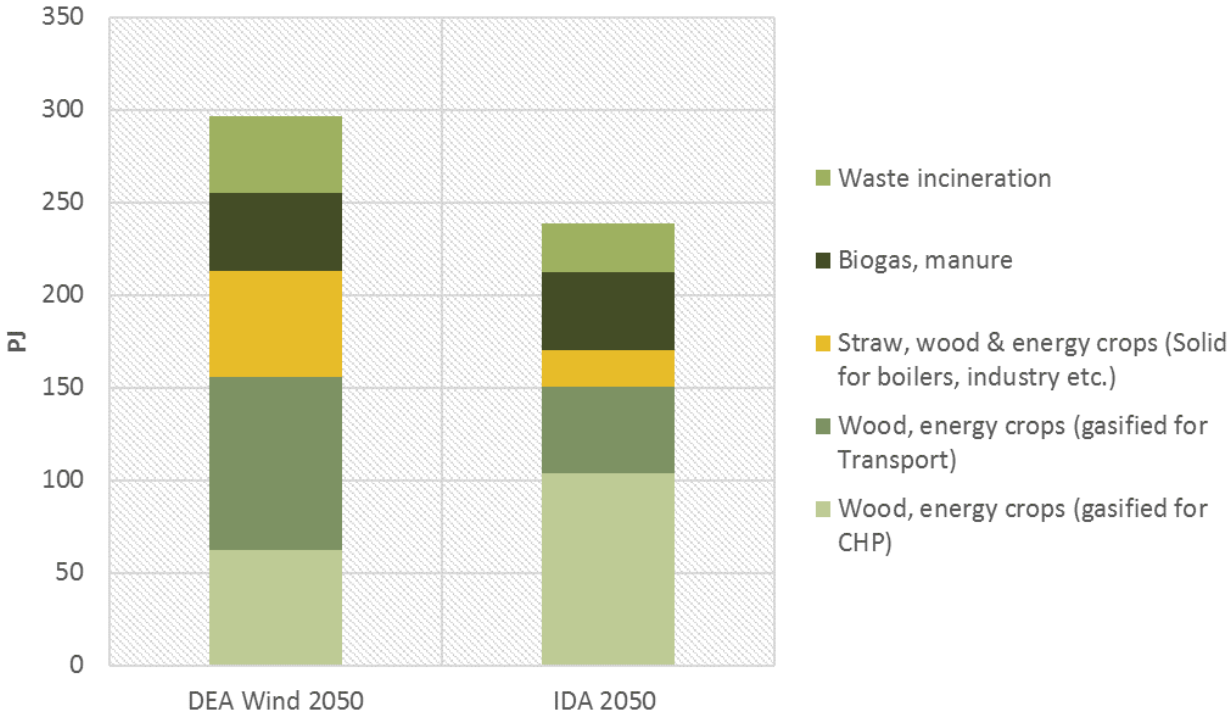

Figure 10: Biomass demands distributed on types in DEA Wind 2050 and IDA 2050

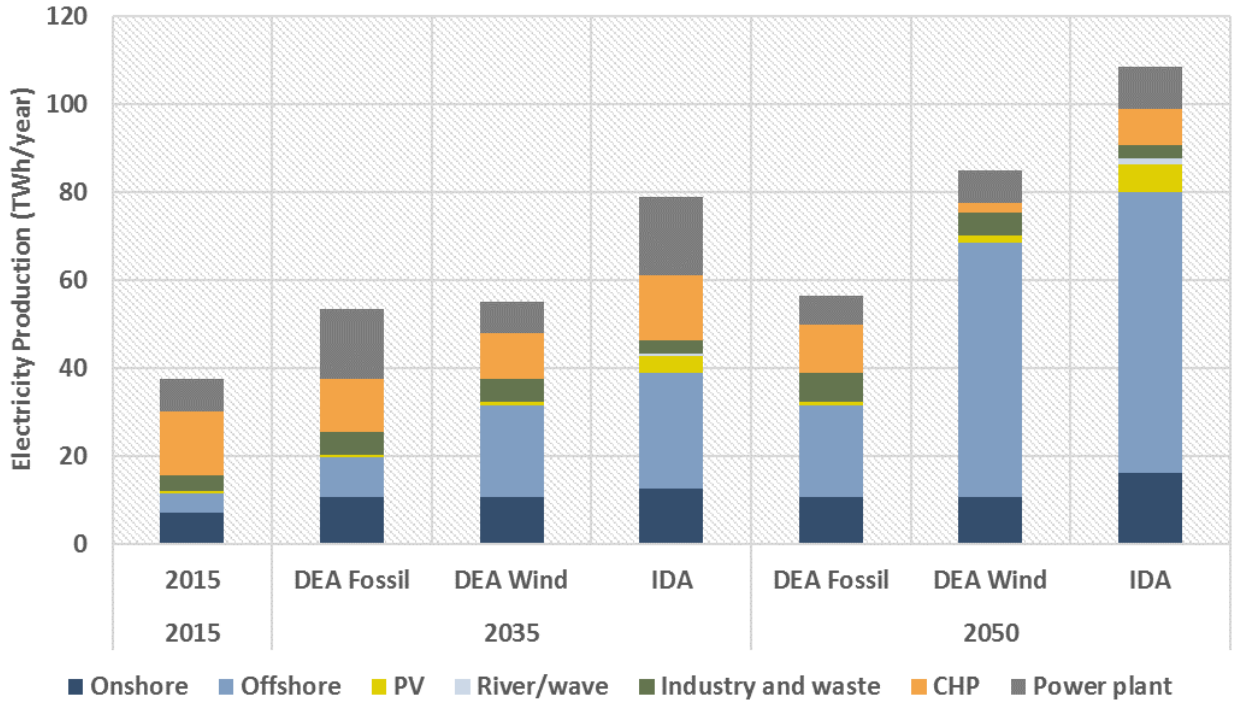

Figure 12: Electricity production for the 2015 reference, the 2035 and the 2050 DEA and IDA scenarios

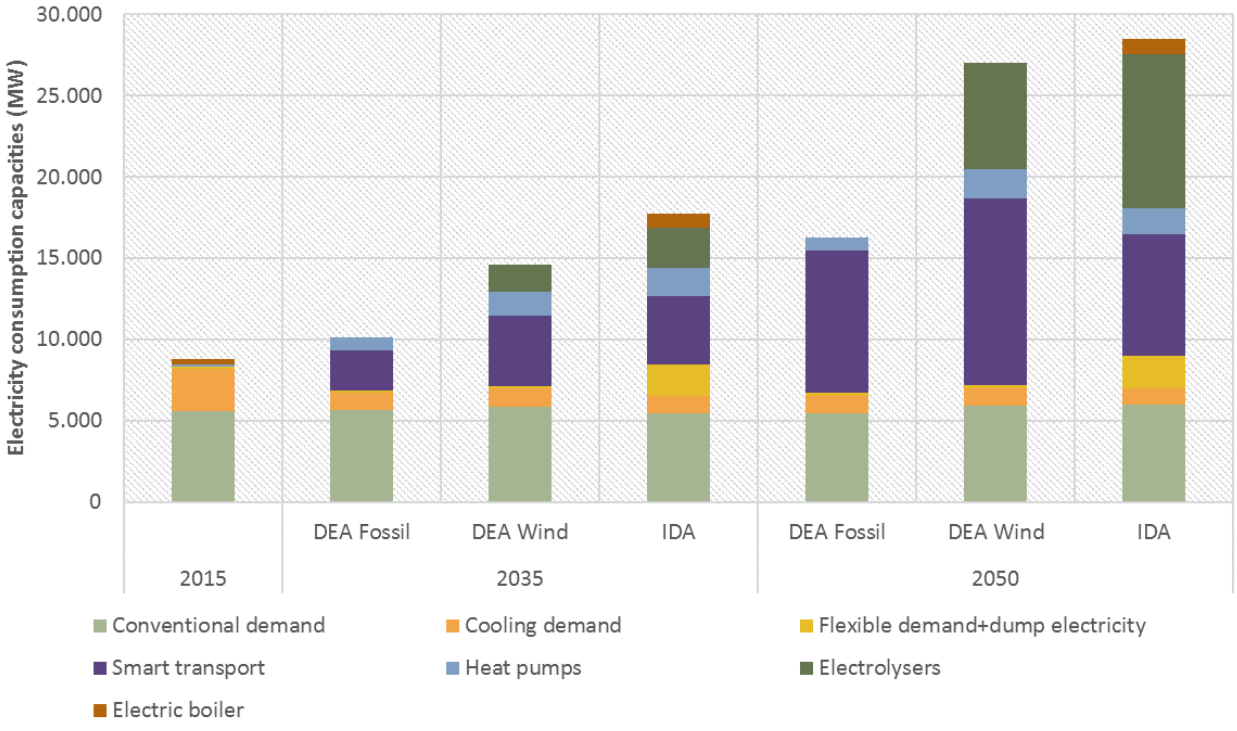

Figure 13: Electricity consumption capacities for the 2015 reference, the 2035 and the 2050 DEA and IDA scenarios

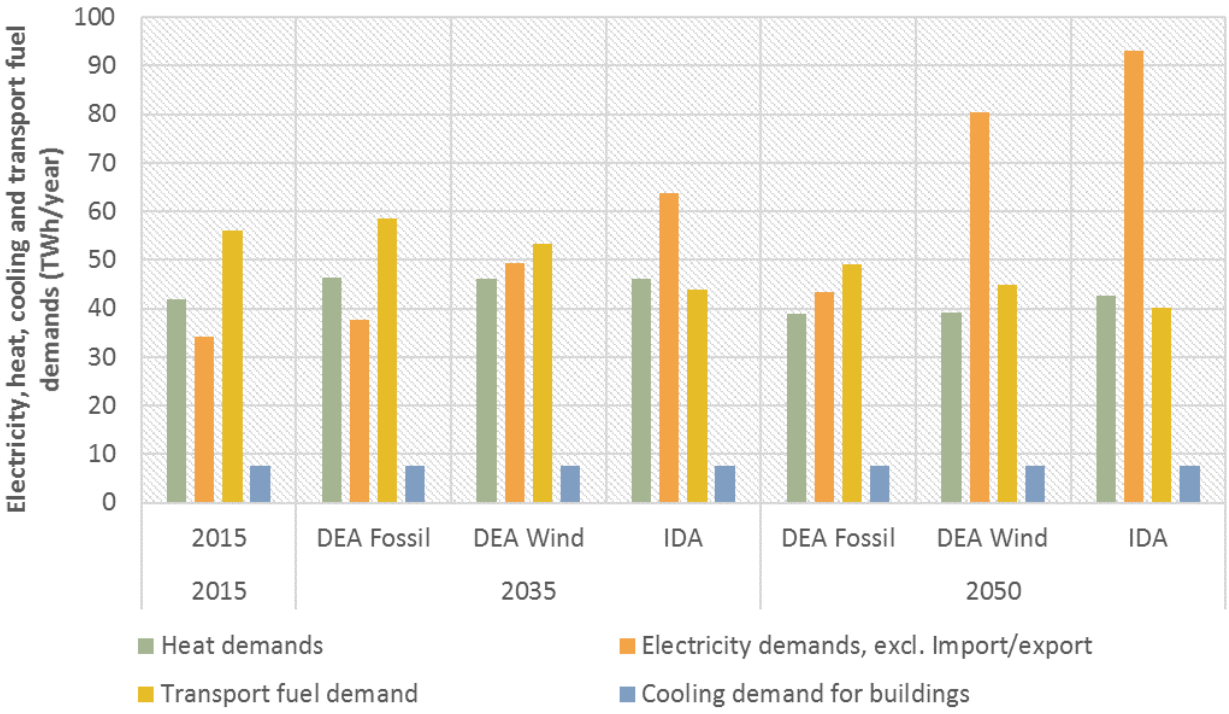

Figure 14: Energy system demands for heating, electricity, cooling and transport fuels, excluding losses in the conversion processes, transmission and distribution. Notice that some demands for e.g. heating using heat pumps might be counted twice as part of both the heating demand and the electricity demand

4 References

[1] H. Lund *et al.*, “EnergyPLAN - Advanced Energy Systems Analysis Computer Model - Documentation Version 13,” 2017.

[2] Danish Energy Agency, “Stamdataregister for vindkraftanlæg - September 2017 (Master data register of wind turbines),” 2017. [Online]. Available: https://ens.dk/service/statistik-data-noegletal-og-kort/data-oversigt-over-energisektoren.