Making Renewable Energy Useful

Without new measures a third of the Danish wind energy must be exported by 2025

Combined heat and power (CHP) and wind energy are essential elements of Danish energy policy. In both cases the electricity output depends on other factors than electricity demand. Therefore provision of sufficient and suitable electricity demand is decisive for the efficient utilization of both CHP and wind energy.

Adding wind power to the Danish power systems has caused Denmark to be a net exporter of electricity. This solution may be unsatisfactory in the future when the share of wind energy is supposed to grow from 20% to 50% of the Danish electricity consumption.

This paper presents calculations of the impact of some possible integration measures.

The calculation is based on hourly time series for wind power output and electricity demand for West Denmark in 2008. A synthetic model generates a time series for the demand for district heating. The available data and algorithms do not allow very detailed simulations (like SIVAEL from Energinet.dk), but the tool provides fair magnitudes for an overview of the interaction between integration measures.

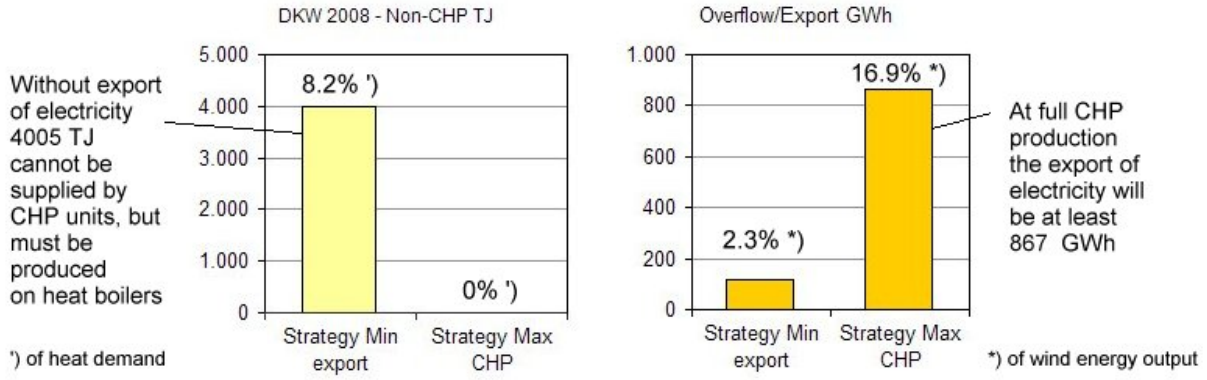
25% wind energy in West Denmark 2008

Key figures for electricity supply in West Denmark in 2008:

	Demand	Net exchange		Wind generation	
	MWh	Export MWh	Import Mwh	MWh	% of demand
DK West	20,550,012	3,171,098	982,890	5,123,249	24.9

The demand for heat is assumed to be 33,000 TJ from central power plants and 16,000 TJ from local power CHP units. A calculation without wind power shows that practically all electricity output from the CHP plants could have been absorbed by the demand for electricity in West Denmark.

The model does not include the international power markets. Instead two strategies have been used. One calculation is minimizing export while a second calculation maximizes electricity output from CHP plants assuming the sufficient foreign demand is available.



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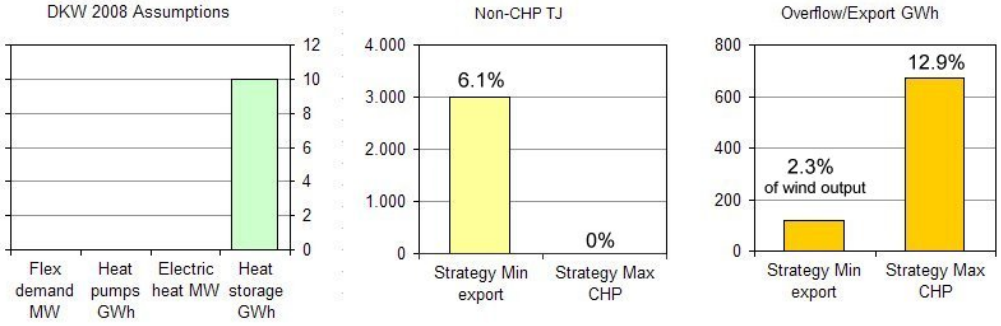
By *minimizing electricity export* only 119 GWh (**2.3%** of wind energy output) must be exported, but 4,005 TJ (**8.2%** of heat demand) cannot be supplied by the CHP units.

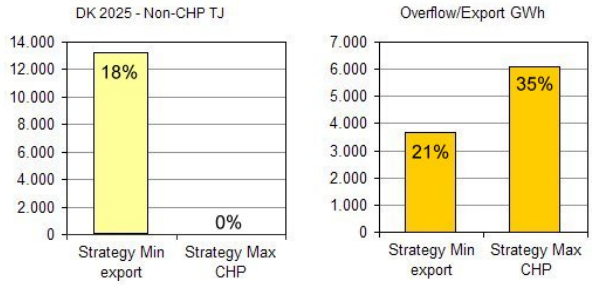
By *maximizing CHP output* 867 GWh (**16.9%** of wind energy output) must be exported. The marginal cost of electricity from a CHP unit is quite low for the combined generation mode. Therefore export of electricity is the normal choice. However, it should be kept in mind that without wind power there would not have been the supply of cheap electricity for export.

Most CHP plants have hot water storages. Some improvement is possible by optimal operation of the storages. The total capacity of the storages is unknown. 10 GWh (= 36 TJ) has been assumed for the calculation:



Minimum export strategy: Necessary export of wind energy: **2.3%.** Heat demand to be served by other sources than CHP: **6.1%**.
Maximum CHP strategy: **12.9%** of the wind energy must be exported.

50% wind energy in Denmark 2025
34,400 GWh traditional electricity demand for Denmark has been assumed in the calculations for 2025. The wind energy generation is supposed to be 17,200 GWh (50% of demand) and the total demand for heat 74,000 TJ. Based on the 2008 time series the calculations give following choices:

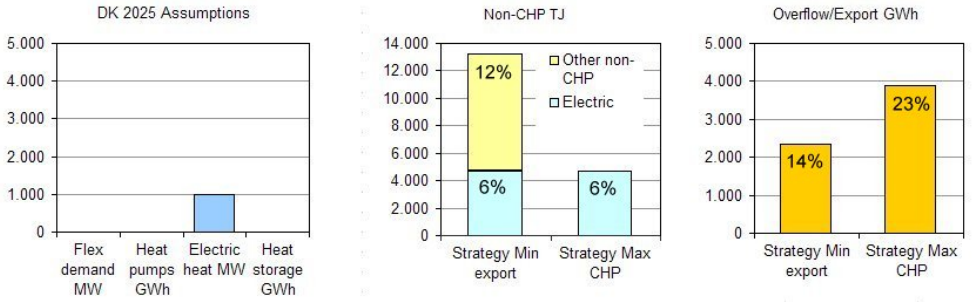


The result of the minimum export strategy will be export of **21%** of the wind energy and **18%** of the heat demand unsupplied by CHP. By maximizing the use of CHP **35%** of the wind energy output must be exported. *This is the starting point* for the subsequent experiments with different integration measures.

By use of the hot water storages the minimum export strategy will still result in export of **21%** of the wind energy, while heat demand unsupplied by CHP is reduced to **14%**. Maximized use of CHP causes **33%** export of the wind energy generation.

Thus the hot water storages have limited impact without being supported by other measures.

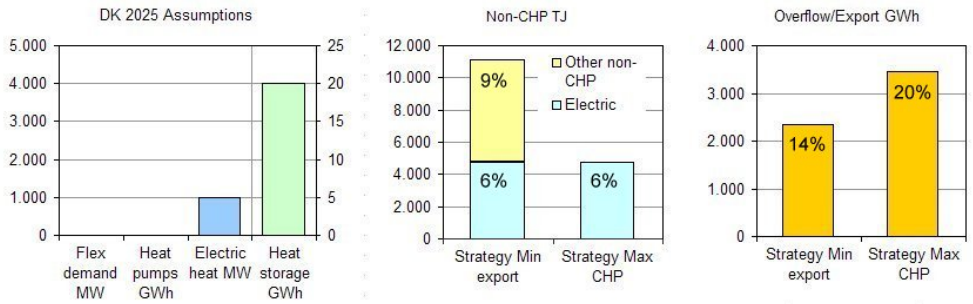
Using electric heating of water for the district heating systems brings the following results:



1,302 GWh (= 4,686 TJ) have been used for electric heating. It is an important condition for the validity of the result that all electric water heating can be justified by current market prices.

Minimum export strategy: Export of wind energy is reduced to **14%**, while **12%** of the heat demand must be served by other sources than CHP and electricity.
Maximum CHP strategy: **23%** of the wind energy must be exported.

As the next step electric heating is combined with use of the hot water storages:

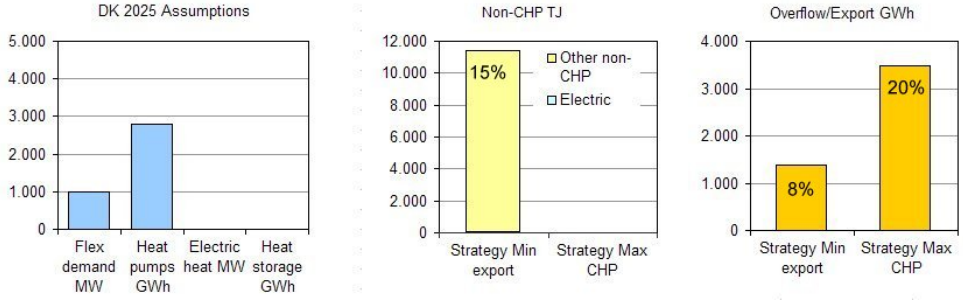


The same amount of electricity as in the previous case is used for electric heating, but the combination causes some further improvement:

Minimum export strategy: Export of wind energy is still **14%**, while **9%** of the heat demand must be served by other sources than CHP and electricity.

Maximum CHP strategy: **20 %** of the wind energy must be exported.

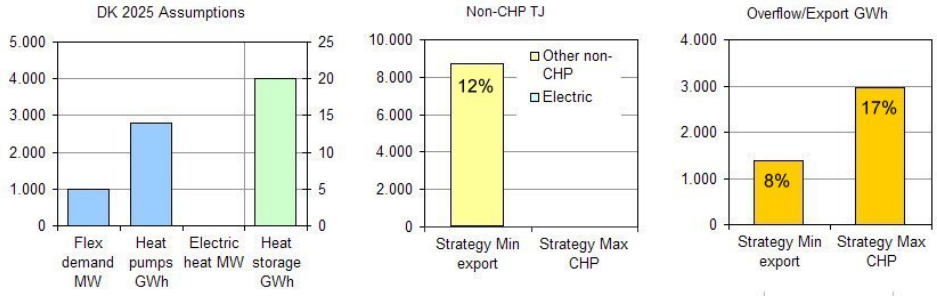
The effect of other untraditional types of electricity demand has been tested:



Heat pumps are served unconditionally and flexible demand occasionally, when there is surplus energy available. The flexible demand has consumed 1,474 GWh.

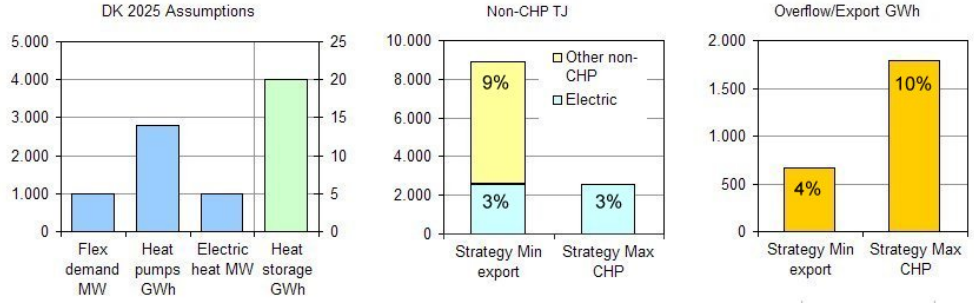
Minimum export strategy: Export of wind energy is **8 %**, while **15 %** of the heat demand must be served by other sources than CHP.
Maximum CHP strategy: **20 %** of the wind energy must be exported.

By combining the previous case with use of hot water storages the following results have been found:



Flexible demand: 1,474 GWh.
Minimum export strategy: Export of wind energy is **8 %**. Other sources than CHP must serve **12 %** of the heat demand.
Maximum CHP strategy: **17 %** of the wind energy output must be exported.

Finally we show the result of using a combination of all four measures:



The flexible demand has consumed 1,474 GWh and 700 GWh (= 2,564 TJ) have been used for electric heating.

Minimum export strategy: Export of wind energy is **4%**. Other sources than CHP must serve **9%** of the heat demand.
Maximum CHP strategy: **10%** of the wind energy output must be exported.

Overview 2025
The model used for this investigation does not consider economic consequences. Therefore no attempt was made to find an optimal combination of the measures.

	Strategy	Minimum export			Maximum CHP		
		Minimum electricity export	Electric heat for distr. heat	Other heat sources	Minimum electricity export	Electric heat for distr. heat	Other heat sources
	Case	% of wind	% of heat	% of heat	% of wind	% of heat	% of heat
A	Base	21	-	18	35	-	0
B	Storage	21	-	14	33	-	0
C	Electric heat	14	6	12	23	6	0
D	B + C	14	6	9	20	6	0
E	Flex demand + H-pumps	8	-	15	20	-	0
F	B + E	8	-	12	17	-	0
G	B + C + E	4	3	9	10	3	0

Without any new measures an increased share of wind energy to 50% will imply a considerable dependency on electricity export and may have consequences for the utilization of CHP. Between a fifth and a third of the annual wind energy output must be exported and up to 18% of the demand for district heating from CHP systems must find other heat sources.

The results demonstrate that better utilization of CHP and reduced dependency on electricity export is possible by a combination of the measures.

New types of electricity demand being related to the demand for heating such as heat pumps are particularly efficient. A complete flexible demand is also efficient, but heat pumps will probably represent a better use of the electricity.