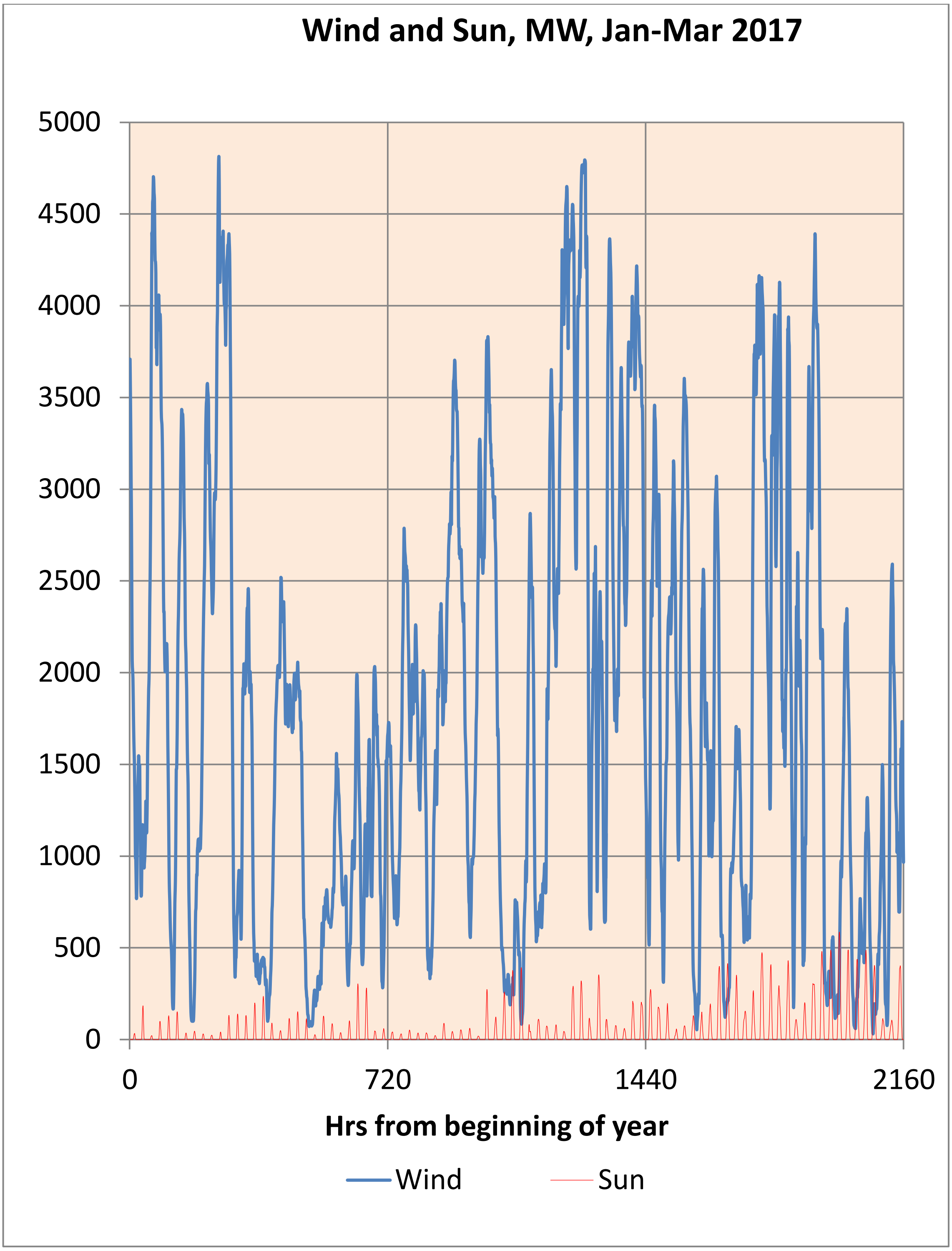
Danish Wind and Sun Energy 2017



Contents

Conclusion

The author worked as production manager in an energy intensive chemical plant when Denmark as the first country in the World introduced a carbon dioxide tax in January 1992. He was then asked to be responsible for handling the problems this tax would give.

The one overwhelming problem was, that after a couple of years it became evident, that the production could not be kept in Denmark because of the steadily increasing energy taxes.

Therefore the production was transferred to Asia where the energy consumption per produced ton surely was higher than in Denmark. Thus the carbon dioxide tax was counterproductive and a lie.

In 1977 a large mob yelled before the Parliament, Christiansborg, in Copenhagen

What shall in
Sun and Wind
What shall väk (away)
Barsebäck.

(*A Swedish nuclear power plant 30 kms from Copenhagen.*)

In 2008 the prime minister Anders Fogh Rasmussen promised us a "Fossil free Denmark in 2050."

This nonsense is now generally adopted as Denmark's energy policy. So you may wonder why the politicians and the rest of the talking establishment are so fond of the term of abuse, ***populism,*** when talking about persons who do not agree with them.

In the first section of this report it is shown how small a part of our energy consumption is supplied by the wind power, about 7%.

Thereafter follow some data of the World's population growth and energy consumption, showing which small role "sustainable energy" plays.

In the section **"Wind + Sun Power relative to load"** it is shown that wind and sun power impossibly can deliver the electricity we need. We must have back up. Full back up, at an undisclosed but high cost. So possibly you can produce wind power at a very low cost under some circumstances but you have to pay for the back up costs too.

In the section "**Useful Wind and Sun Power**" it is shown that some of the produced electricity must be exported, so when it is claimed that the wind power delivered about 44% of our electricity in 2017 it is simply not true. After correction for export the figure falls to about 38%.

The next sections show how dependent we are of exchange of electricity with our Scandinavian neighbours, and how small the exchange is with Germany.

Germany produces a lot of wind power too, mainly at the same time as Denmark, so there is little basis for mutual support.

In the section **“Wind and Sun Power variation per Week”** it is shown that there is a high degree of simultaneousness for wind power in Germany, France and England. So even strong European grids can’t smoothen out the variations in the wind energy.

“Storage of Wind Energy” deals with this impossible idea, and shows that not even Elon Musk has a useful concept. However, batteries may play an important role in regulating short time variations.

The idea of building a **North Sea Cable** between Denmark and England, seems to be a very bad idea. But it may be useful for those investing in new off shore parks to produce electricity without having a market for it.

It has been shown that we are very dependent on exchange with Norway and Sweden. If Sweden chooses to **phase out nuclear power** and replace it by wind power the Swedish demand for regulatory power from hydro power will increase dramatically probably leaving no resources to smoothen out the uncontrollably varying Danish wind power and thus be a catastrophe for Denmark

Prime minister Anders Fogh Rasmussen in 2008:

We shall create a Fossil free Denmark.

Foreword

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is retired since more than 10 years and has neither any obligations to anybody nor any economic interests in energy production or distribution, so the views expressed in this report are fully his own.

Sources
The main source for this report giving data every hour for production, consumption (load) import, export and many others was

http://osp.energinet.dk/_layouts/Markedsdata/framework/integrations/markedsdatatemplate.aspx

Numbers.
Decimal division is indicated by a , and not a . The . (point) is used to separate large numbers thus making them more readable. Example: 1 million is written as **1.000.000** and a quarter as **0,25.**

Units.
Generally there exists a severe confusion about **Energy** and **Effect.**

Energy is measured in J(oule) and **Effect in joule per a unit of time.** If the time is a second the unit is named **W(att)** which is defined as **joule/second.**

Most statistics indicate a country's energy consumption as **PJ/year, (10^15 Joule), or TJ/year. 1 PJ** roughly corresponds to **25.000 tons of oil** and a **TJ** to **25 mio tons oil.**

PJ is an **Energy unit**. **PJ/Year** is **energy/time** i.e. an **Effect unit,** like **Watt.** So you can divide **PJ/year** with the **number of seconds per year** (31.536.000 in a normal year and 31.622.400 in a leap year) to obtain the Consumption in **Watt.**
The author prefers to use this unit where possible, because electric effect and capacity always is expressed in watt.

(The wind power industry generally prefers to express the production in MWh or GWh per year, to hide the discrepancy between nominal capacity and production.)

Prefixes

Kilo	**k**	**1000**	**10^3**
Mega	**M**	**1.000.000**	**10^6**
Giga	**G**	**1.000.000.000**	**10^9**
Tera	**T**	**1.000.000.000.000**	**10^12**
Peta	**P**	**1.000.000.000.000.000**	**10^15**
Exa	**E**	**1.000.000.000.000.000.000**	**10^18**

Main data Denmark 2016

Average Effect Consumption	25,2	GW

It is not normal to express a country's energy consumption in WATT, i.e. ***Joule Per Second*** .
The Danish energy consumption in 2016 was 797 PJ. 797 PJ/year expresses an energy consumption in a certain time and thus the real ***dimension*** *is* ***EFFECT.***
So we can transfer ***joule/year*** *to* ***watt by dividing*** *by the number of seconds in 2016, i.e. 31.622.400 and we get the figure 25,2 GW.*

Then it becomes easy to compare with the generation of electricity.

The Danish electricity consumption is about 4 GW, and the wind power yielded on average about 1,5 GW. ***About 6%*** *of the total energy or effect consumption*

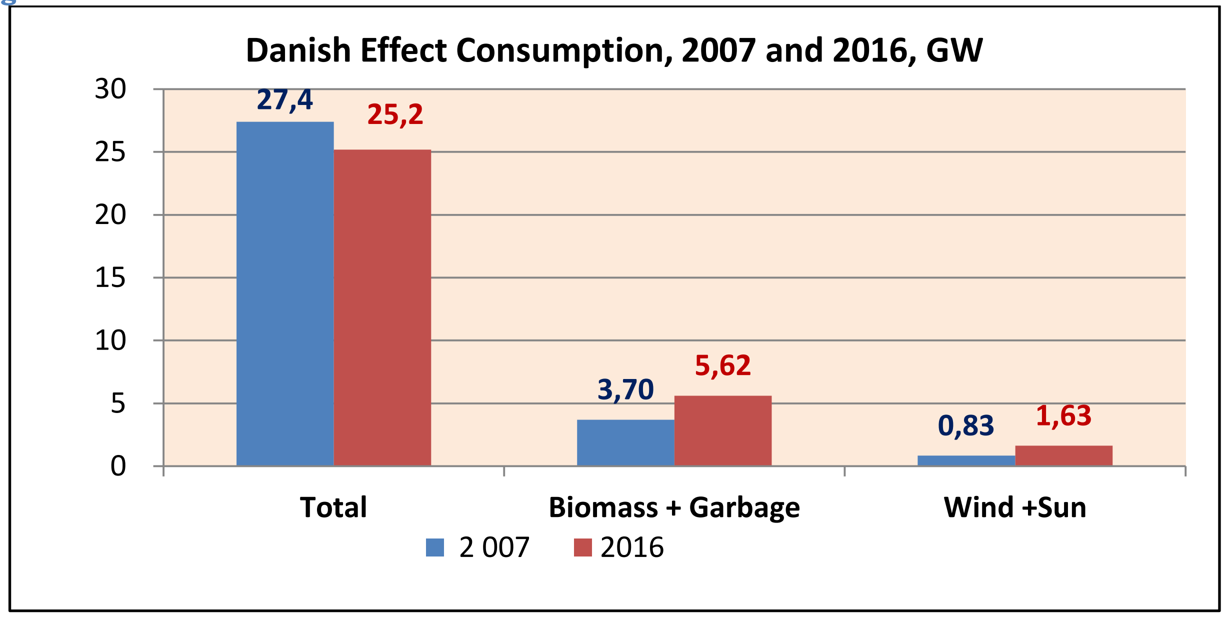
The total Danish effect consumption corresponds to ca. 630 kg oil/second i.e. ca. 20 Mio tons of oil per year

Wind Power average	1.5	GW
Wind Power minus export average	1.2	GW
Electricity load average	3.9	GW
Wind Power Capacity end of year	4,9	GW
Wind Power % of total effect consumption	6	%
Wind Power % of electric load	38	%
After Correction for export		
Wind Power % of total effect consumption	4,9	%
Wind Power % of electric load	32	%
Wind Power relative to installed generation capacity	30	%

Sources[i]

So there is a long way, a very long way to the "fossil free society."

Figure 1



The energy or effect consumption fell, the wind power was doubled but imported biomass and imported garbage, e.g. from London, increased much more. We are even paid for burning outlandish garbage. Some politicians talk about a "garbage free" society, so burning of foreign garbage will hardly be considered "sustainable".

Figure 2

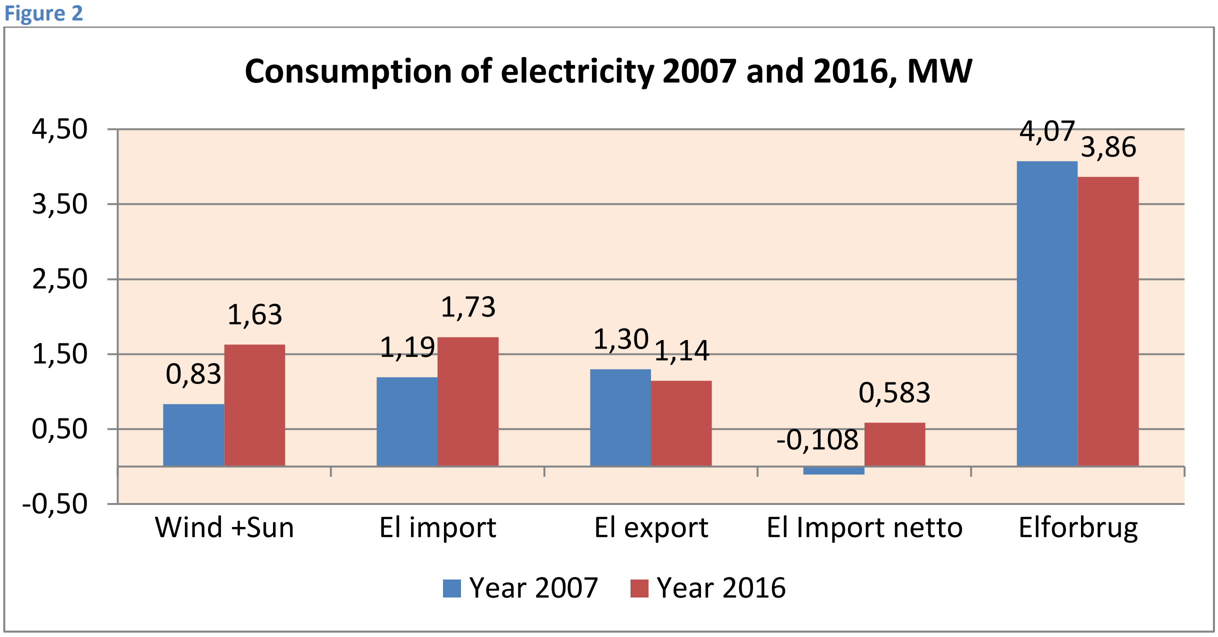


Figure 2 shows that wind and sun power was nearly doubled in the years from 2007 to 2016, but it shows too that the import of electricity increased and that the consumption fell. (*Elforbrug means Electricity consumption)*

Burning of fossil or non fossil fuels will always imply some pollution. Wind and sun power are not polluting – in principle - so if you are obsessed with cleanliness, you must get your energy from wind, sun and hydro power. This energy only exists in the form of electricity.

Luckily the Wind Power lobby informs us, that wind power is clean, cheap and plentiful. Therefore you may wonder why the consumption of electricity is declining. It ought to be increasing. If not we will never ever obtain a "fossil free society."

World, Energy Consumption and Population 1990-2016

Sources[ii, iii]

Conclusions:

It is not true that the increase in the World population is slowing down. On the contrary the yearly increase in the last 26 years has varied between 89 and 77 million with a standard deviation of 3,0 million/year and no difference between start and end of the period.

The increase in effect consumption varies between 755 GW and -199 GW per year with a mean value of on average **197 GW** per year. Ca. 4 times the Swedish effect consumption and about 8 times the Danish effect consumption, Total consumption, not just consumption of electricity.

For Comparison the **production** of energy or more correctly expressed **effect** from (**wind + sun + geothermal + biomass + other**) was **160** GW, **185** GW and **212** GW in 2014, 2015 and 2016, which should be compared with an average increase in the consumption of **262** GW/year in the period 1990-2016.

The population growth is on average 82 million per year, and the **effect** consumption is on average 2,16 kW per capita. That alone gives an increase in the effect consumption of **177** GW/year.

Increasing standards of living necessarily increases the effect consumption per capita.

Remembering that the World effect consumption is about **17.000** GW, it becomes very very difficult to see how the use of fossil fuels should decline.

Table 1

Variation in increase of consumption of Effect and Population, 1990-2016					
		Average	**Max**	**Min**	**Stddev**
Increase Effect Consumption	GW/Year	262	755	-199	197
Population Growth	Million	82	89	77	3,0
Effect per Capita	kW	2,16	2,38	1,98	0,16

Table 2 below shows the World's energy consumption in the units:
Mtoe, (million ton oil equivalent),
EJ (Exajoule = 10^18 Joule),
TWh (Tera watt hours). For comparison the Danish electricity consumption is around 33 TWh/year, and the Swedish hydro power magazines contain when full a hydro energy corresponding to 33-34 TWh.
GW (Giga Watt = 10^9 joule/second). The Swedish Nuclear power plants yield about 9 GW in the winter months, and the total Swedish electricity consumption is on average about 17 GW. The total Danish energy consumption or more correct effect consumption is about 24 GW. The average electric load (consumption) is a little less than 4 GW.

Table 2

World Energy Consumption 2014-2016 according to BP Statistics											
Year		**Oil**	**Natural Gas**	**Coal**	**Biofuel**	**Nu-clear**	**Hydro**	**Solar**	**Wind**	**Geo-thermal, Biomass Other**	**Sum**
2014	**Mtoe**	4.252	3.082	3.911	80	219	334	17	61	43	11.997
	EJ	178	129	164	3	9	13,99	0,71	2,55	1,79	502
	TWh	49.446	35.838	45.487	927	2.541	3.886	196	709	497	139.528
	GW	5640	4088	5189	106	290	443,28	22,4	80,9	56,6	15.916
	% of total	35,44	25,69	32,60	0,66	1,82	2,79	0,14	0,51	0,36	100
	Capacity	**GW**						**177**	**353**		
	Yield	**% of Capacity**						**12,6**	**22,9**		
2015	**Mtoe**	3204	3135	3840	80	221	336	22	71	46	12.083
	EJ	181	131	161	246	9	14,05	0,92	2,98	1,93	748
	TWh	50.373	36.462	44.658	68.224	2.575	3.903	256	828	536	207.816
	GW	5746	4159	5094	106	294	445	29,2	94,5	61,2	16.029
	% of total	35,85	25,95	31,78	0,66	1,83	2,78	0,18	0,59	0,38	100
	Capacity	**GW**						**226**	**419**		
	Yield	**% of Capacity**						**12,9**	**22,6**		
2016	**Mtoe**	4418	3204	3732	80	225	346	29	83	48	12.164
	EJ	185	134	156	3	9	14,48	1,20	3,45	2,02	509
	TWh	51.384	37.264	43.403	927	2.617	4.023	333	960	562	141.472
	GW	5861	4251	4951	106	727	458,89	38,0	109,5	64,1	16.566
	% of total	36,32	26,34	30,68	0,66	1,85	2,84	0,24	0,68	0,40	100
	Capacity	**GW**						**301**	**69**		
	Yield	**% of Capacity**						**12,6**	**23,3**		

The watchful reader might say, that the units used are incomparable since GW is an effect unit i.e. energy/time (Joules per second) whereas the other units are energy units. But actually Mtoe, EJ, TWh as shown in the table are effect units too because they mean **consumption/year**.

Table 3

Oil, Gas and Coal % of Consumption				
Year	Oil	Natural Gas	Coal	Sum
2014	35	26	33	93,7
2015	36	26	32	93,6
2016	36,3	26,3	30,7	93,3

Figure 3

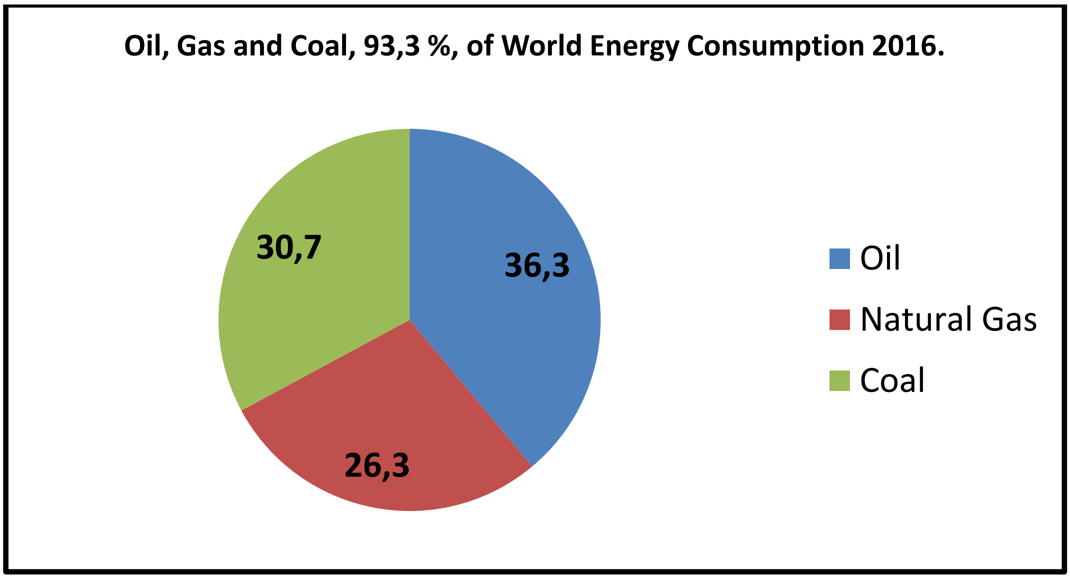


Table 4

Renewables plus Nuclear % of consumption							
Year	**Nuclear**	**Hydro**	**Biofuel**	**Solar**	**Wind**	**Geothermal, Biomass Other**	**Sum**
2014	1,82	2,79	0,66	0,14	0,51	0,36	6,28
2015	1,83	2,78	0,66	0,18	0,59	0,38	6,42
2016	1,85	2,84	0,66	0,24	0,68	0,40	6,66

Figure 4

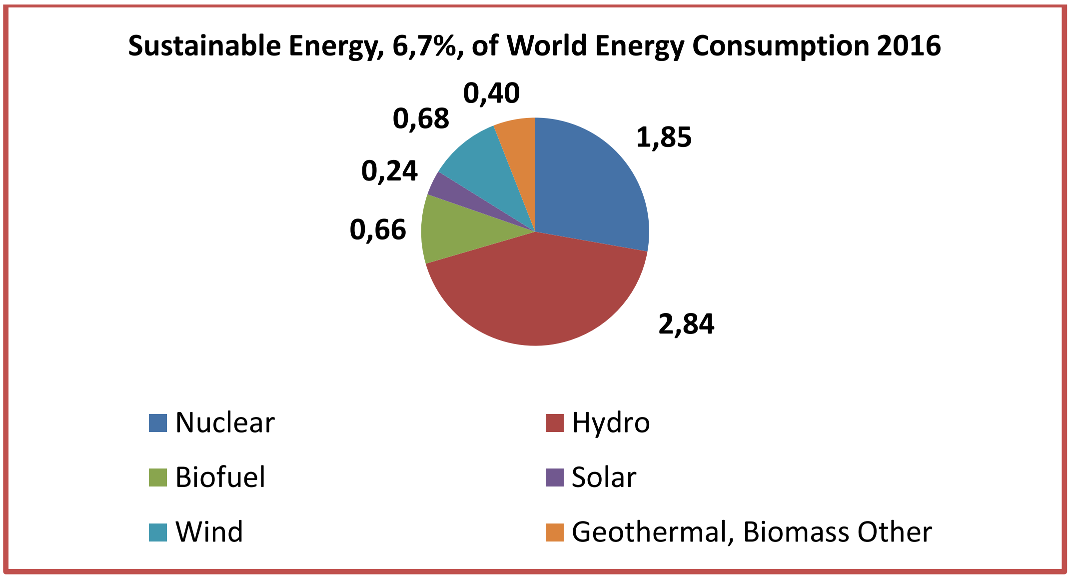
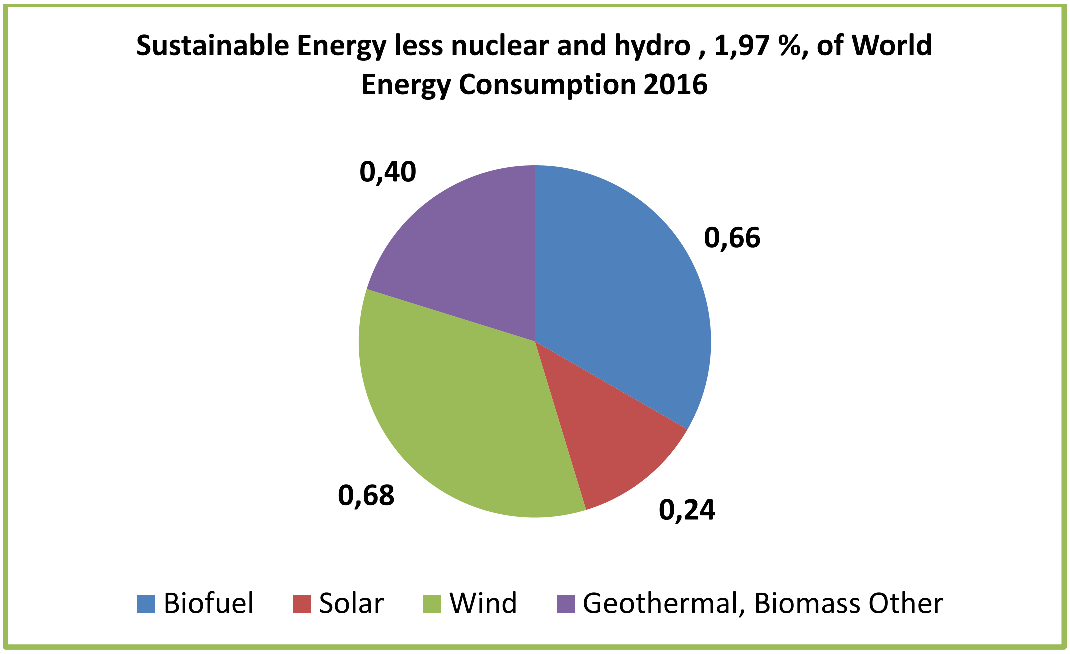


Table 5

"Green Energy" % of Consumption					
Year	Biofuel	Solar	Wind	Geothermal, Biomass Other	Sum
2014	0,66	0,14	0,51	0,36	**1,67**
2015	0,66	0,18	0,59	0,38	**1,81**
2016	0,66	0,24	0,68	0,40	**1,97**

Figure 5



Tabel 6

World Population and Energy Consumption										
	Year	1990	1995	2000	2005	2010	2013	2014	2015	2016
Effect World	TW	10,8	11,4	12,4	14,5	16,2	17,1	17,2	17,4	17,6
Sun, Wind, Bio, Geothermal	TW	0,01	0,02	0,02	0,04	0,09	0,14	0,16	0,19	0,21
Population	Mio	5310	5735	6127	6520	6930	7182	7266	7349	7433
Population Growth	Mio/year	89	80	78	81	84	84	84	84	84
Effect per Capita	kW	2,04	1,99	2,03	2,23	2,33	2,38	2,37	2,37	2,36

Figure 6

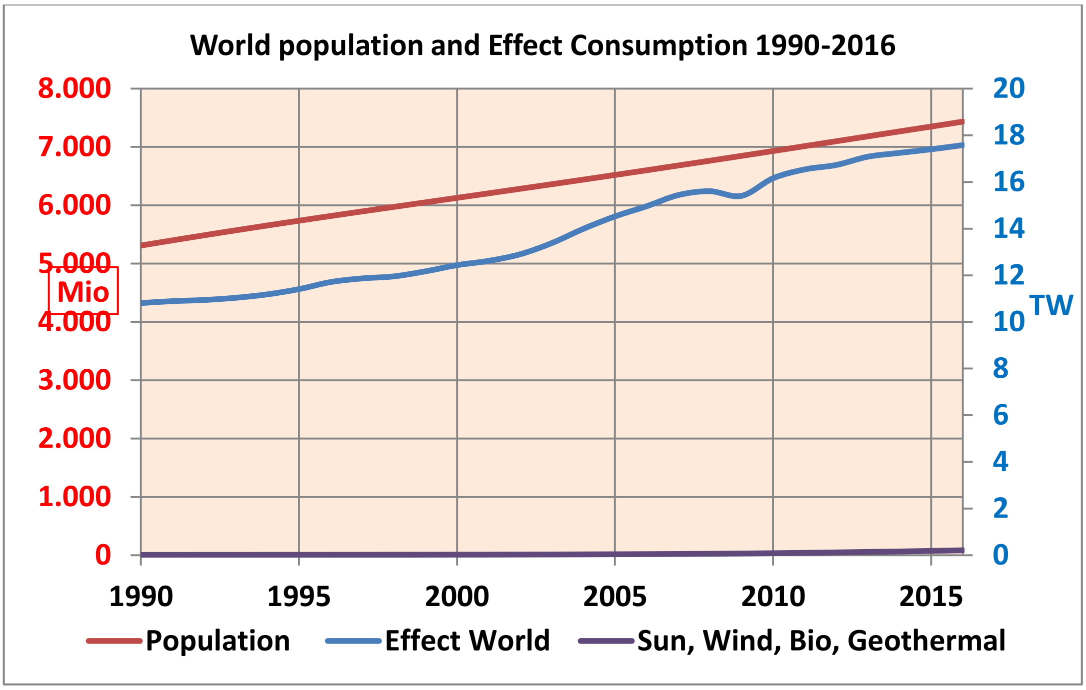
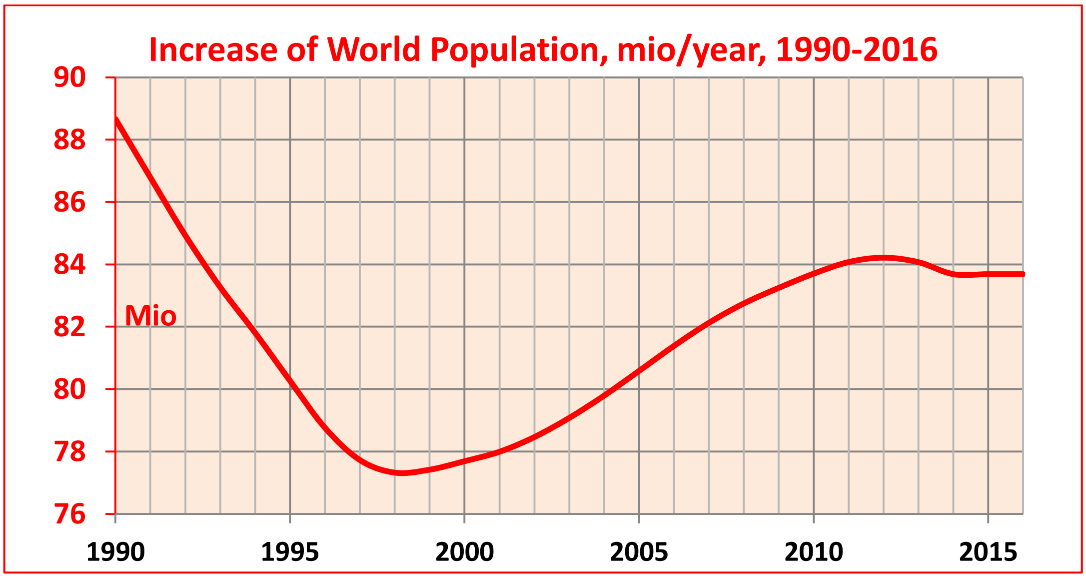


Figure 7



Danish Electricity Consumption (Load) 2017

Sources: All the data in this and the following sections are obtained from http://osp.energinet.dk/_layouts/Markedsdata/framework/integrations/markedsdatatemplate.aspx

There is nothing special about the Danish Electricity consumption. The figures for 2017 are shown in table 6:

Table 7

Load MW, 2017					
	2017	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
Average	**3887**	4234	3628	3540	4150
Max	**5982**	5905	5081	5786	5982
Min	**1810**	2784	2359	1810	2553
Stddev	**780**	764	637	682	777
Observations	**8760**	2160	2184	2208	2208

(The term "observations" used throughout this report means the number of figures behind the average etc. There was 8760 hours in 2017 and the data base gives a value for each hour)

However it is remarkable that the consumption is constant or nearly constant, as shown in table 8. The only way to obtain zero carbon dioxide emission is a massive increase in the consumption of "green" electricity. We are even told again and again that wind energy is cheap and plentiful. **So why is the consumption not increasing?**

Table 8

Danish Load, MW Average, in 2015, 2016 and 2017	
2015	3826
2016	3862
2017	3887

The Danish electricity consumption per capita is comparable with the German, but not the Swedish.

Table 9

Electricity consumption and Carbon Dioxide Emission per Capita, DE, S, Fand DK								
Country	Average Load	Population		Per Capita	Carbon Dioxide Emission			
	GW	**Mio**		**kW**	**Mio Ton**		**Ton per capita**	
Year	***2016***	***1990***	***2015***	***2015/16***	***1990***	***2016***	***1990***	***2015/16***
Germany	54,8	78,9	80,7	0,679	1.003	775,7	12,71	9,61
Sweden	17,4	8,56	9,78	1,775	56,7	44,7	6,62	4,57
Denmark	3,86	5,14	5,67	0,681	53,0	38,0	10,31	6,70
France	54,4		64,4	0,845		331,5		5,15

Conclusions: Nuclear Power and a high use of electricity per capita is a condition for low carbon dioxide emissions**.**

The figures 8-11 below show the Danish electric loads in 2017.

Figure 8

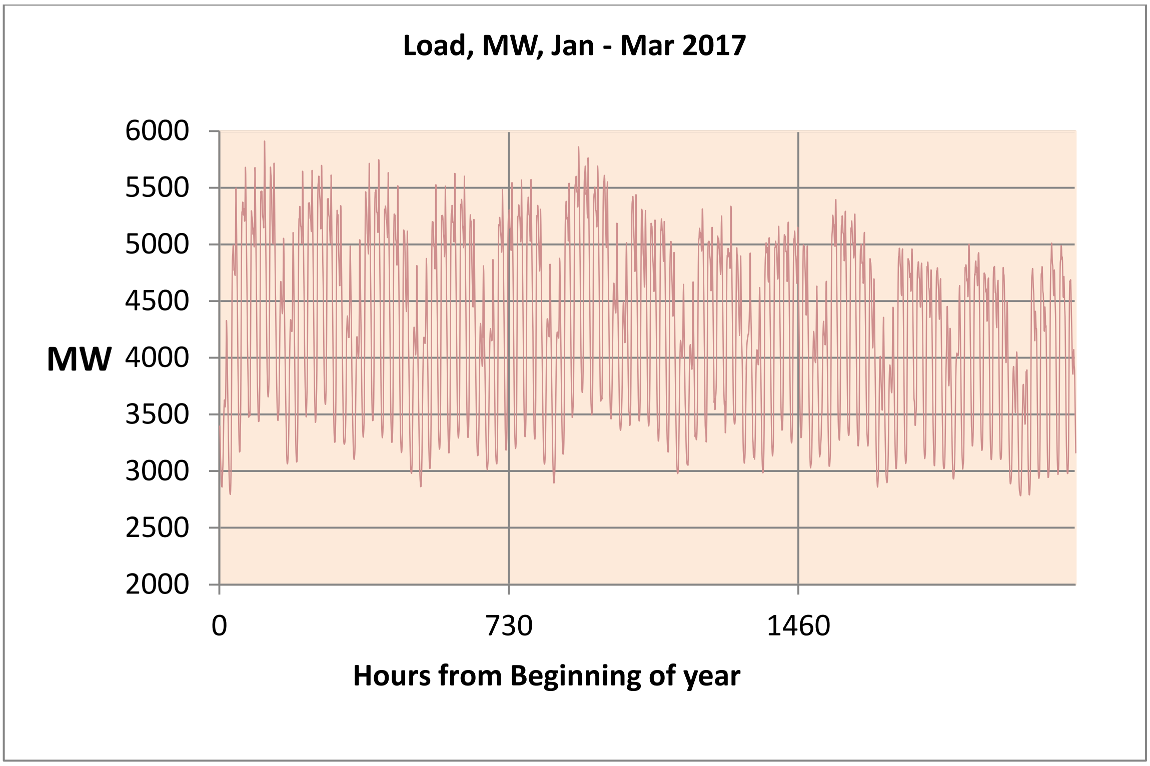


Figure 9

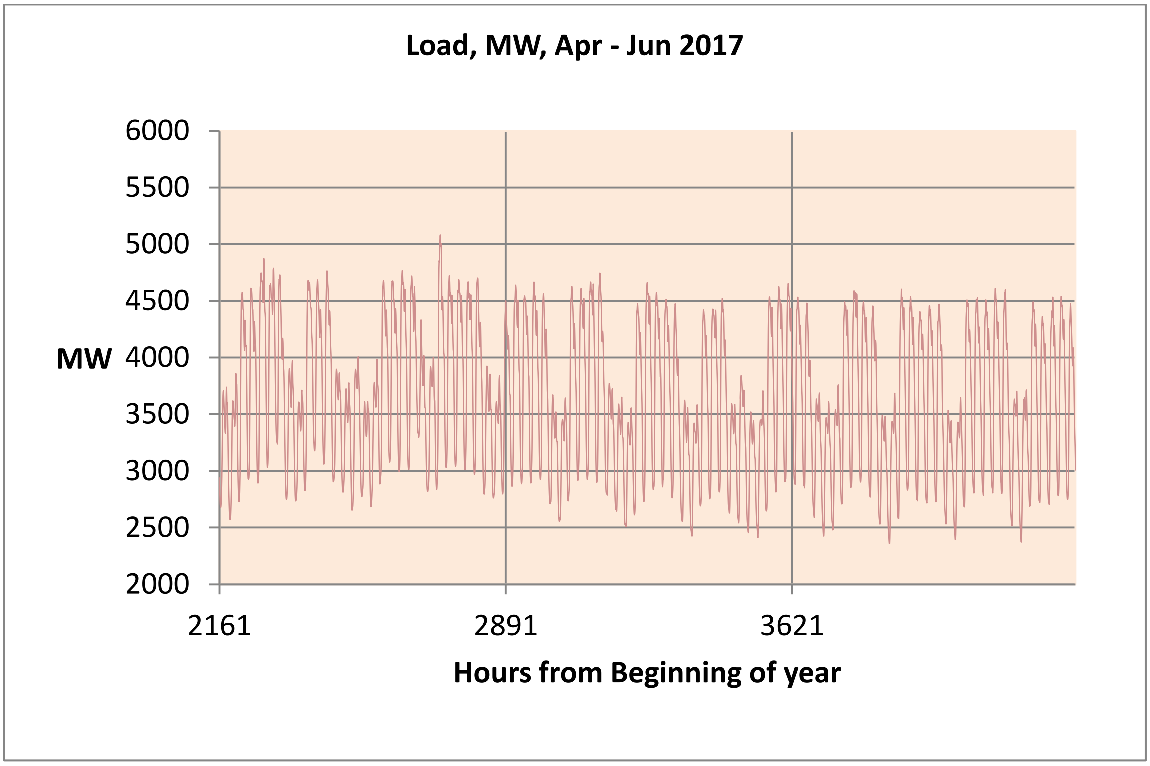


Figure 10

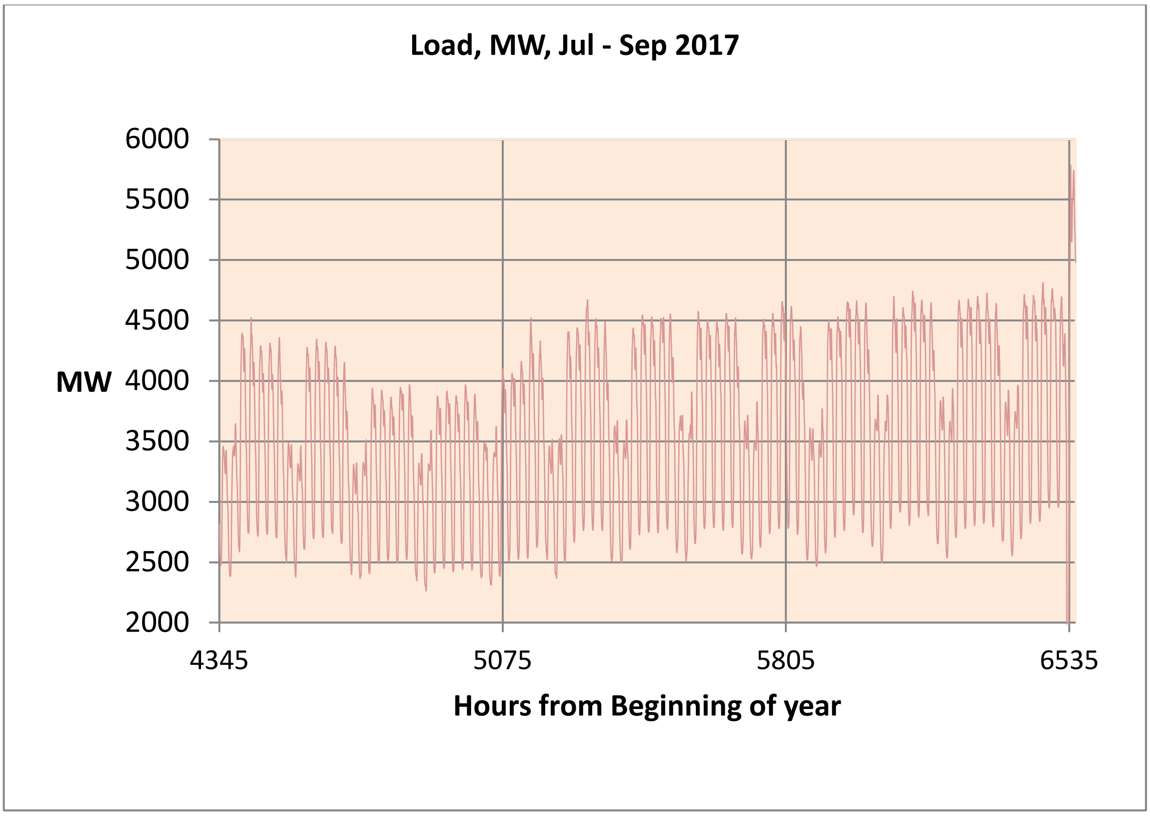
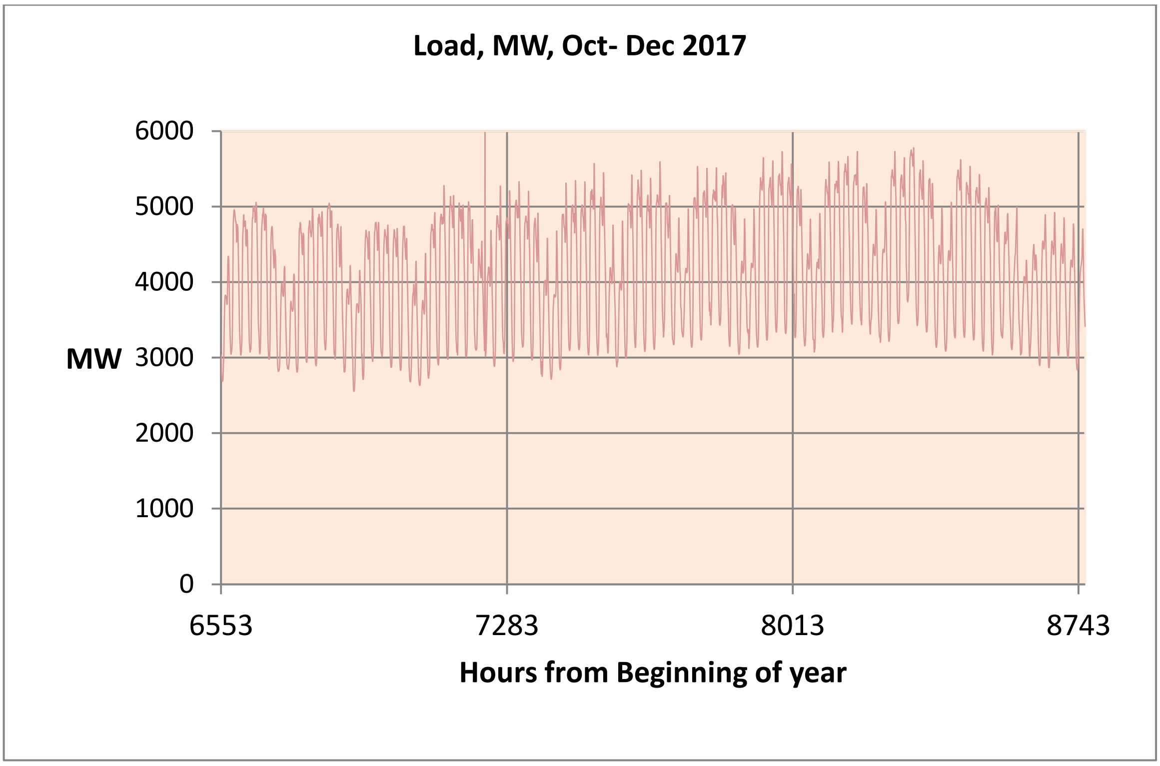


Figure 11



Danish Thermal Electricity Production 2017

The data for 2017 are shown in table 9 below:

Tabel 10

Thermal Power, MW, 2017					
	2017	Jan Mar	Apr-Jun	Jul-Sep	Oct-Dec
Average	1586	2541	1214	873	1734
Max	4530	4530	3891	2399	4161
Min	293	1242	320	293	507
Stddev	872	564	669	460	701
Observations	8760	**2160**	2184	2208	2208

It is seen that the thermal power stations have yielded between 293 MW and 4530 MW with an average of 1549 MW. The average is a third of the maximal ouput. **I.e. we have very low utilization of the power stations.**

The capacity of the transmission lines from our neighbours is not less than 6200 MW and the maximal load in 2017 was 5982 MW, so you may wonder why we need a thermal power capacity of not less than 4530 MW, when they on average produce only 1549 MW.

And you may wonder too what it costs to maintain this back-up capacity.

The graphs 13-16 below illustrate the very fluctuating operation of our thermal power stations.

Everybody who has been responsible for operating a complicated production plant will know, that a production varying as shown will be very uneconomic.

Figure 12

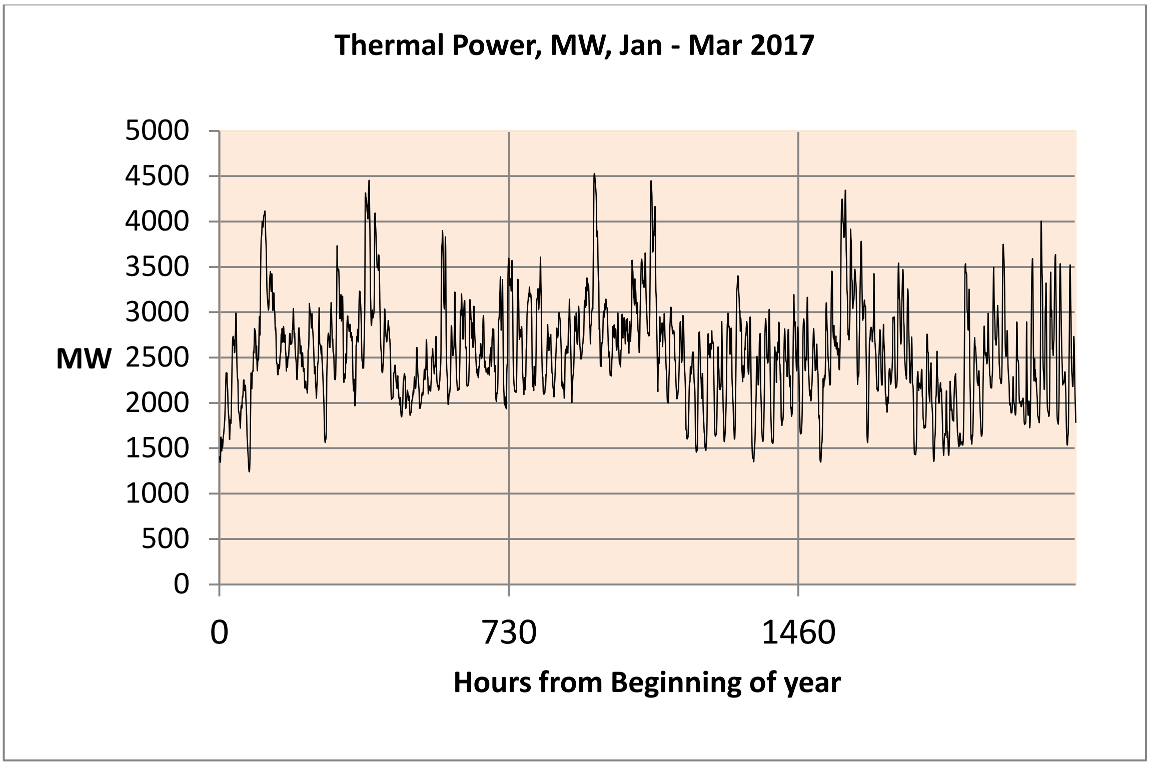


Figure 13

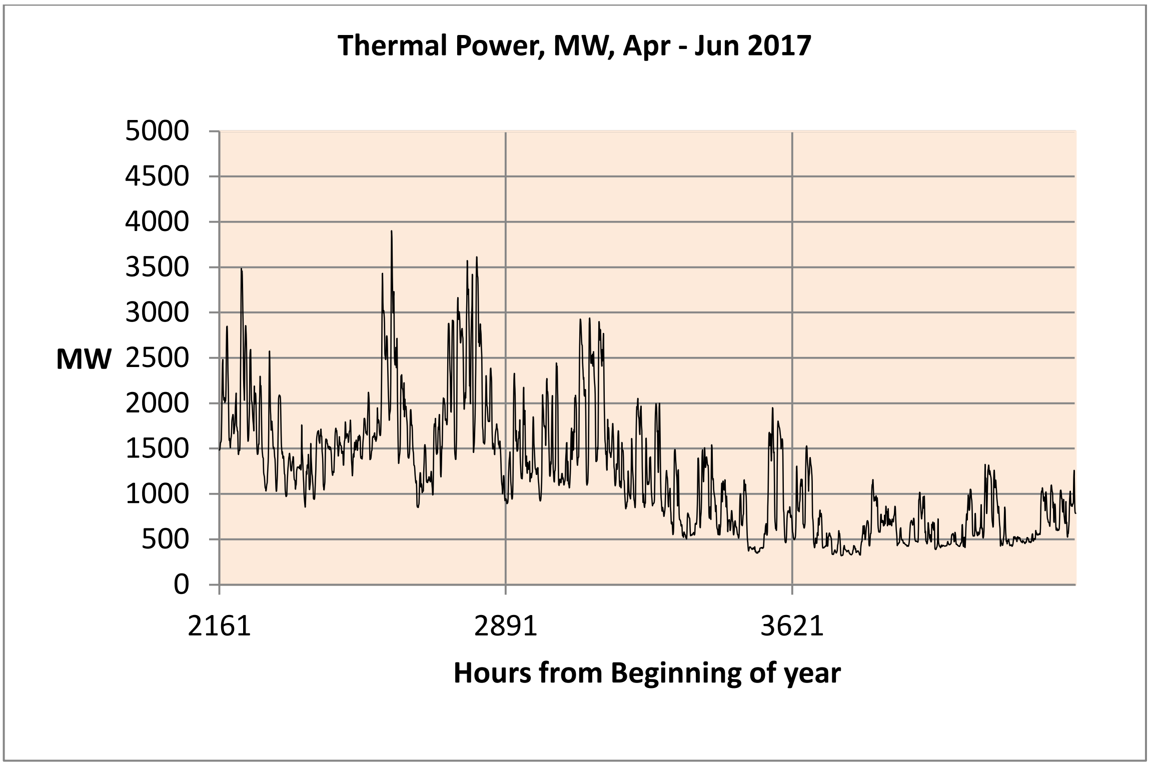


Figure 14

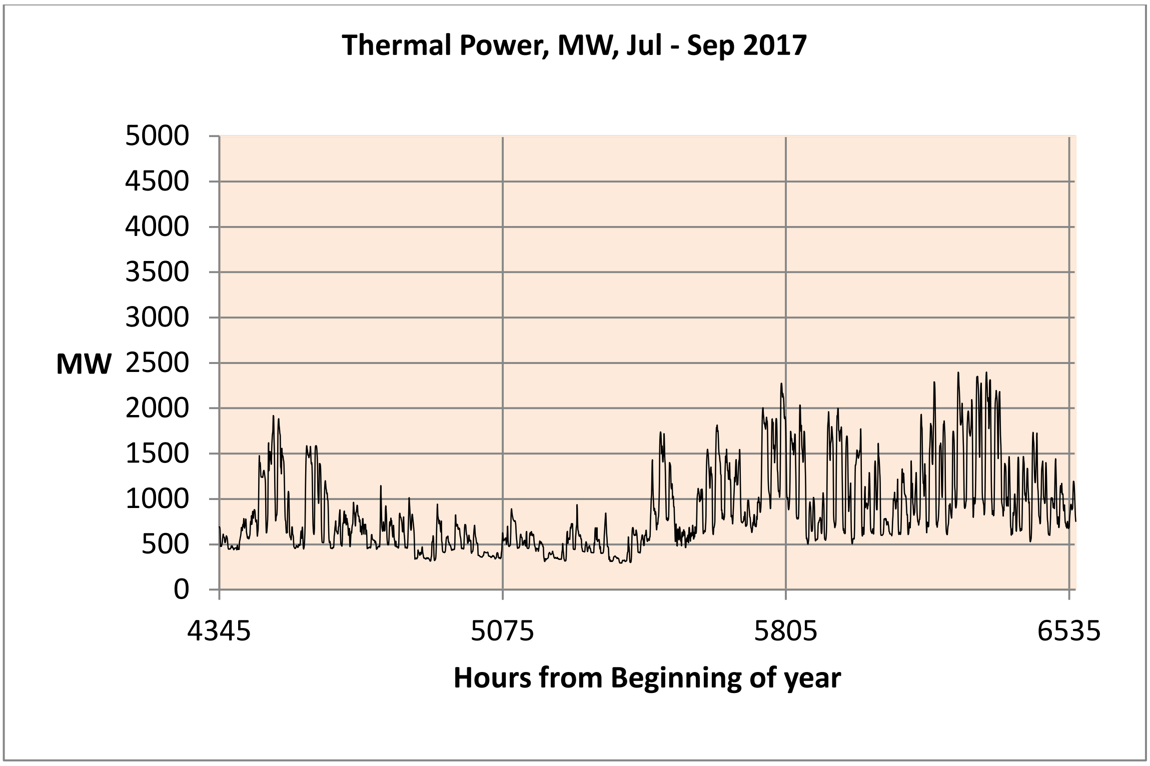
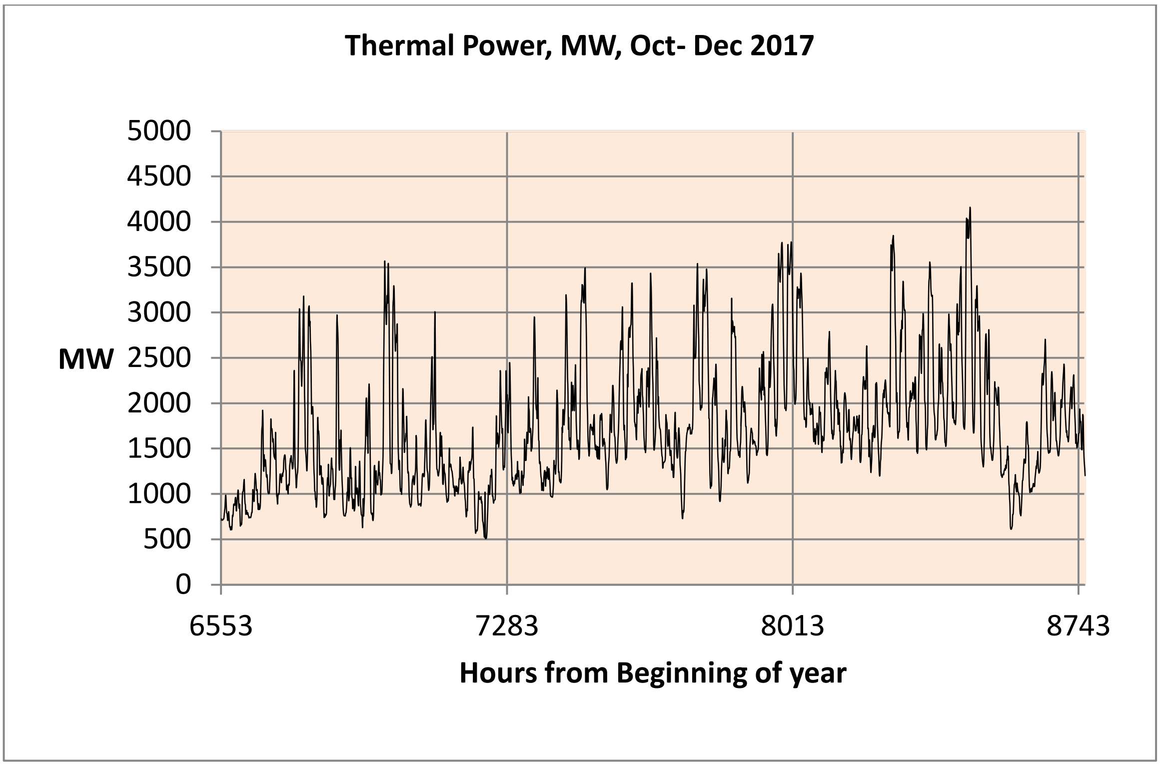


Figure 15



Danish Wind and Solar Power production

Table 11

Wind and Sun Power, 2017					
	2017	**Jan Mar**	**Apr-Jun**	**Jul-Sep**	**Oct-Dec**
Wind, MW					
Average	1687	1800	1678	1206	2067
Max	5487	4812	4639	4177	5487
Min	3	31	12	3	21
Stddev	1212	1236	1253	953	1219
Observations	8760	2160	2184	2208	2208
Sun, MW					
Average	90	43	150	127	40
Max	673	586	673	617	584
Min	0	0	0	0	0
Stddev	145	92	181	157	88
Observations	8760	2160	2184	2208	2208
Wind+Sun, MW					
Average	1777	1843	1829	1333	2107
Max	5487	5031	4880	4440	5487
Min	11	53	26	11	21
Stddev	1214	1239	1273	977	1217
Observations	8760	2160	2184	2208	2208

The figures 16-19 illustrate the well known fact that wind and solar power fluctuates, from nearly zero to close to the installed capacity. It is no surprise that there is no solar power during the nights, but it may be surprising that our 5000-6000 wind turbines spread over a distance of 400 km from north to south and 400 km from east to west sometimes produce nothing or nearly nothing.

The average wind power in 2015, 2016 and 2017 was **1612 MW, 1452 MW and 1687 MW.**

Table 12

Wind On Shore and Off Shore 2017			
	On shore	Off shore	Total
Average MW	1096	592	1687
Max MW	5005	1227	5487
Min MW	1	0	4
Stddev MW	874	374	1212
Stddev % of average	**79,7**	**63,2**	**71,8**

The on shore production is slightly more variable than the off shore production, however, as shown in the following graphs the off shore production frequently approaches zero just as well as the on shore production.

Figure 16

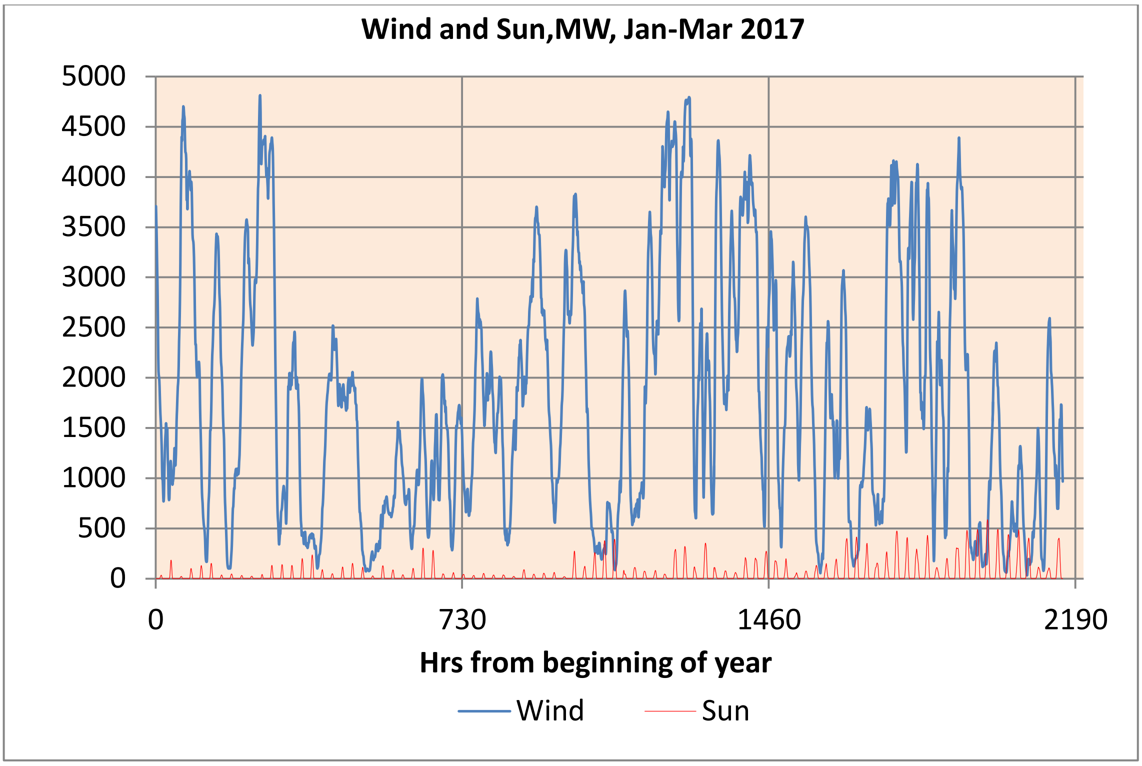


Figure 17

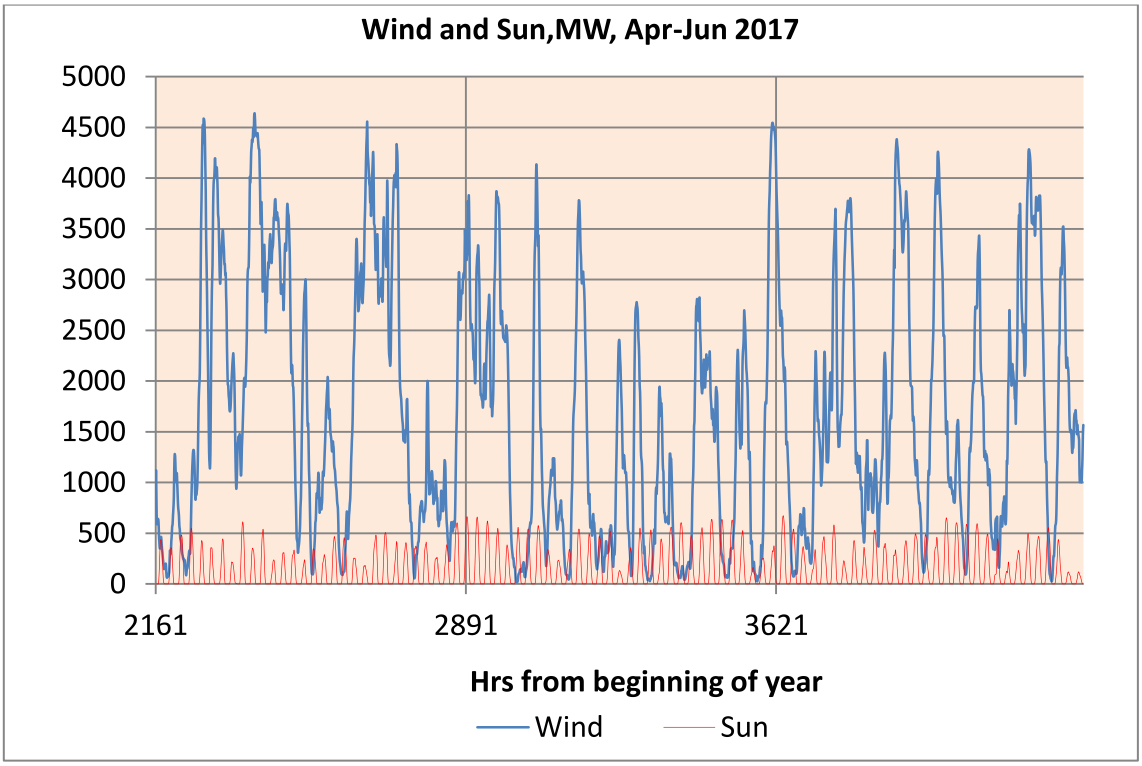


Figure 18

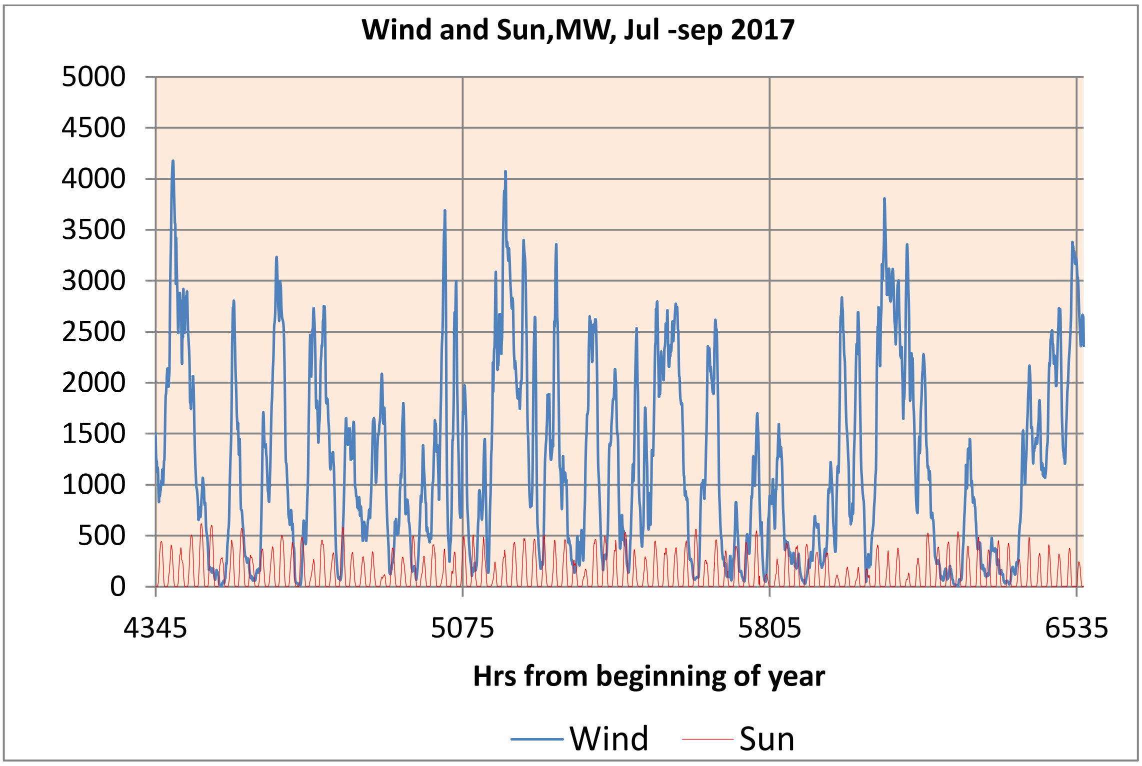


Figure 19

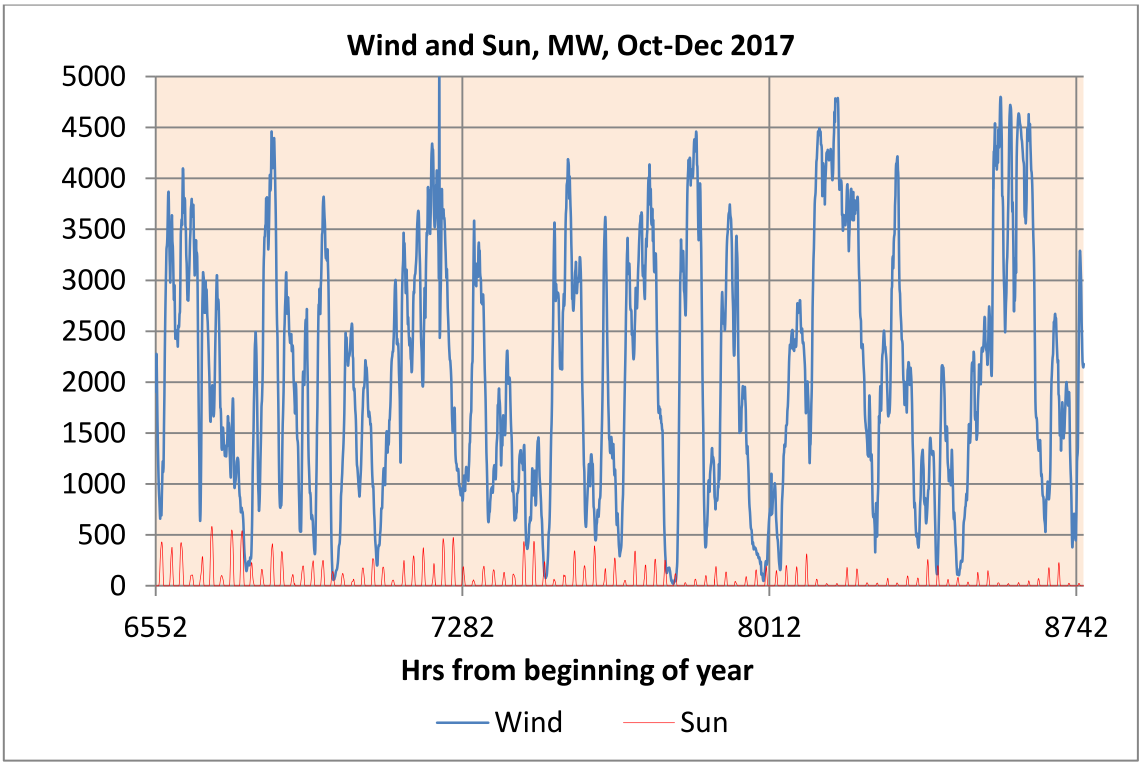


Figure 20

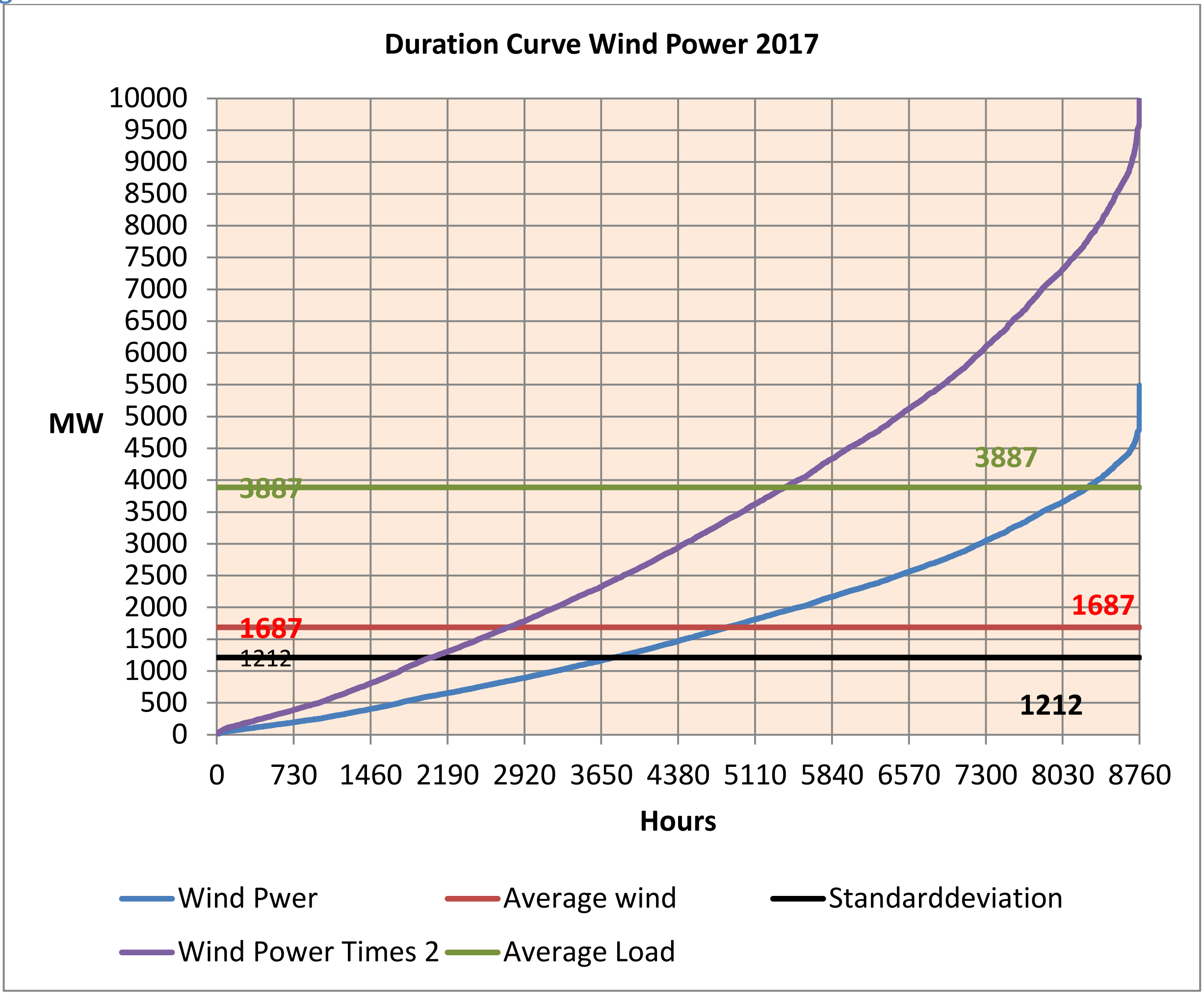


Figure 20 may need a little explanation.

The green line shows the average power consumption, 3887 MW.
The red line the average wind power, 1687 MW
The black line shows the standard deviation for the wind power, 1212 MW.
The abscissae is divided in 730 hours, the average number of hours per month.

Thus the **blue** curve shows for instance that the wind power in 730 hours was less than 200 MW, in 1460 hours less than 450 MW and in half of the year less than 1500 MW. And in about 450 hours higher than the average demand.

The **violet** curve shows the **conditions by doubling the wind power**. There would still be 5200 hours where the wind production is lower than the load and 3560 hours where the wind production is higher than the load. And about 2900 hours where the wind power is less than half of the load.

The only known and thinkable method to store large amounts of electricity is to behold the water in hydroelectric reservoirs. The Scandinavian reservoirs have a nominal capacity of about 120 TWh, or about 14 GWYear. They would surely be large enough to supply back up to the Danish system with a consumption of 3,8 GW on average. However, they are not created to satisfy the Danes only.

Wind + Sun Power relative to load

Table 13

(Wind+Sun)/Load W/kW					
2017	Jan-Dec	Jan Mar	Apri-Jun	Jul-Sep	Oct-Dec
Average	462	435	504	377	508
Max	1811	1318	1368	1811	1388
Min	4	13	9	4	4
Stddev	312	299	338	284	306
Observations	8760	**2160**	2184	2208	2208

Table 13 shows how large a part of the load is covered by wind and sun power in 2017. The unit is Watt/kW, i.e. promille.

The average is 462 Watt/kW in the period Jan-Dec. This means that on average 462 watt is supplied for each kW or 1000 Watt consumed, so that you could say that wind + sun delivers **46,2 %** of the load.

However, if you look at the next line you find the max values. These sometimes surpass 1000 W/kW so that more wind- and sun power is produced than the consumers use. Then the average figure of 46,2% wind and sun power in the system becomes meaningless.

So if you at any time subtract the net export from the wind and sun power produced you find the useful wind + sun power is 1512 MW. According to table 15 you find that wind and sun have supplied 389 W/kW Load or **38,9%**.

Table 14

Useful Wind +Sun 2017		
Wind+Sun Average	**MW**	1777
Useful Wind + Sun Power	**MW**	1512
Proportion useful	**W/kW**	851
Load average	**MW**	3887
Real wind + sun proportion	**W/kW**	389

It is easy to see that wind and solar power can't stand alone.

The graphs fig. 21-24 below are showing variations in the relation between (wind+solar power) and the load or consumption. They clearly illustrate how impossible it is to supply the needed electricity by wind and sun power.

The unit is watt/kW. If you wish to transfer the figure to % just divide by 10.

Figure 21

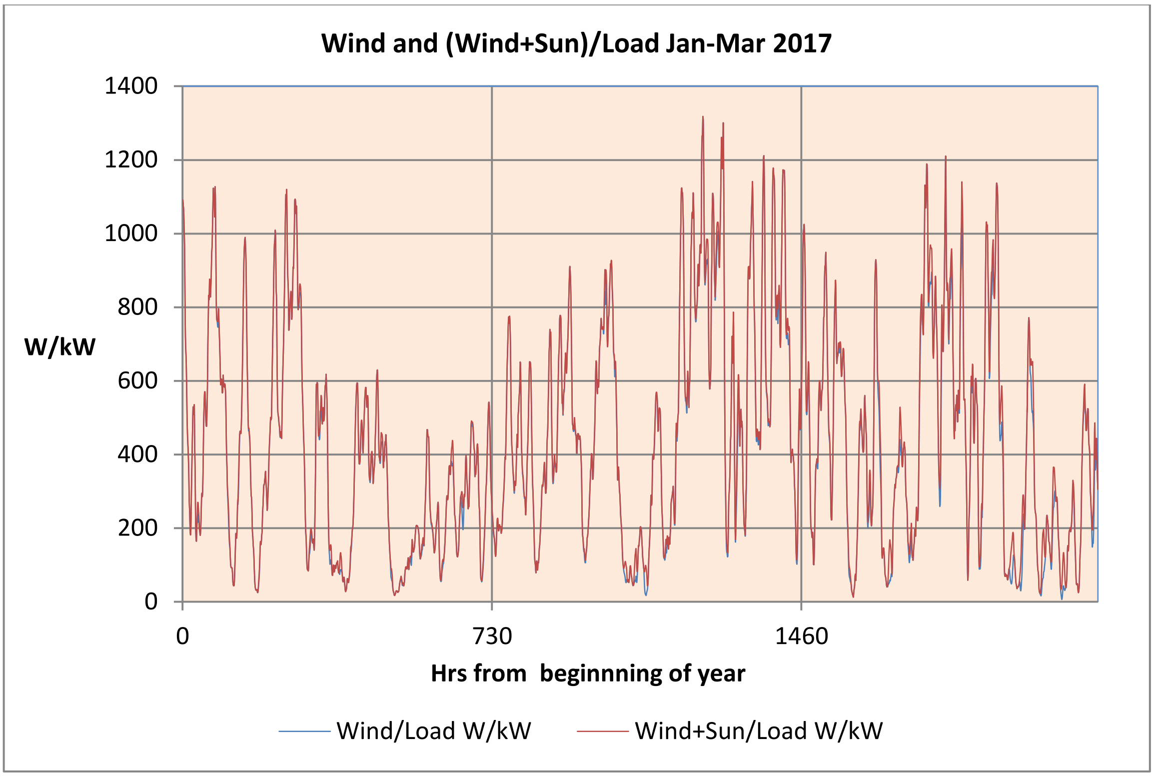
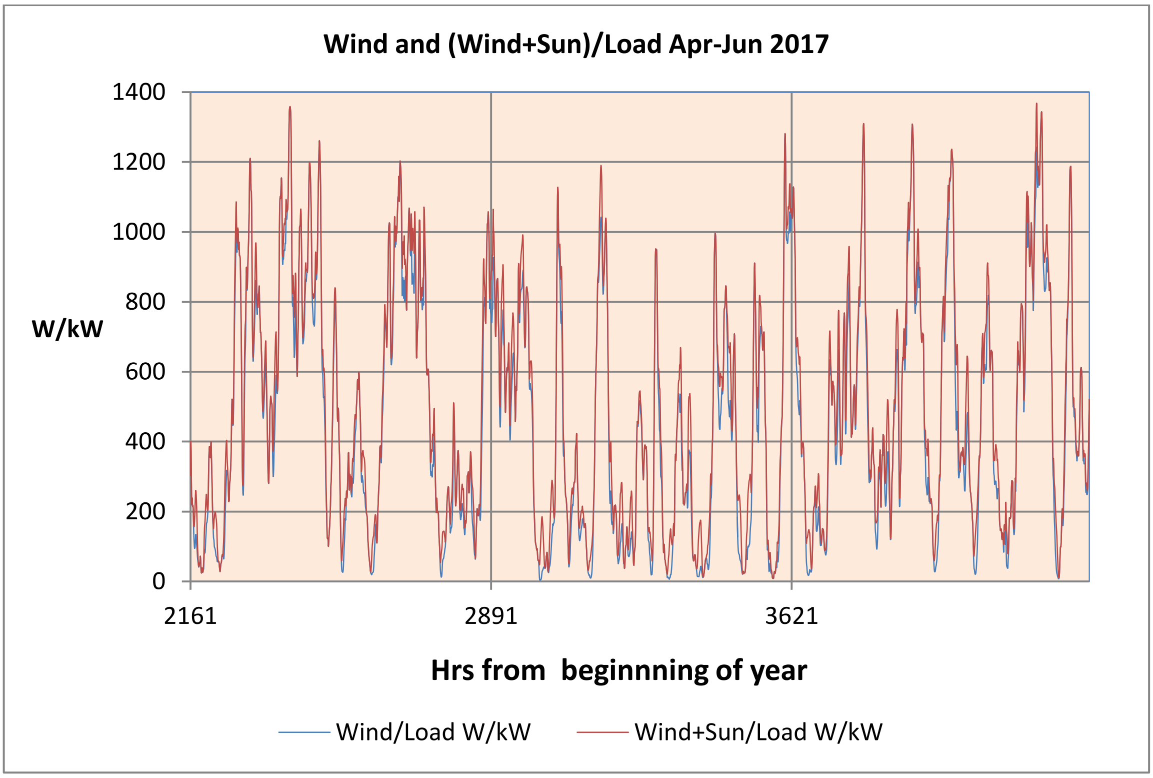


Figure 22



In the ideal world the blue curve would be a straight line with the value 1000 watts produced per kW consumed.

You can hardly see more than one curve. This indicates that the sun power contribution is very low. But that may change.

Figure 23

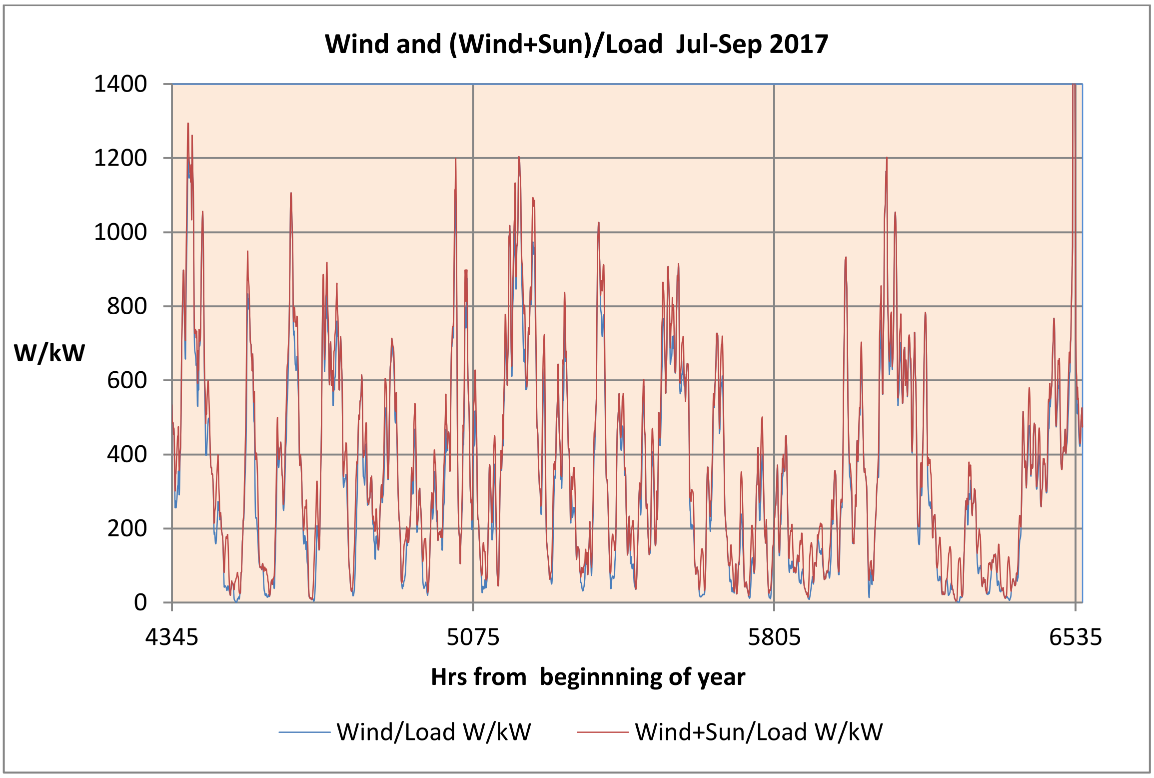


Figure 24

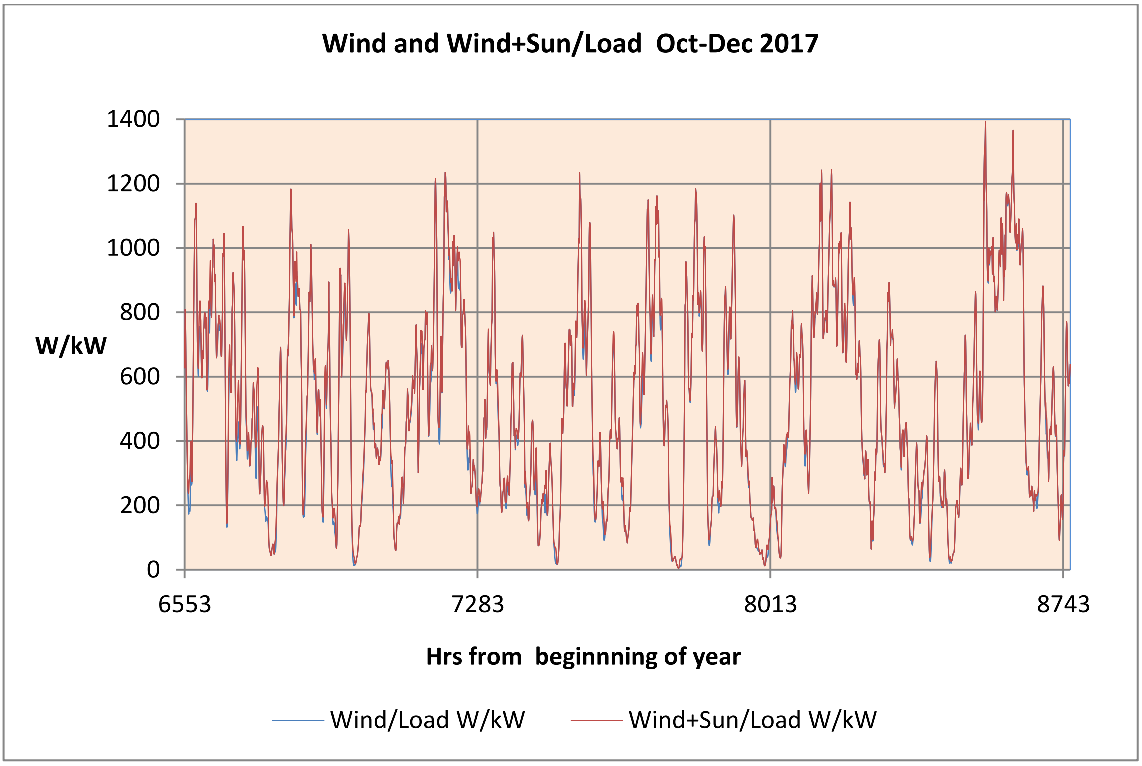
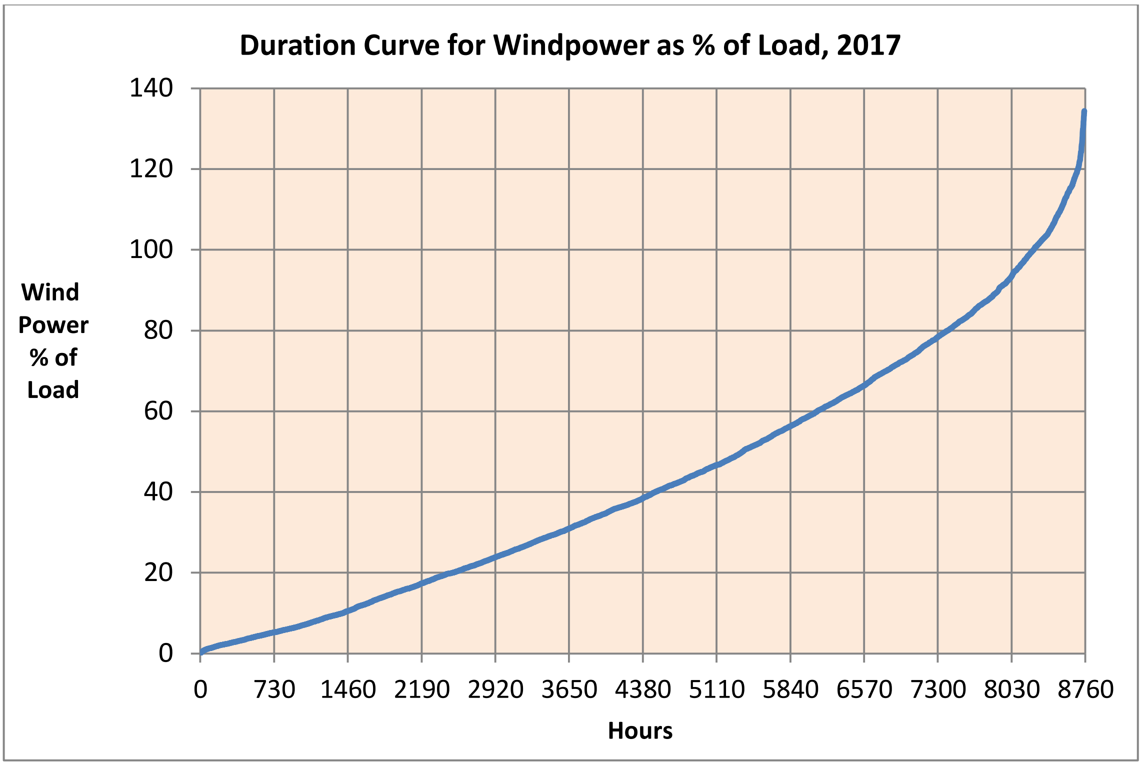


Figure 25



It is seen that the wind power is less than 20% of the load in 2550 hours and higher than the load in 500 hours.
So wind power demands back-up.

Useful Wind and sun power

If we subtract the net export from the wind and sun power we obtain the wind and sun power used in Denmark. We name this part the **useful sun and wind power.**

Table 15

2017	Jan-Dec	Jan Mar	Apri-Jun	Jul-Sep	Oct-Dec
Useful Wind MW					
Average	1422	1382	1382	1169	1382
Max	4962	3489	3830	3573	4962
Min	3	31	12	3	21
Stddev	906	718	946	889	931
Observations	8760	2160	2184	2208	2208
Useful Wind + Sun MW					
Average	1512	1479	1479	1296	1479
Max	4962	3489	4039	3819	4962
Min	11	53	26	11	21
Stddev	917	721	974	915	934
Observations	8760	2160	2184	2208	2208

Table 15 shows the amount of useful Wind and Sun power and the variation in these. You see that the system must be able to handle a variation between 4962 MW useful input and down to 11 MW.

The wind + sun effect and the proportion of the load is shown in table 16 hereunder.

Table 16

2017	Jan-Dec	Jan- Mar	Apr–Jun	Jul-Sep	Oct-Dec
Average Wind + Sun Power, MW					
Wind	1687	1800	1678	1206	2067
Sun	90	43	150	127	40
Wind+Sun	1777	1843	1829	1333	2107
Average useful W/kW produced					
Wind	843	768	823	969	669
Sun+ Wind	851	803	809	972	702

It is seen that the lowest proportion of useful wind + sun power is obtained in the months October-December.

Table 17

Load, Wind Power and Exchange in February 2017						
February 2017	Load MW	Wind MW	Exchange MW	Wind % of load	Import % of Load	Export % of load
Average	4325	2183	-506	50	5	17
Max	5852	4795	1989	132	37	81
Min	2895	84	-2823	2	0	0
Stddev	751	1256	1076	31	8	21
Observations	672	672	672	672	672	672

Figure 26

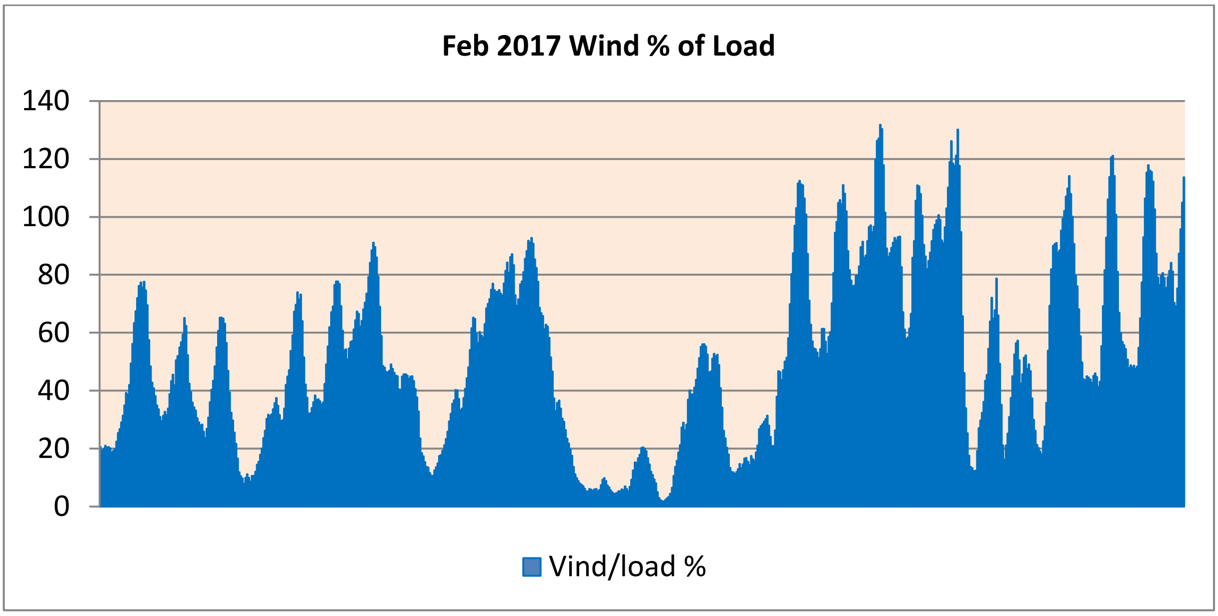
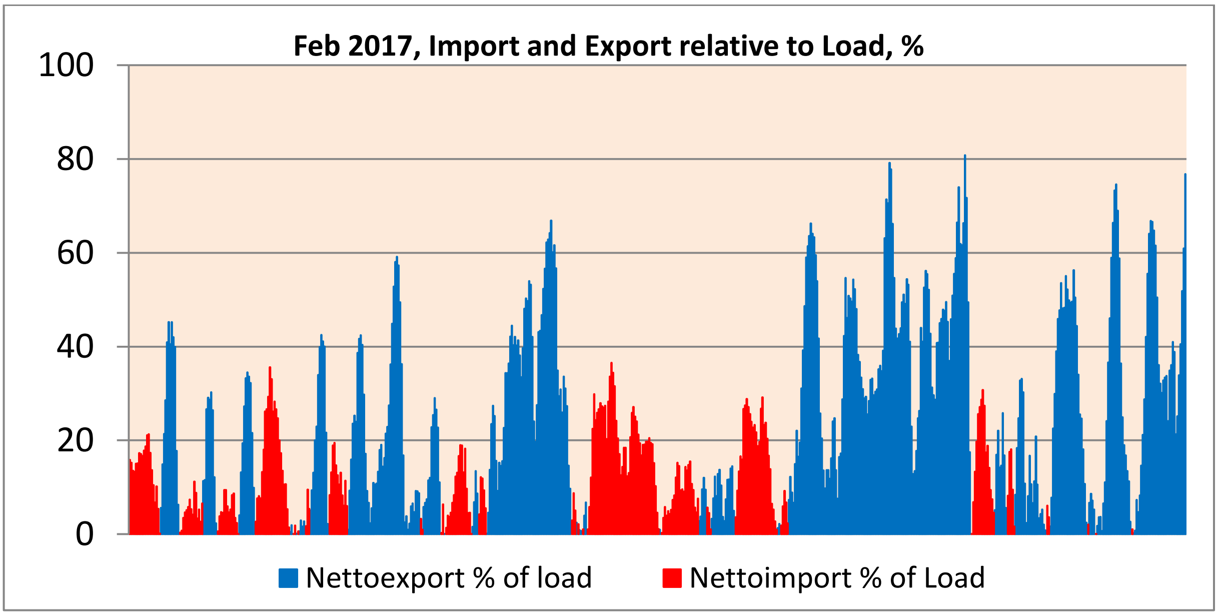


Figure 27



It is very easy to see that in the cold and windy month of February we export a large part of the wind power. The wind power was on average 2183 MW and 506 MW was **ex**ported.

Table 18

May 2017	Load MW	Wind MW	Exchange MW	Wind % of load	Import % of Load	Export % of load
Average	3592	1364	843	38	426	285
Max	4744	4545	2894	128	1281	799
Min	2415	12	-2119	0	9	0
Stddev	642	1177	1096	32	324	234
Observations	744	744	744	744	744	744

Load, Wind Power and Exchange in May 2017

Figure 28

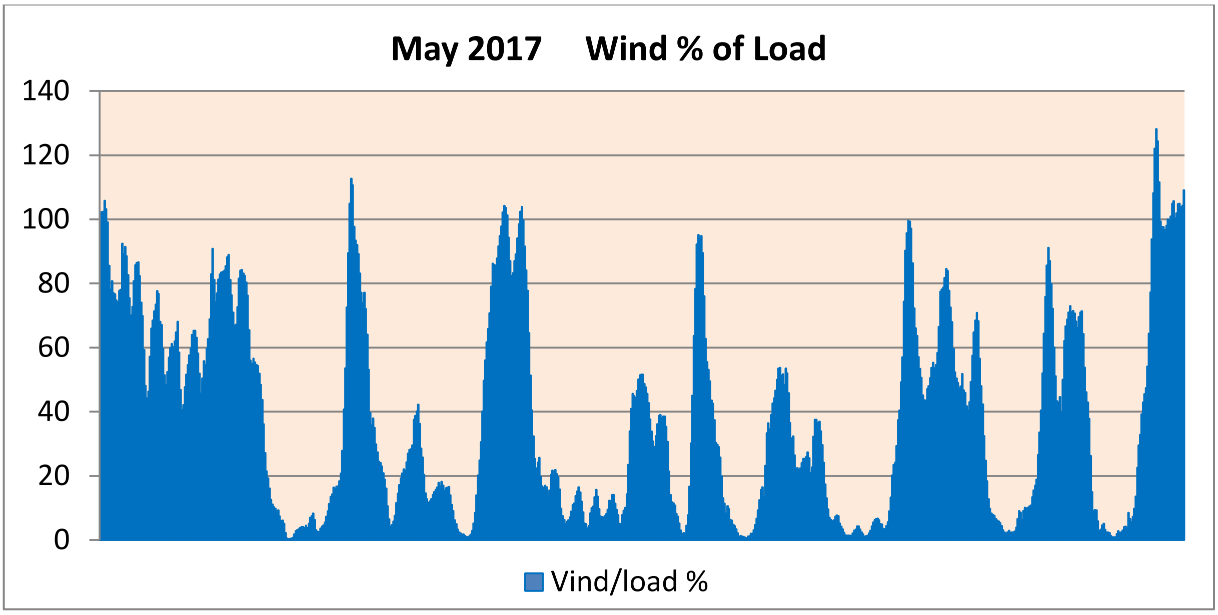
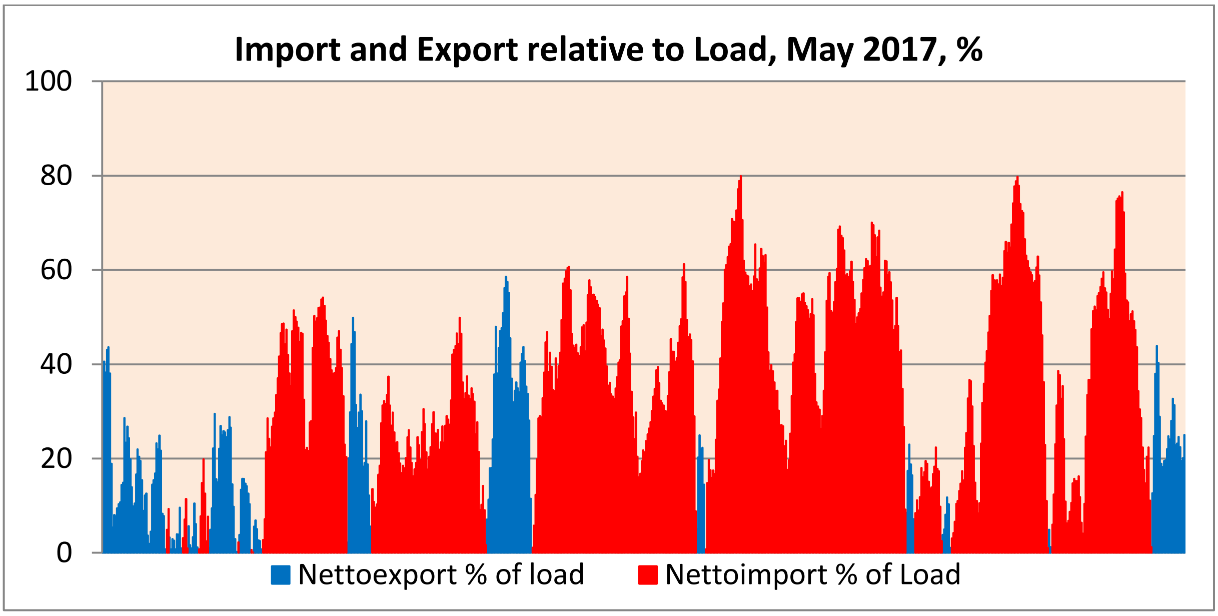


Figure 29

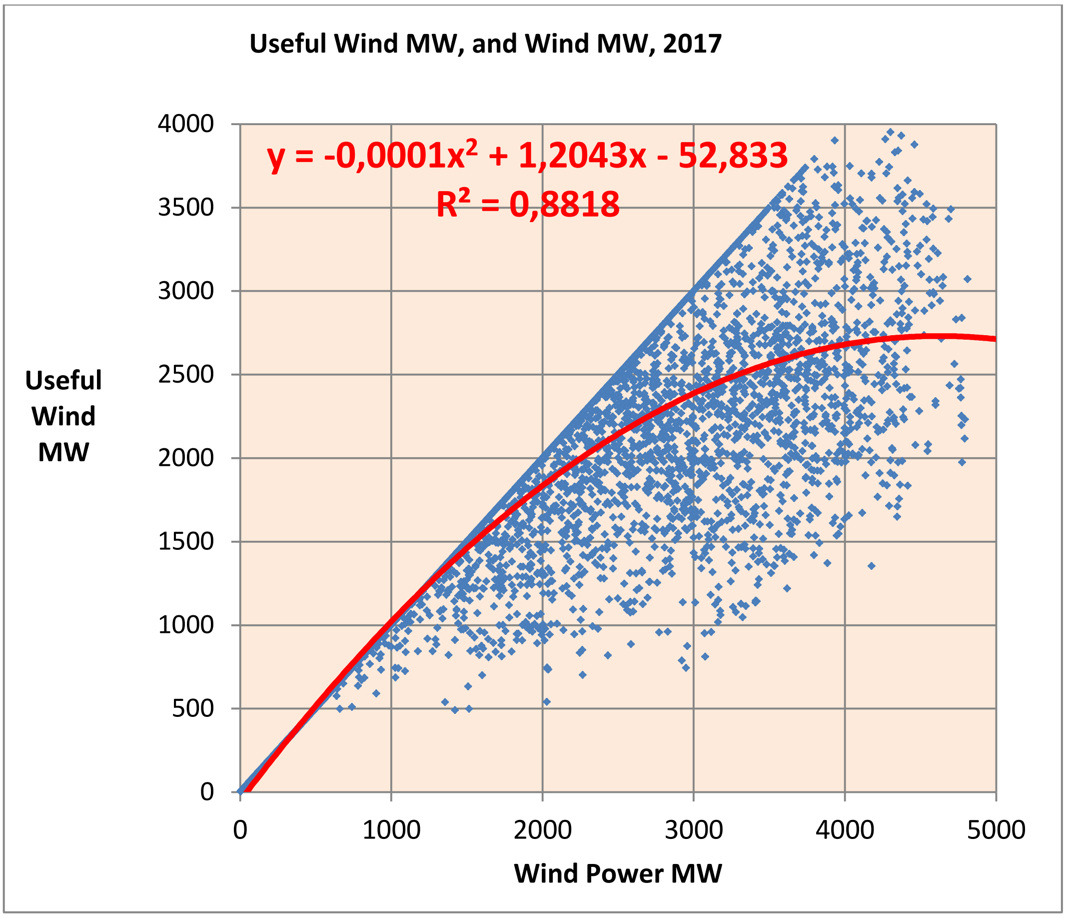


May is very different from February. The wind power was on average 1364 MW and the **im**port on average 843 MW.

The difference in im- and export between February and May can only be possible as long as you have neighbours who don't rely on wind power-

Figure 29 shows how the usefulness of wind and sun power depends of the effect produced.

Figure 30



Every point in the above graph represents a measurement of wind+ sun power and a calculation of how much wind and sun power is left after subtraction of the simultaneous net export. For example the point x=2000 and Y=500 means that 2000 MW wind + sun power was produced, but only 500 MW was useful and thus 1500 MW must have been exported. The graph illustrates that there is nearly no export when the wind + sun power is less than 2000 MW, but when the output increases to 3000 MW on average only 2500 MW is used in Denmark. By 4000 MW production and higher on average about 2800 MW is used in Denmark.

So until we have improved our ability to use large amounts of fluctuating electric power it does not seem to make much sense to build new wind turbines or solar cells.

Therefore it is proposed to build a cable to England to handle the extra wind power from the planned 1350 MW large off shore wind parks. Extra cost about 180 million €. But wind power becomes ever cheaper!

Danish Electricity Exchange with our Neighbours 2017

To overcome the problem with the varying (wind and sun) power, import and export necessarily plays a crucial role in the Danish electric system. This is shown in the table and graphs below. The import is on average 157 W/kW load or 15,7% of the consumption. But the variation is considerable. In the extreme case Denmark exported 1216 watt/kW consumed and imported up to 816 watt/kW used or expressed as per cent **121,6 % and 81,6%.**

It is unimaginable that a larger country could do the same.

Therefore bigger countries could not follow in Denmark´s footsteps in building wind and sun power. The graphs below illustrate the dependency of the foreign exchange.

Table 19

Exchange/Load W/kW					
2017	Jan-Dec	Jan Mar	Apr-Jun	Jul-Sep	Oct-Dec
Average	142	-35	162	377	74
Max	816	429	799	816	553
Min	-1216	-808	-768	-1216	-756
Stddev	312	255	321	255	241
Observations	8760	2160	2184	2208	2208

Please observe that import is positive and export negative in the following graphs.

Figure 31

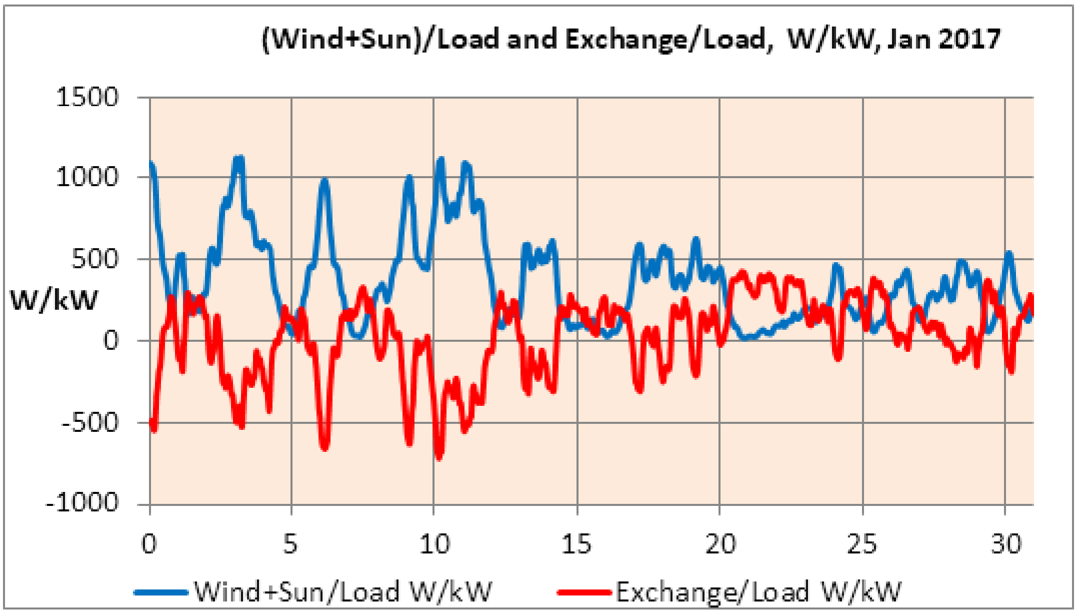
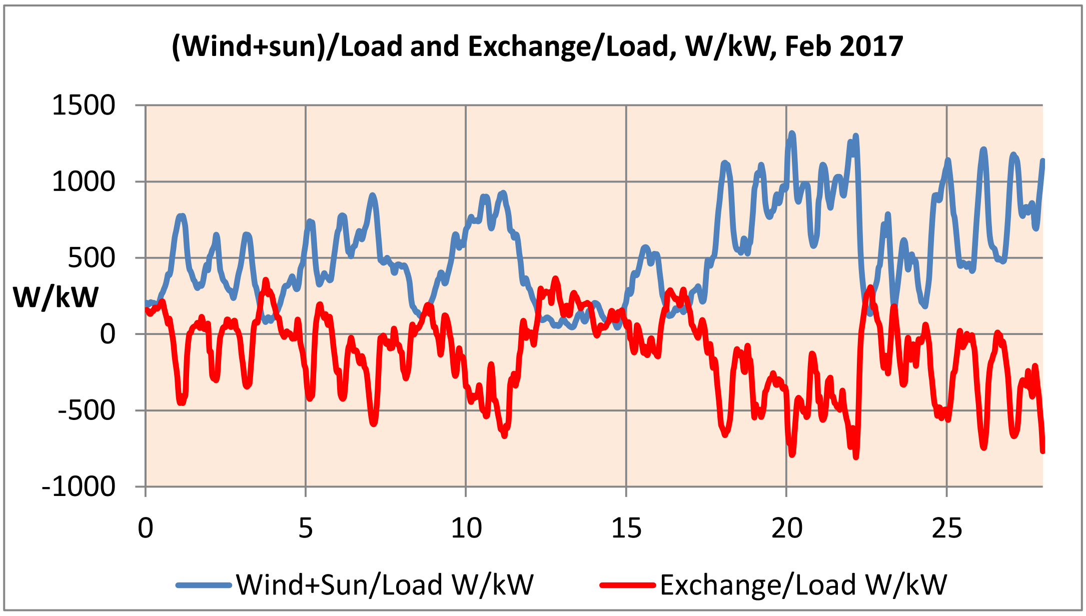


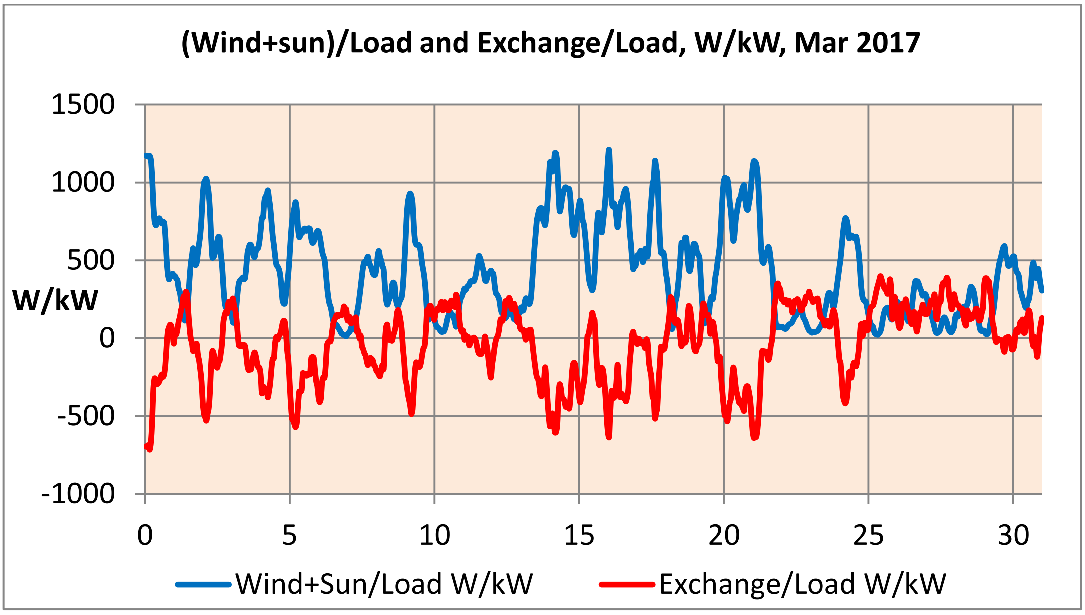
Figure 31 shows very clearly that electricity is exported, when it blows and vice versa.

Figure 32



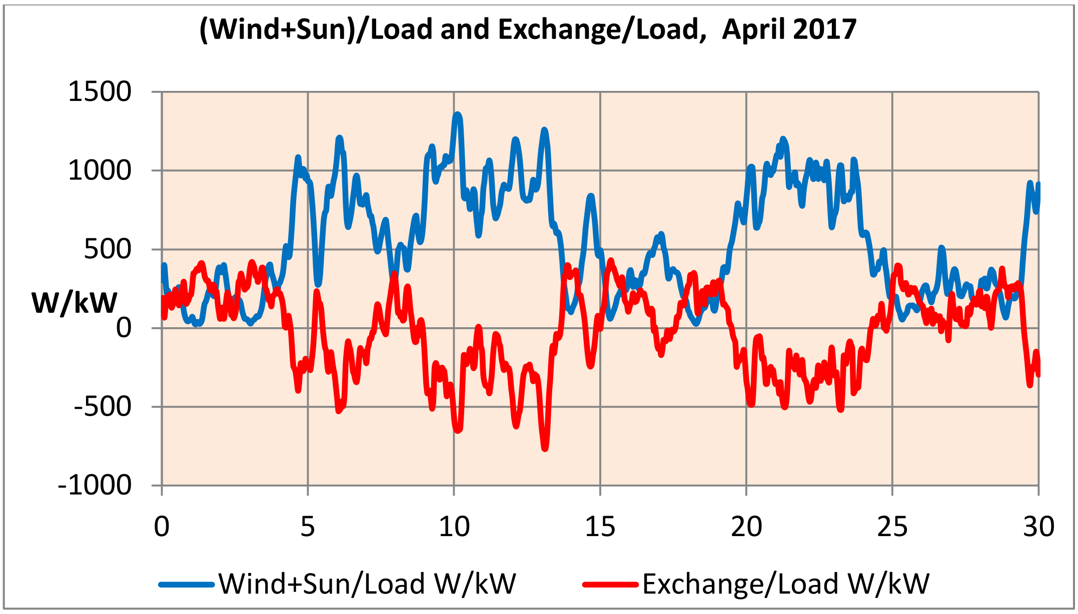
The relation between wind power and export is very clear. But there is not much import in February. The power stations have to produce heat for district heating and then they produce electricity too.

Figure 33



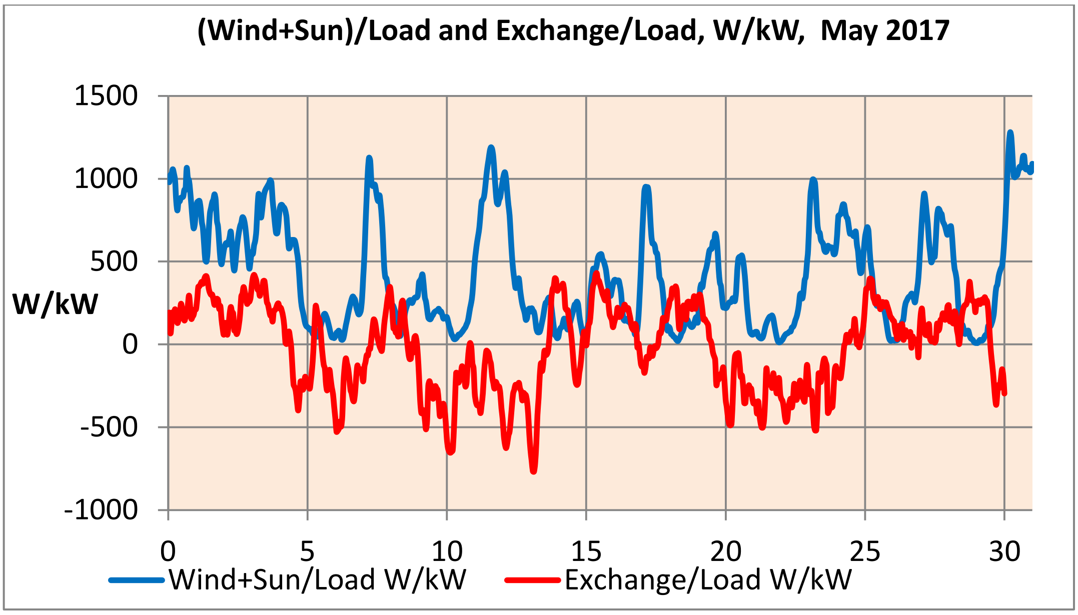
Essentially the same condition as in February

Figure 34



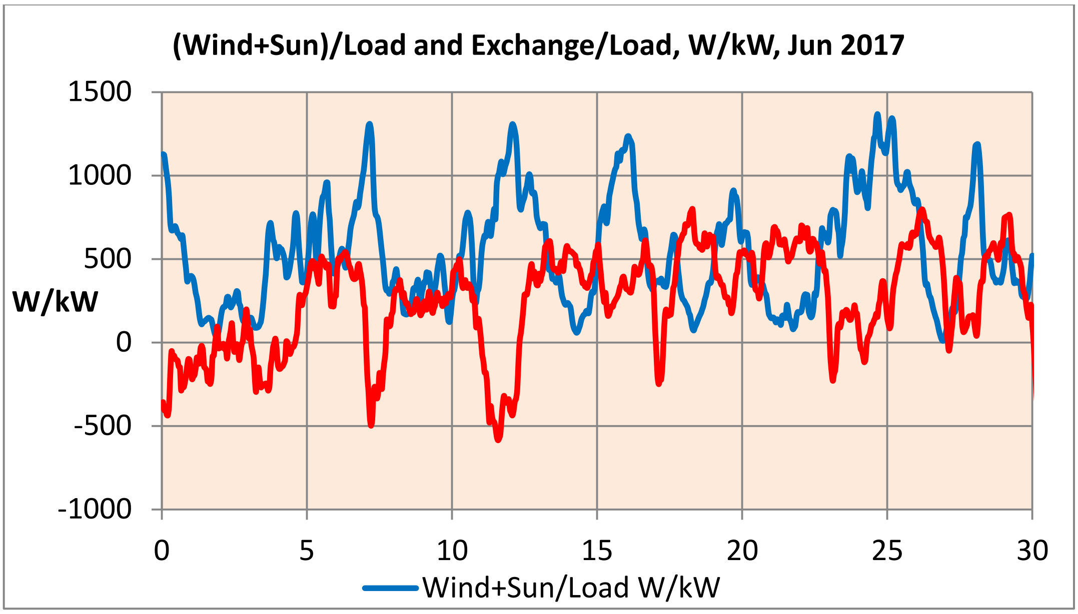
It is very easy to see, the interdependence of export/import and wind power in April. For instance on April 13 the wind power reaches 1300 W/kW load and the export at the same time 750 W/kW load. I.e. in this case less than half of the wind power is used in Denmark.

Figure 35



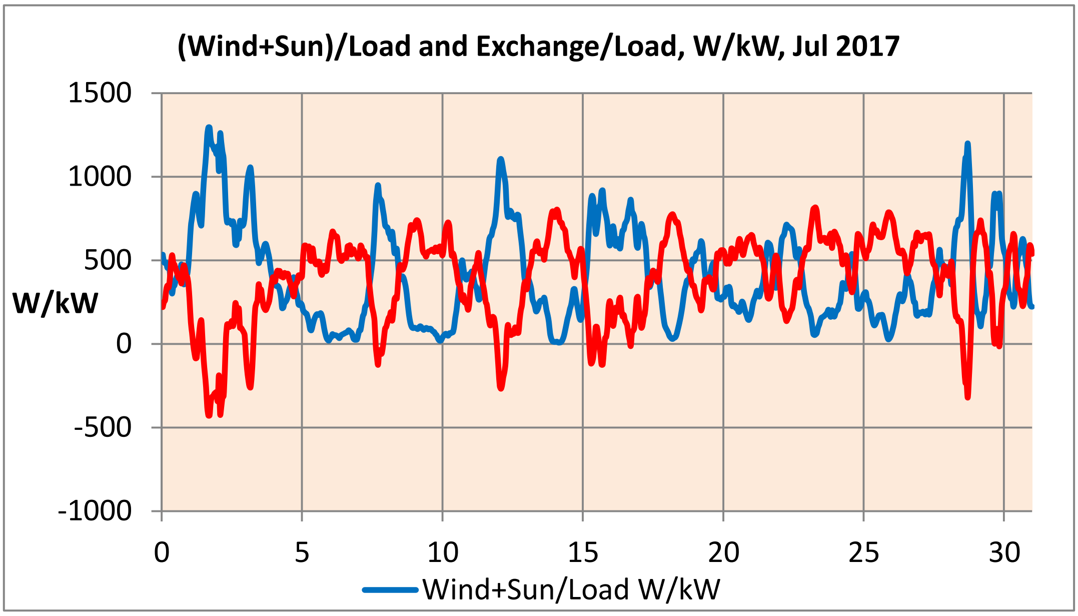
In some cases the export in May is higher than the wind power.

Figure 36



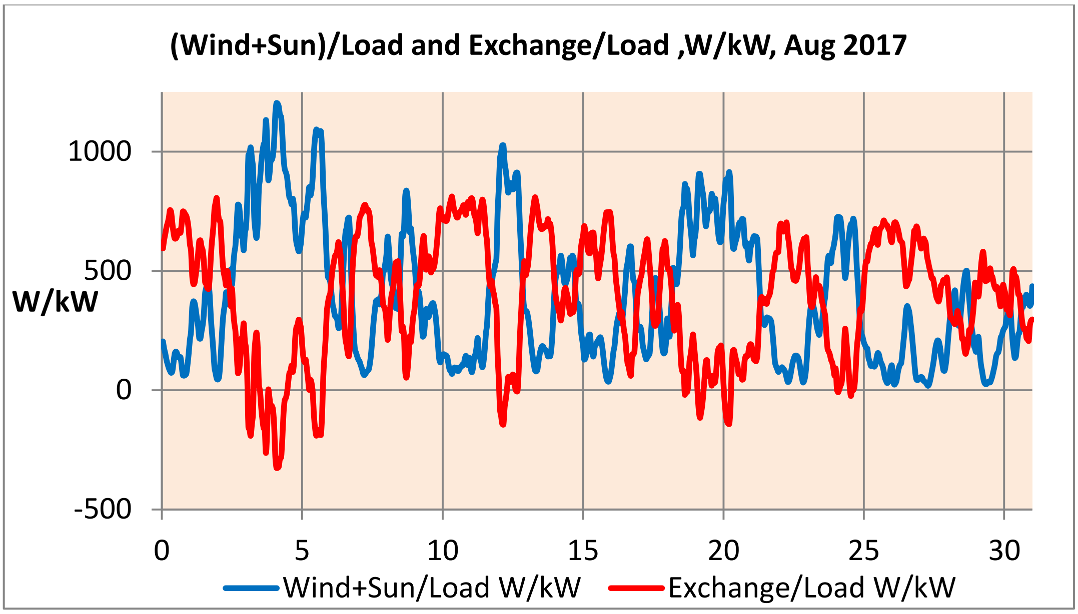
Again in June the wind power is sometimes larger than the load.

Figure 37



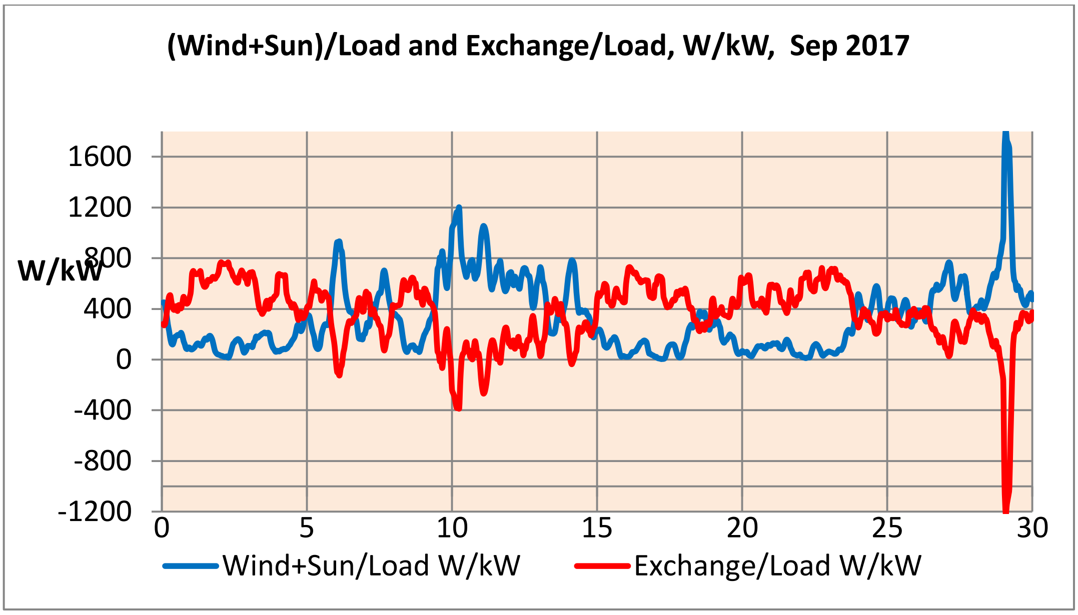
In July there is some import and nearly no export

Figure 38



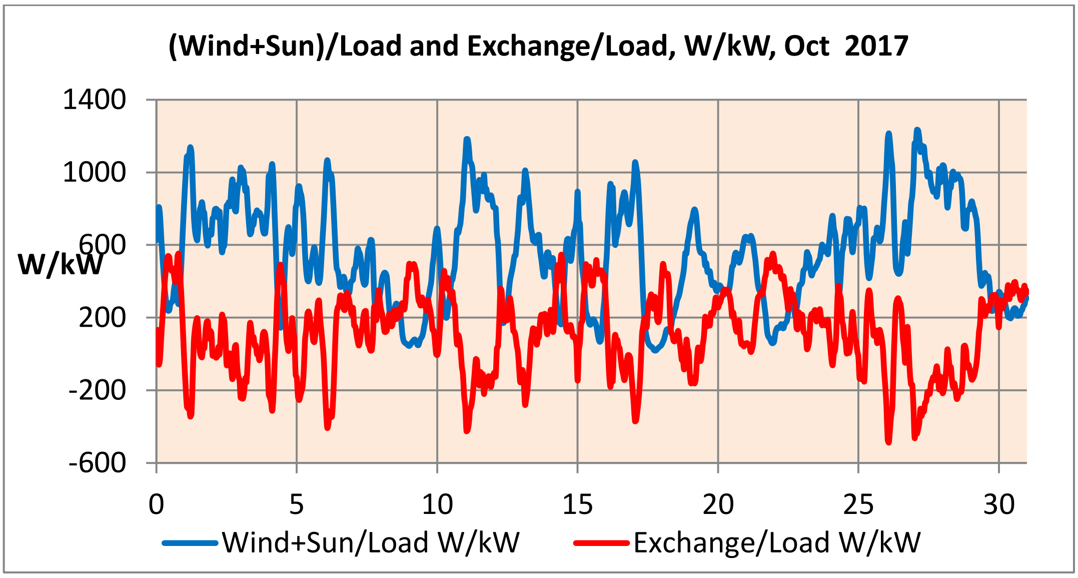
The interdependence between wind and ex/import is very clear

Figure 39



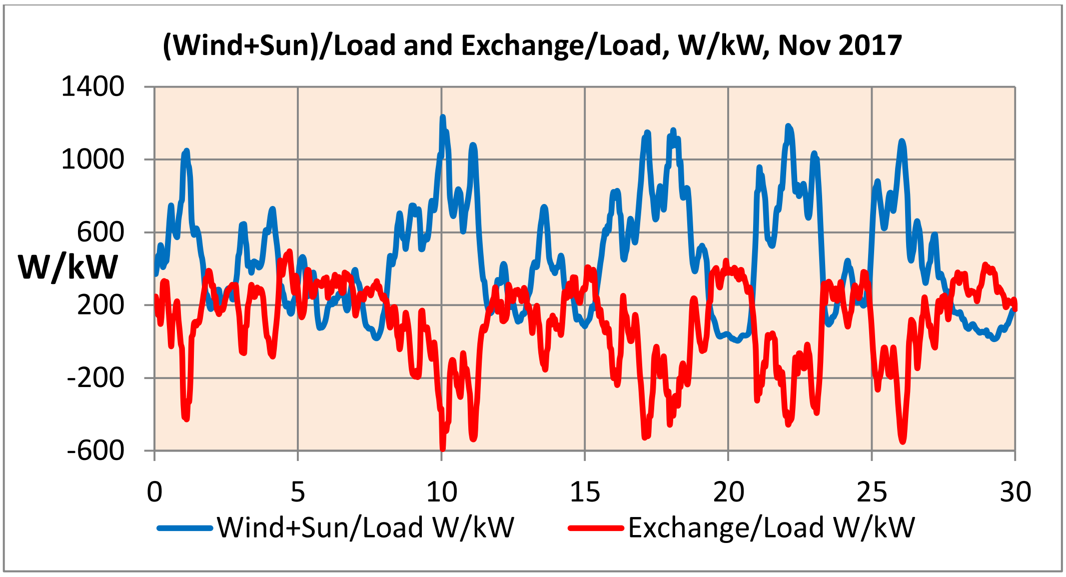
September was a month with a pleasant and not very windy weather.

Figure 40



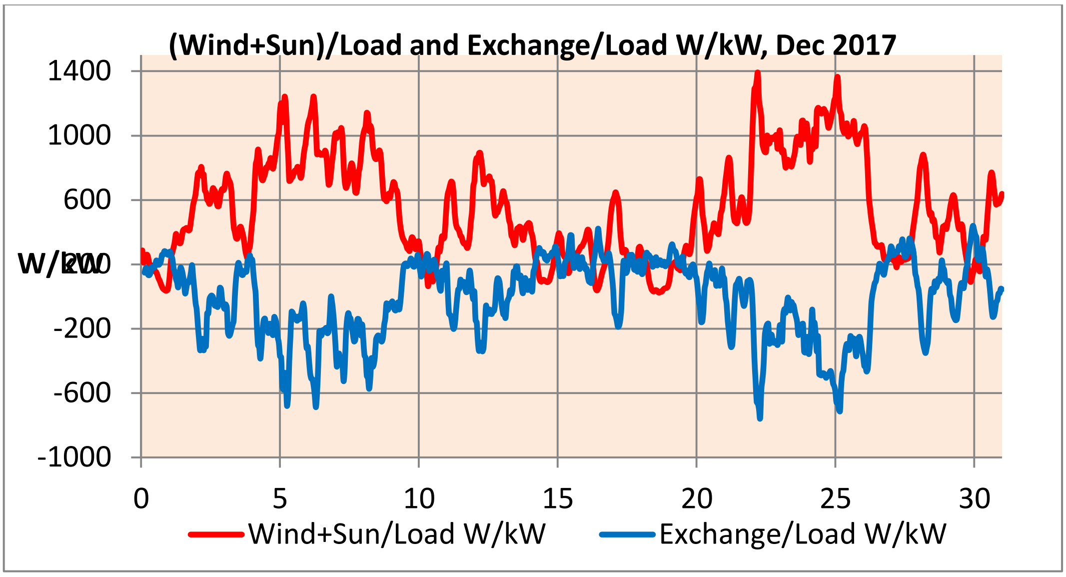
October was more windy than September

Figure 41



In November it is colder, and more wind power is exported because the power stations begin to produce again, see Figures 14 and 15 above.

Figure 42



Exchange with Germany and Norway + Sweden.

The table below illustrates once again how dependent Denmark is of exchange of electricity with the neighbouring countries.

Tabel 20

2017	Jan-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
			Wind MW		
Average	1687	1800	1678	1206	2067
Max	5487	4812	4639	4177	5487
min	3	31	12	3	21
Stddev	1212	1236	1253	953	1219
Observations	8760	2160	2184	2208	2208
Stddev % of average	72	69	75	79	59
			Netto Import, MW		
Average	523	-149	586	1334	308
Max	3339	2073	3326	3339	2397
Min	-2823	-2823	-2207	-2202	-2466
Stddev	1139	1042	1145	849	958
Observations	8760	2160	2184	2208	2208
Stddev % of average	218	-699	195	64	311
			Load MW		
Average	3887	4234	3628	3540	4150
Max	5982	5905	5081	5786	5982
Min	1810	2784	2359	1810	2553
Stddev	780	764	637	682	777
Observations	8760	2160	2184	2208	2208
Stddev % of average	20	18	18	19	19

The mathematically oriented reader will observe, that the standard deviations as per cent of the averages are very different from the wind power, the import and the load, i.e. 72%, 218% and 20% for the whole year, and conclude that with a wind power with that high variation a considerable im- and export must be a necessity.

There is per se nothing wrong with that, as long as our neighbours accept it and the export prices in DK/MWh are comparable with import prices. The author has not been able to find relevant data for the prices per MWh, but assumes that an imported MWh costs considerably more than an exported MWh.

The import/export for every hour is shown in the following graphs. It is observed, that we import electricity when the wind does not blow and vice versa.

Figure 43

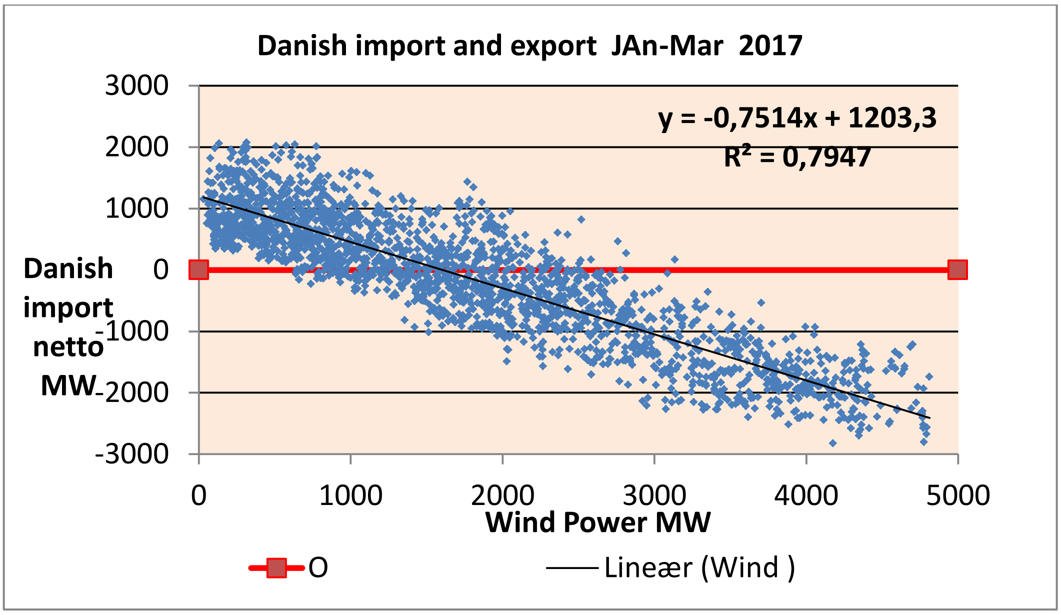


Figure 44

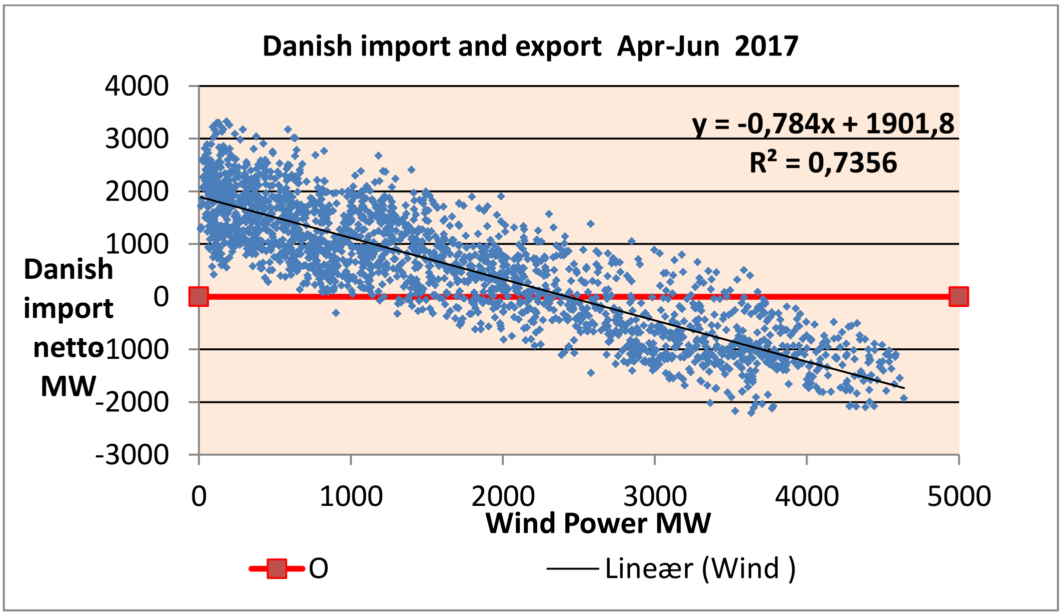


Figure 45

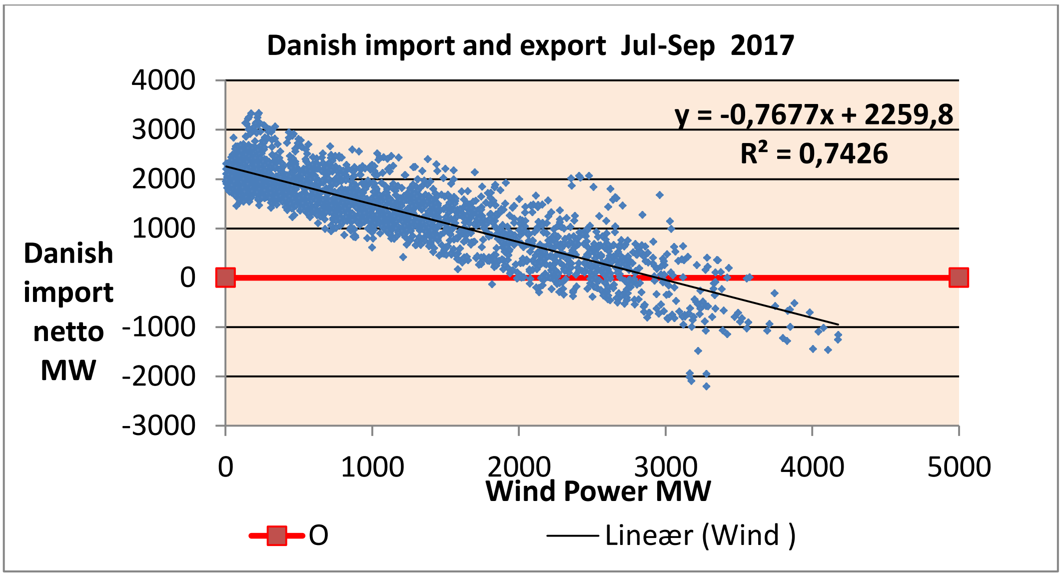


Figure 46

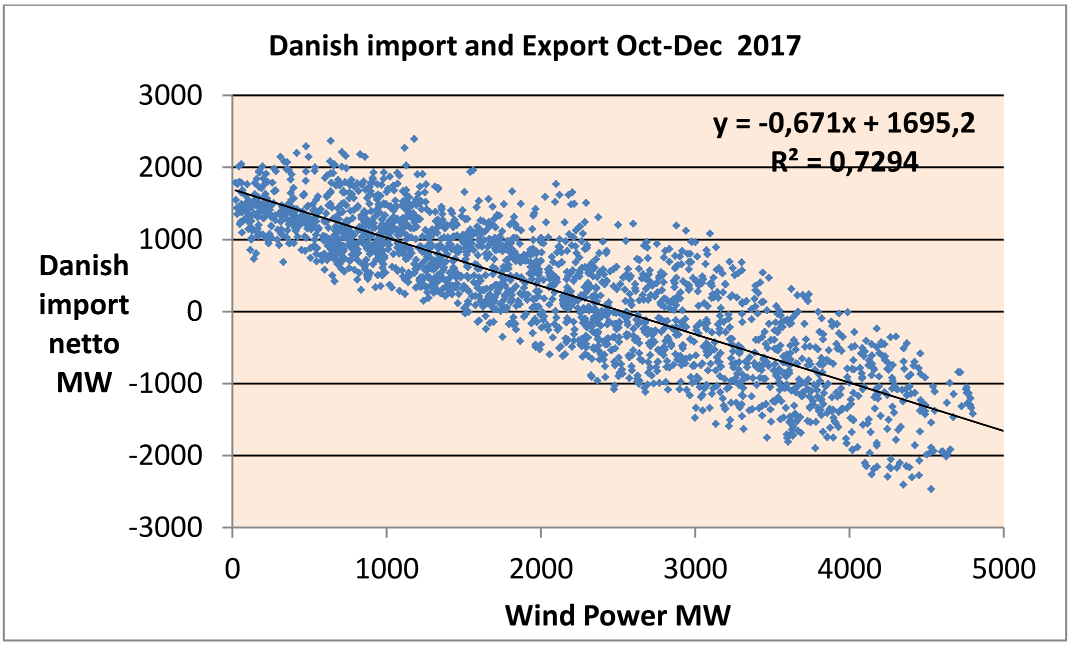
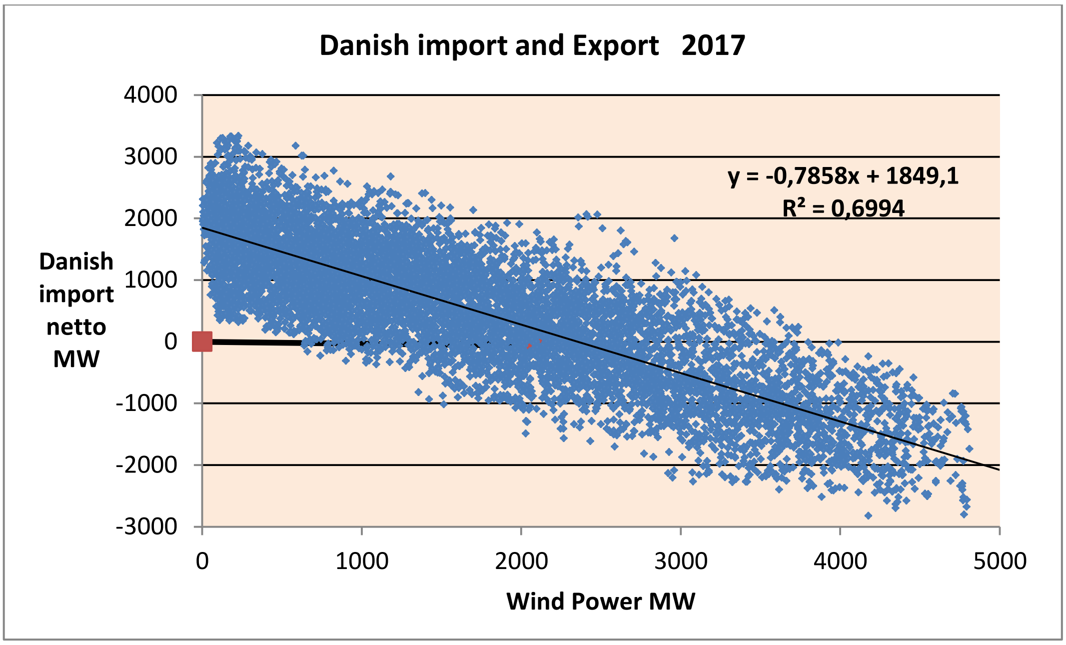


Figure 47



The German wind power is about 3,5 times the Danish, and the German electricity consumption is about 14 times the Danish consumption.

The Danish wind power in 2017 is ca. 44 % of the load. The corresponding German figure for 2016 was 16%.

The author assumes that Germany would come into deep trouble if the German wind power was expanded to the same level as the Danish.

Exchange with Germany and (Norway +Sweden)

Tabel 21

2017	Jan-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
	Exchange with Norway and Sweden, MW				
Average	451	-66	523	1092	235
Max	3180	2073	3180	3007	2213
min	-2706	-2706	-1834	-1466	-2466
Stddev	1001	976	968	822	893
Observ	8760	2160	2184	2208	2208
Stddev% of average	222	-1474	185	**75**	380
	Exchange with Germany, MW				
Average	70	-96	63	233	73
Max	2076	1506	2076	1991	1873
min	-1747	-1747	-1572	-1029	-1149
Stddev	417	286	497	437	303
Observ	8760	2160	2184	2208	2208
Stddev% of average	593	-300	785	188	414

It is easily seen that the exchange with Norway and Sweden is much larger than the exchange with Germany.
The conclusion is evident: Neighbouring Countries with a large wind power production can't assist each other against the problems arising from the varying wind power.
It will be shown later, that the Danish wind power works well together with the Scandinavian hydro power, but only as long as we do not have to compete with Germany and other countries about this back up resource, and as long as Sweden keeps her nuclear power stations operating.

Figure 48

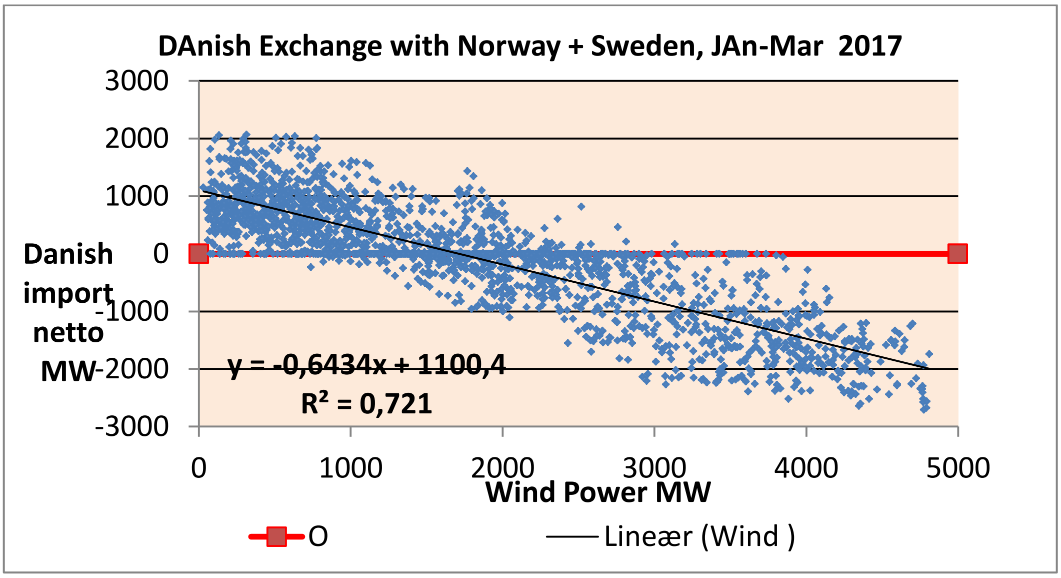


Figure 49

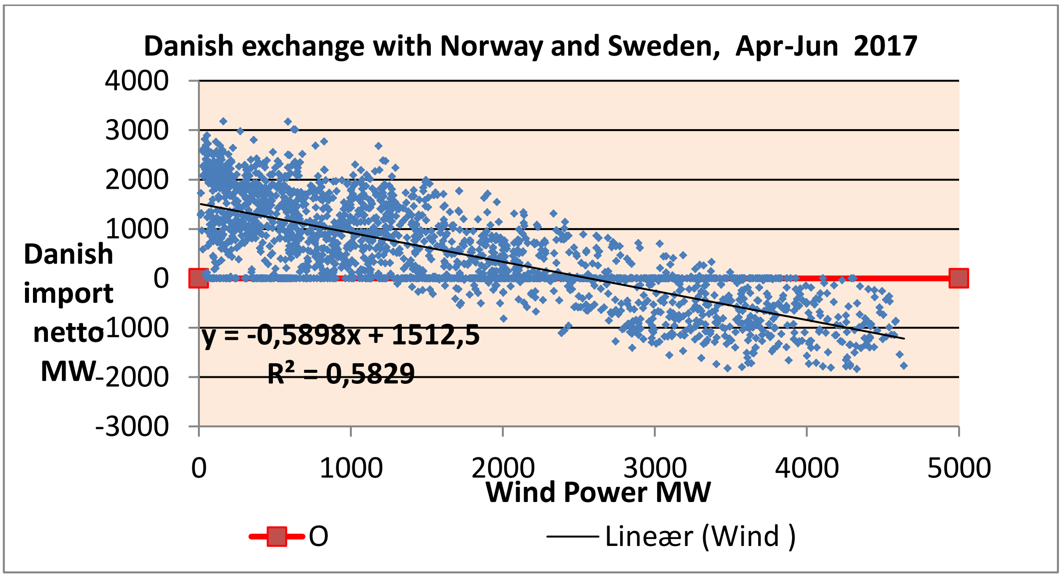


Figure 50

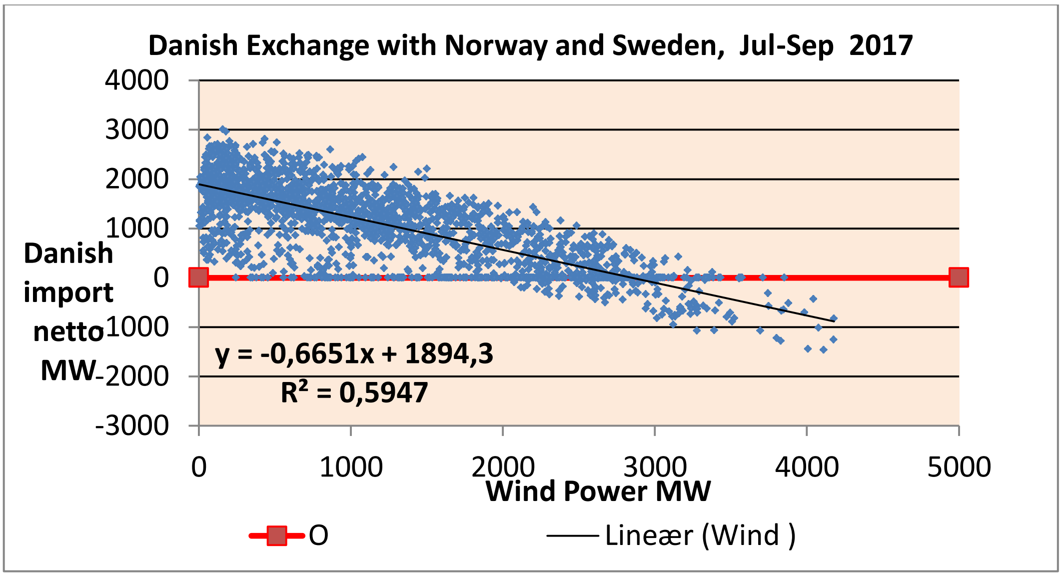


Figure 51

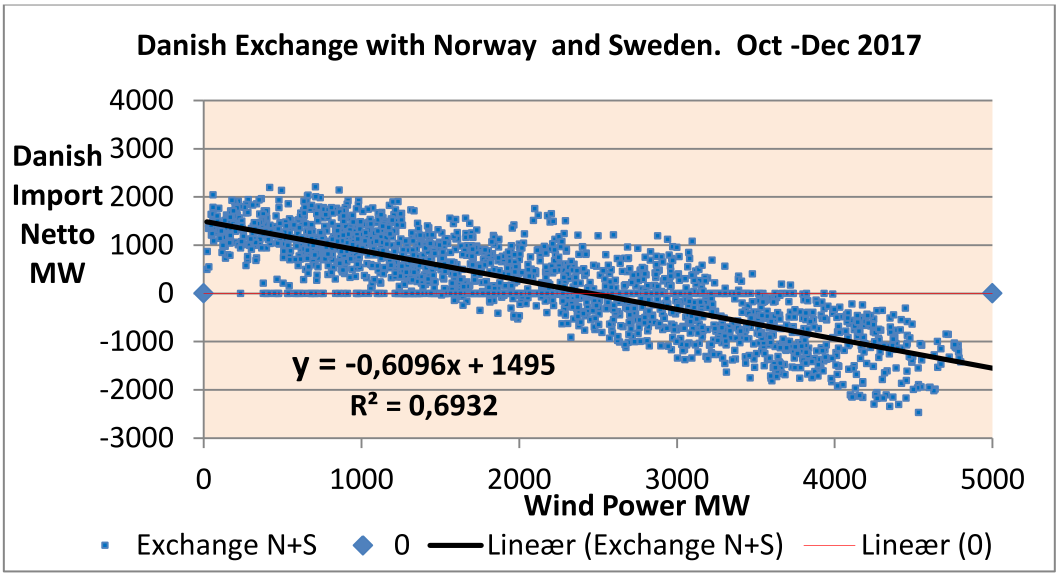


Figure 52

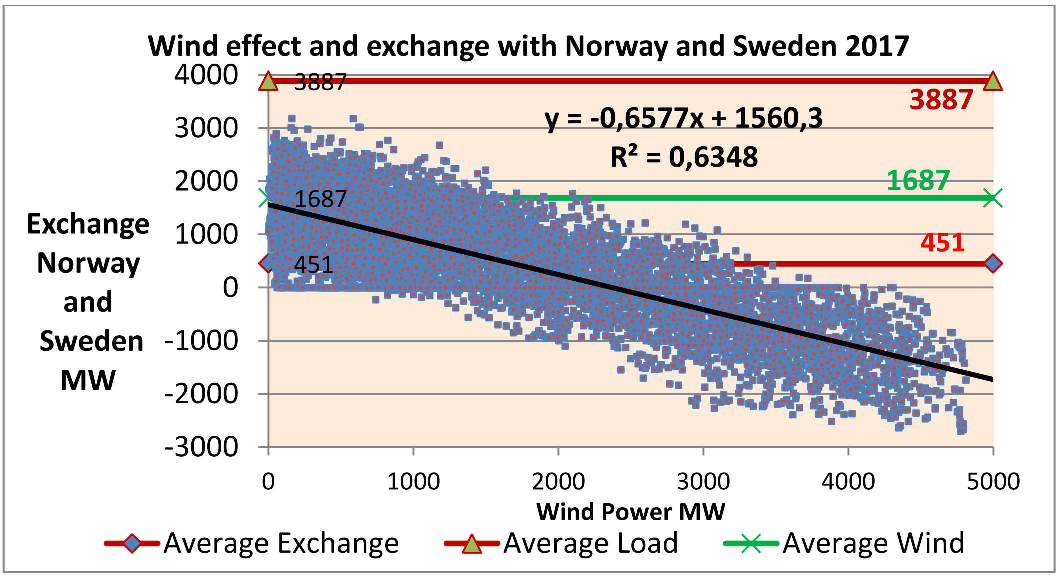
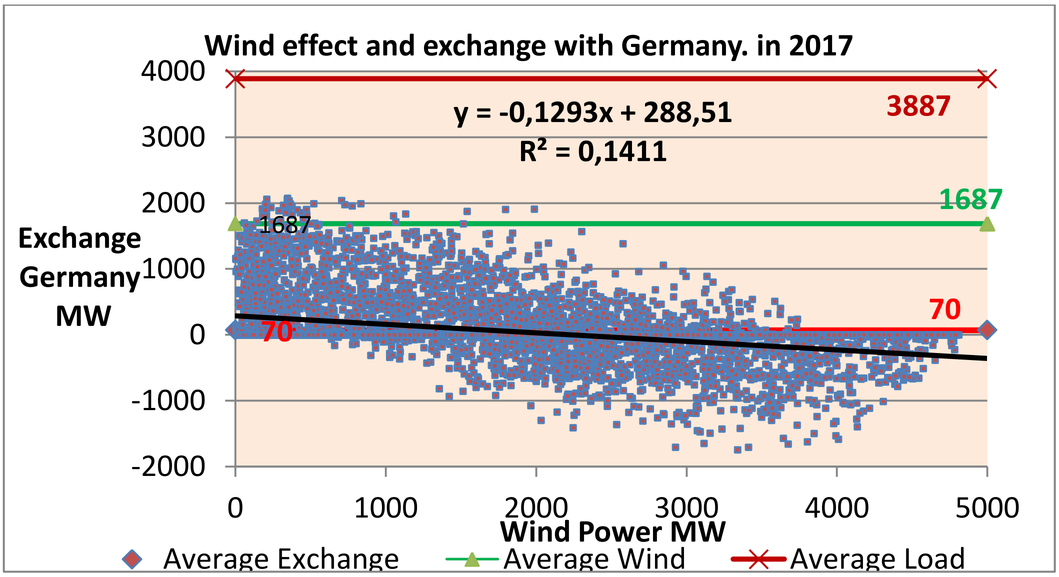


Figure 53



There is a very weak correlation between Danish wind power and the exchange with Germany, for the simple reason that when the wind blows in Denmark it blows in Germany too, and vice versa.

The Graphs show very clearly that we import electricity from Norway and Sweden when there is no or little wind power and export when the wind is blowing. So it is a relevant question if it is reasonable to expand the wind power capacity. Swedes and Norwegians have no reason what so ever to pay very much for the Danish wind power.

Regression equations:

Y = Exchange, MW
X = Wind Power, MW

Norway and Sweden 2017

$$Y = -0{,}658 -1560$$

Germany 2017

$$Y = -0{,}129X + 288$$

Wind Power and Exchange

The following graphs and tables show the Wind Power, Exchange, Import and Export in MW for the months January to November 2017.
It is seen that the Danish Wind Power is unthinkable without the sometimes very considerable exchange with our neighbours. Sometimes we import a very high proportion of the load and sometimes we export. The "exchange" in these tables equals (import –export).

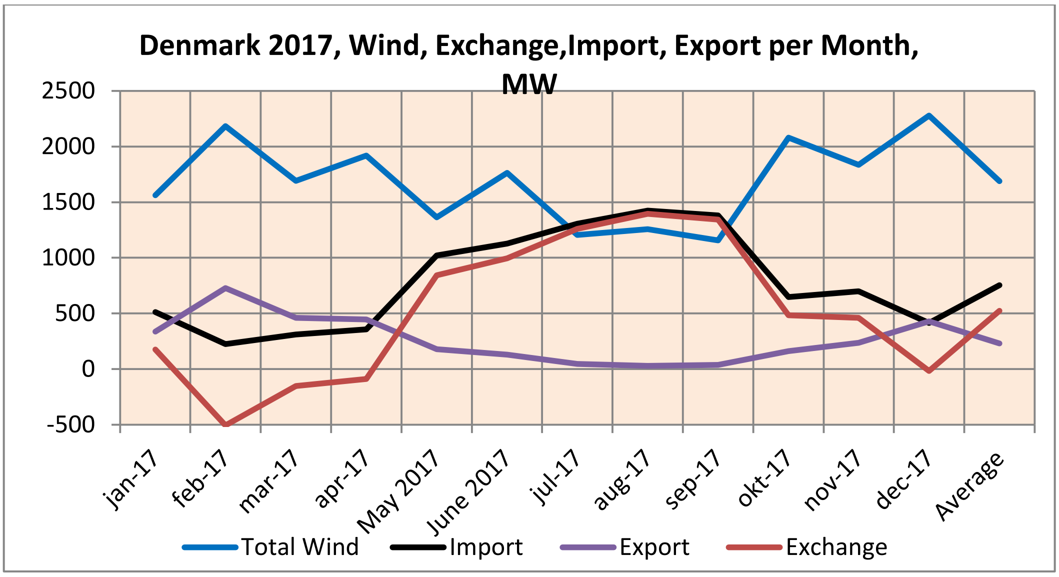
Tabel 22

Denmark, 2017, Total Wind and Export and Import, Average MW per period				
	Total Wind	Exchange	Import	Export
jan-17	1561	175	511	336
feb-17	2183	-506	223	729
mar-17	1692	-151	310	461
apr-17	1917	-90	357	447
may-17	1364	843	1022	180
jun-17	1765	997	1127	130
jul-17	1204	1261	1307	46
aug-17	1257	1395	1425	29
sep-17	1156	1345	1382	37
okt-17	2079	485	647	163
nov-17	1836	461	698	237
dec-17	2278	-16	415	430
Average	1687	525	755	230
Max	2278	1395	1425	729
Min	1156	-506	223	29

The Max and Min values are to be understood as max or min monthly average.
Thus on average the wind power in January was 1561 MW and in February 2183 MW.
So we are very dependent on Scandinavian Hydro Power,

We exported power in the months February, March, April and December and imported in the rest of the time.

Figure 54

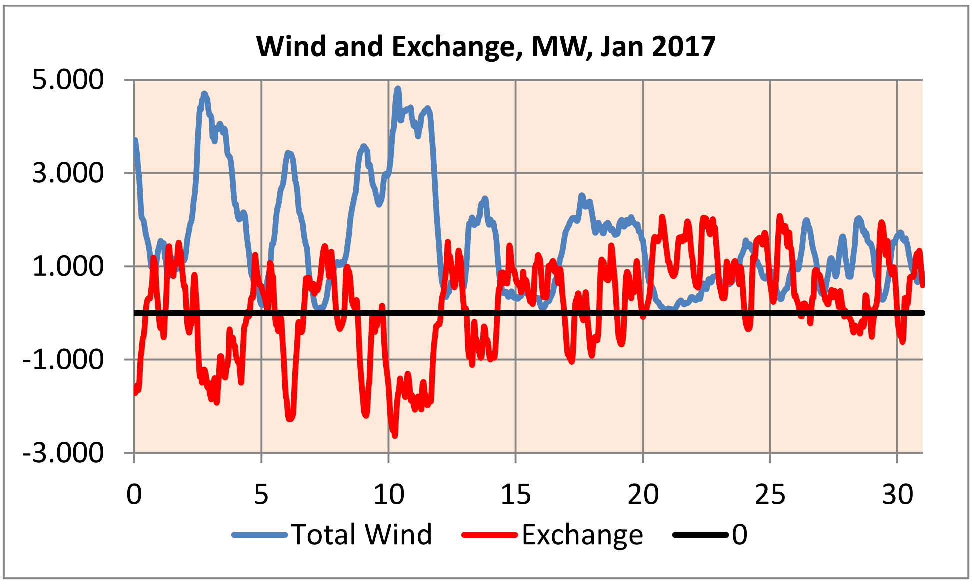


It is clearly seen, that the main part of the import takes place in the summer months. When it is cold we must start our power plants to cover the need for district heating, And Norway and Sweden need more electricity for heating.
You can't count on higher wind power in the cold months. In January the average wind power was 1561 MW and in June 1765 MW.
Denmark can only hope that the Sweden keeps her nuclear power. If Sweden exchanges nuclear power for wind the hydro power must fluctuate opposite to the wind power, and there would hardly be anything left for Denmark.

Tabel 23

jan-17	Total Wind	Exchange	Import	Export
Average MW	1561	175	511	336
Max MW	4812	2073	2073	2638
Min MW	71	-2638	0	0
Stddev Mw	1169	1013	570	598

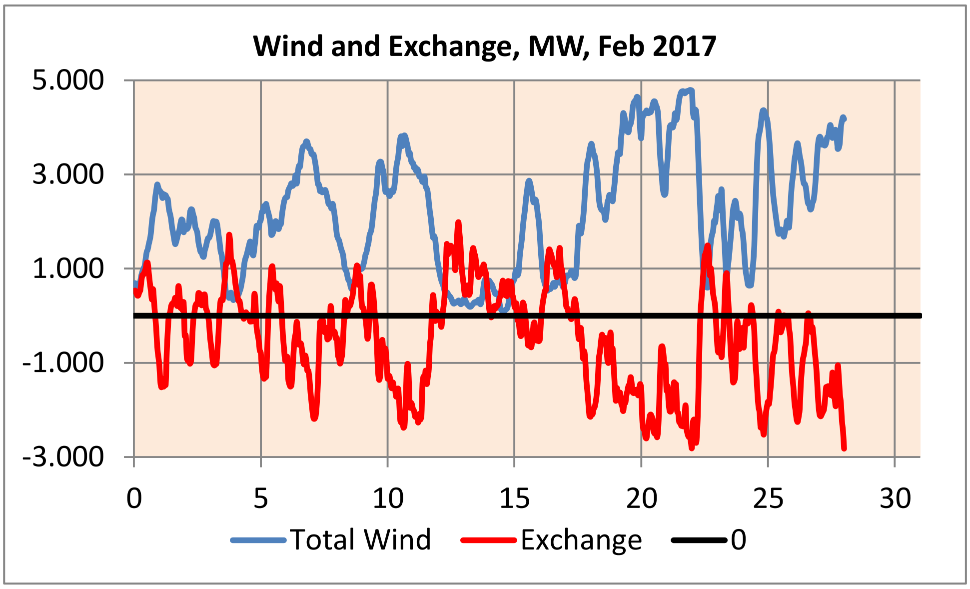
Figure 55



Tabel 23

feb-17	Vind	Exchange	Import	Export
Average	2183	-506	223	729
Max	4795	1989	1989	2823
Min	84	-2823	0	0
Stddev	1256	1076	398	820

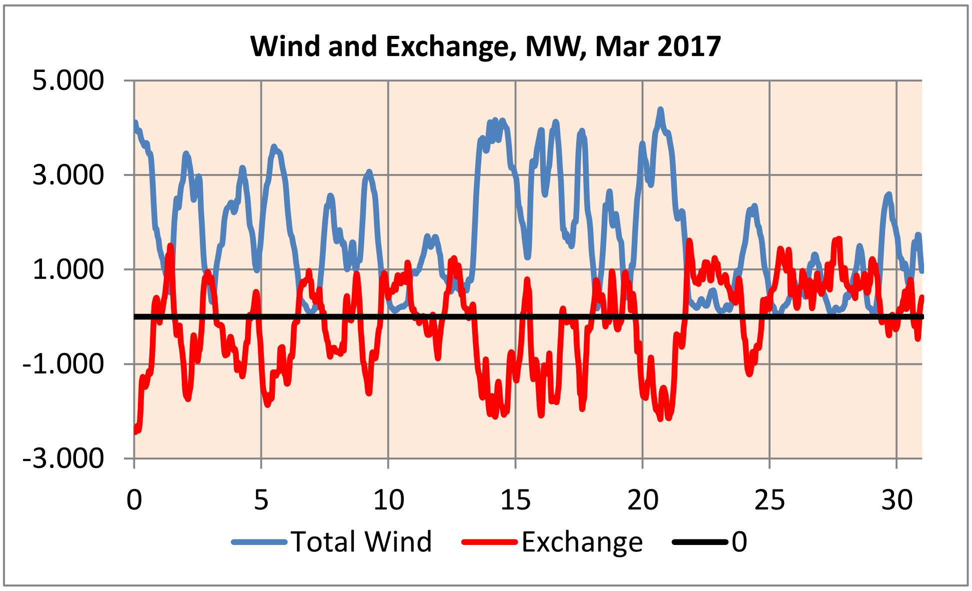
Figure 56



Tabel 24

mar-17	Vind	Exchange	Import	Export
Average	1692	-151	310	461
Max	4392	1646	1646	2444
Min	31	-2444	0	0
Stddev	1203	929	407	641

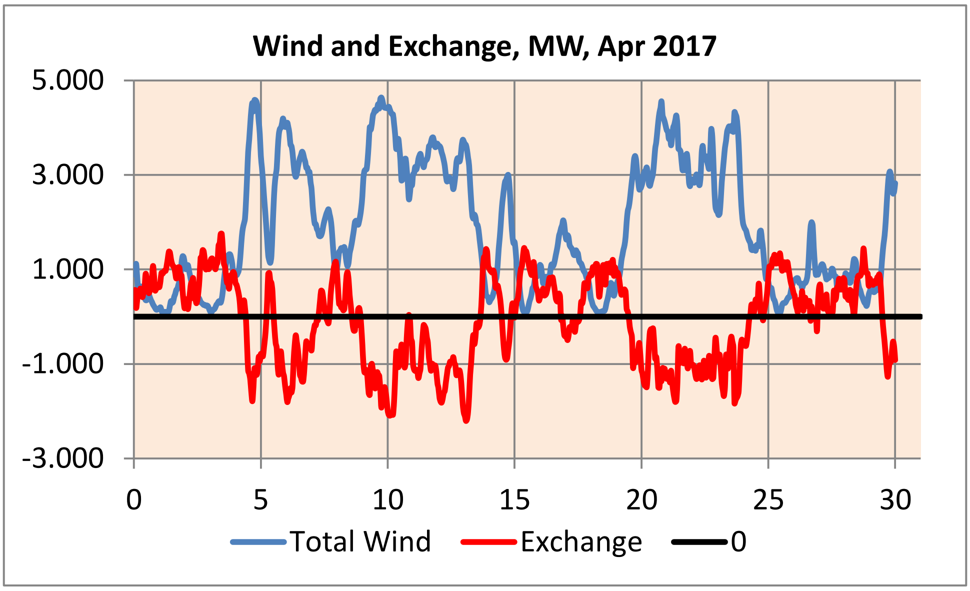
Figure 57



Tabel 25

April 2017	Vind	Exchange	Import	Export
Average	1917	-90	357	447
Max	4639	1754	1754	2207
Min	56	-2207	0	0
Stddev	1341	926	436	590

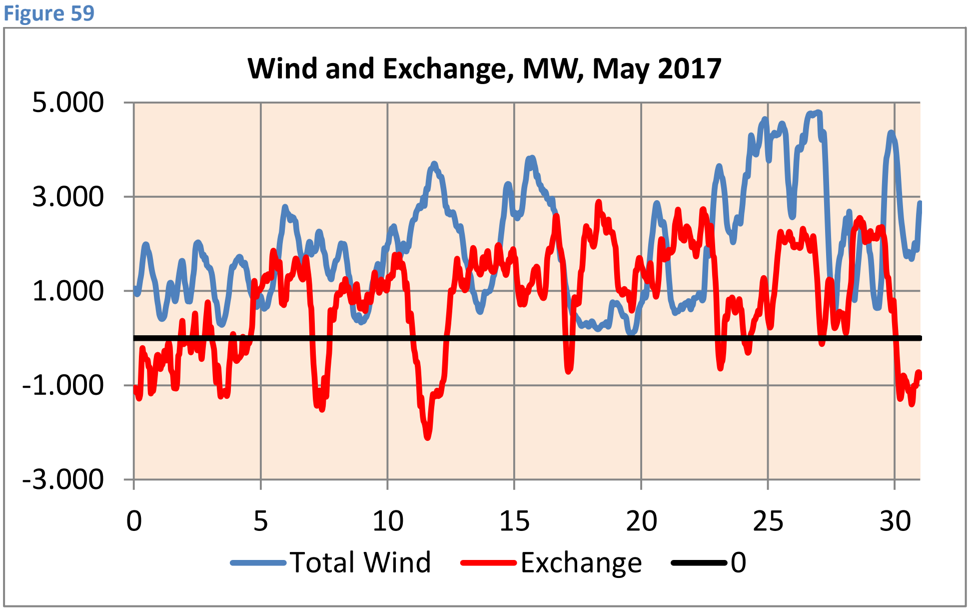
Figure 58



Tabel 26

May 2017	Vind	Exchange	Import	Export
Average	1364	843	1022	180
Max	4545	2894	2894	2119
Min	12	-2119	0	0
Stddev	1177	1096	822	397

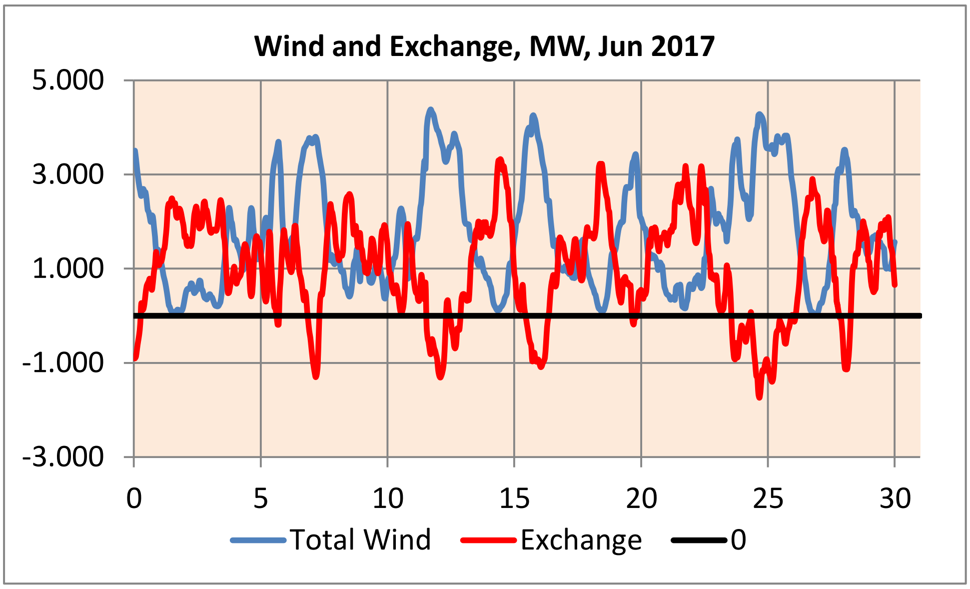
Figure 59



Tabel 27

June 2017	Vind	Exchange	Import	Export
Average	1765	997	1127	130
Max	4383	3326	3326	1740
Min	27	-1740	0	0
Stddev	1172	1092	890	323

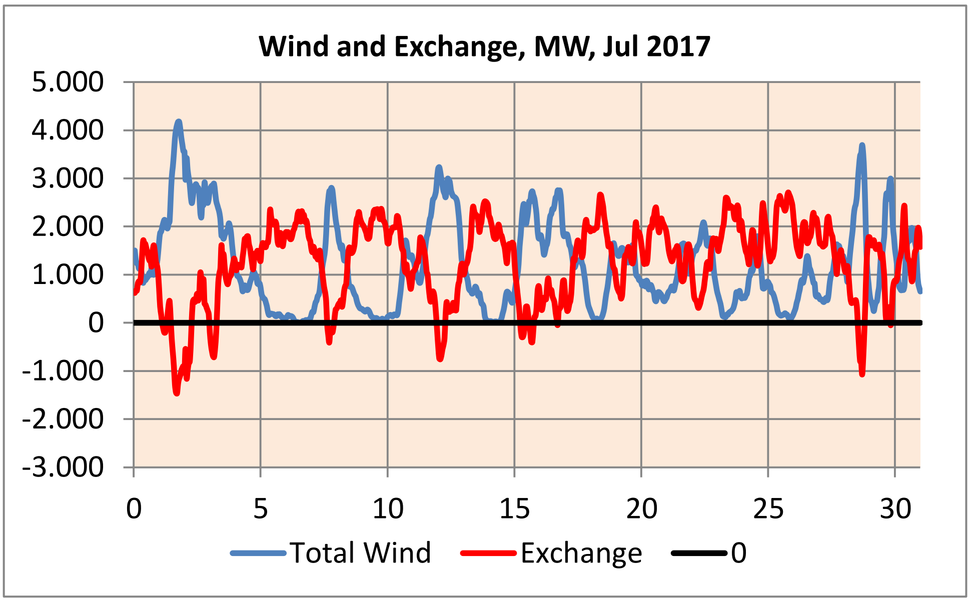
Figure 60



Tabel 28

July 2017	*Vind*	*Exchange*	*Import*	*Export*
Average	*1204*	*1261*	*1307*	*46*
Max	*4177*	*2707*	*2707*	*1466*
Min	4	-1466	0	0
Stddev	918	830	731	188

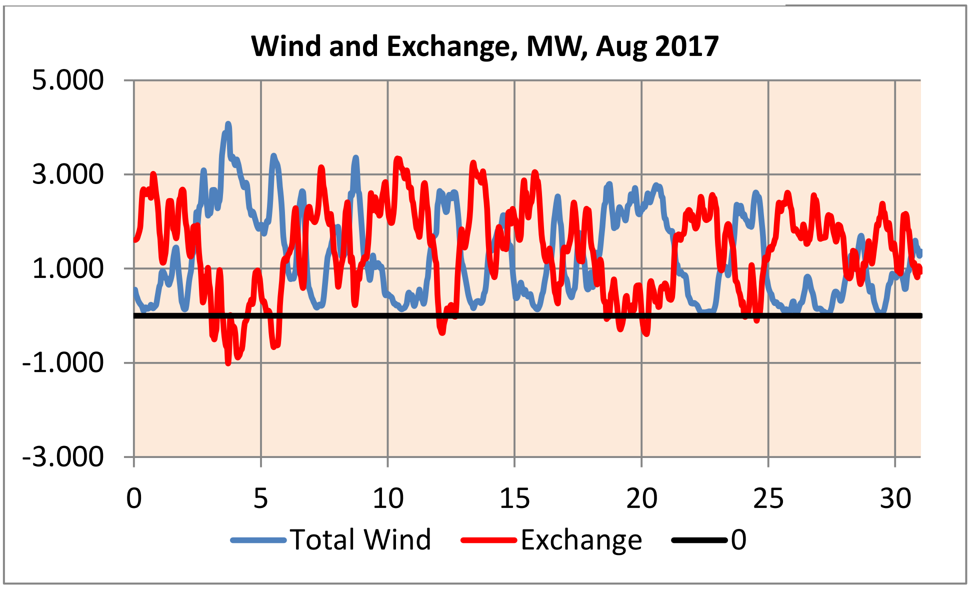
Figure 61



Tabel 29

August 2017	Vind	Exchange	Import	Export
Average	1257	1395	1425	29
Max	4076	3339	3339	1014
Min	50	-1014	0	0
Stddev	938	932	877	123

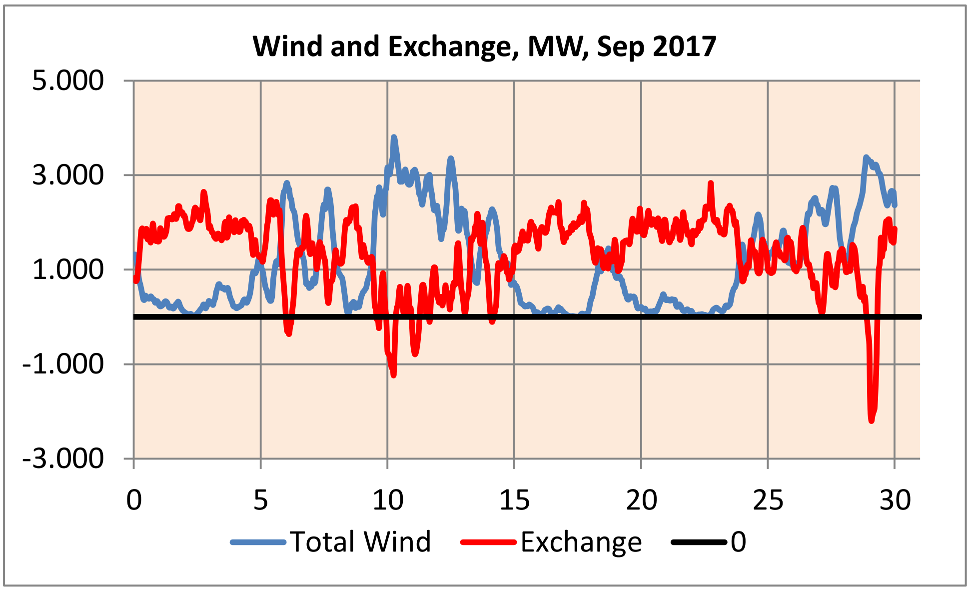
Figure 62



Tabel 30

sep-17	Vind	Exchange	Import	Export
Average	1156	1345	1382	37
Max	3801	2835	2835	2202
Min	3	-2202	0	0
Stddev	1001	771	668	214

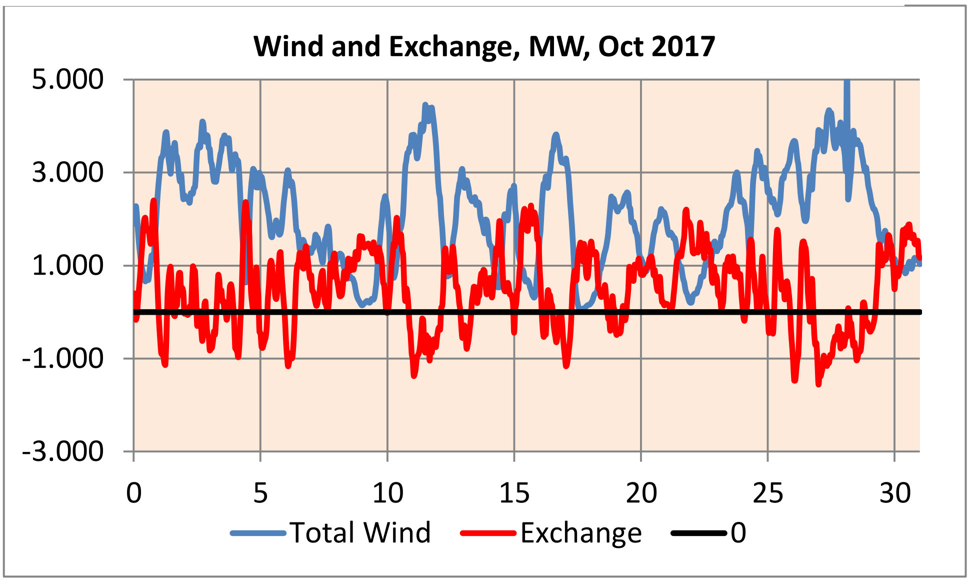
Figure 63



Tabel 31

October 2017	Vind	Exchange	Import	Export
Average	2079	485	647	163
Max	5487	2397	2397	1553
Min	58	-1553	0	0
Stddev	1097	839	624	322

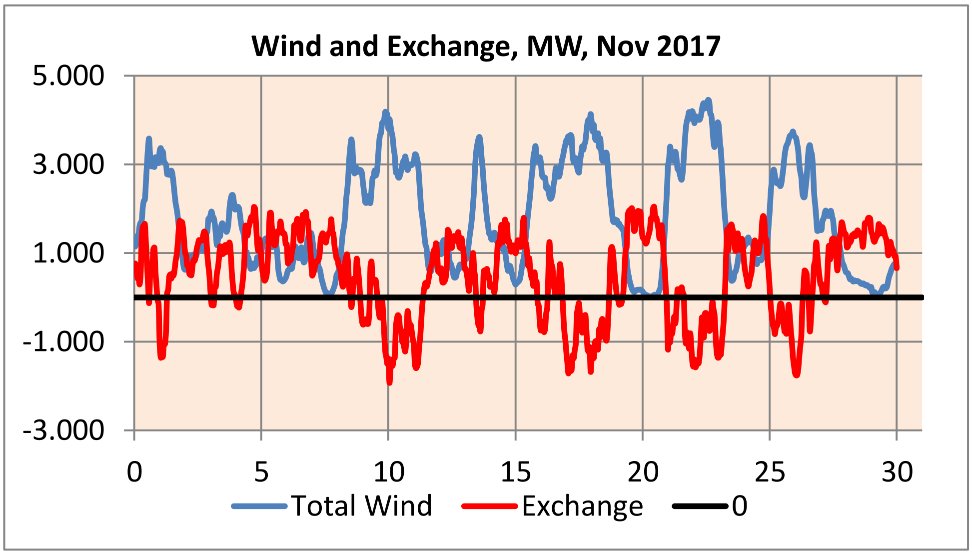
Figure 64



Tabel 32

November 2017	Wind	Exchange	Import	Export
Average	1836	461	698	237
Max	4460	2044	2044	1926
Min	21	-1926	0	0
Stddev	1209	962	631	443

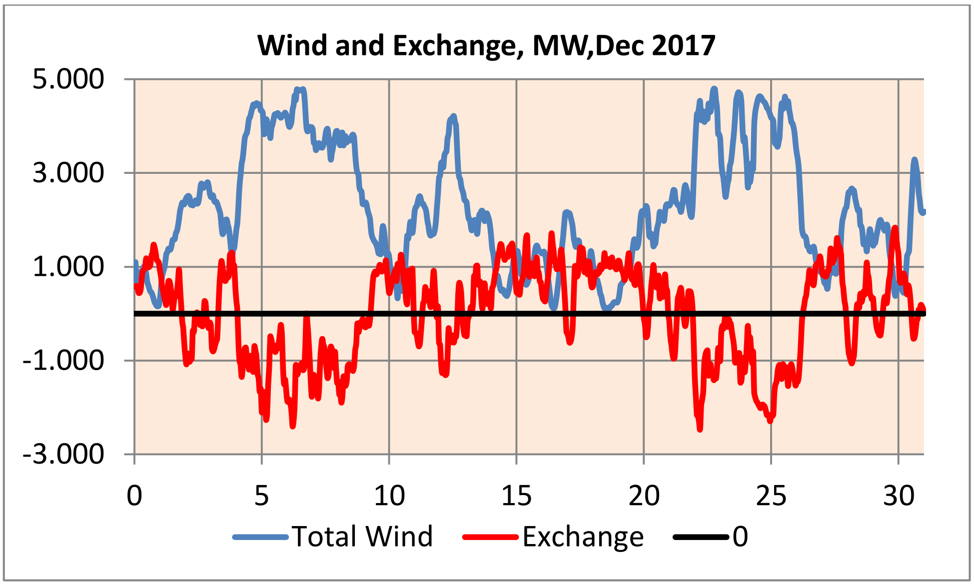
Figure 65



Tabel 33

December 2017	Vind	Exchange	Import	Export
Average	2278	17	2295	1984
Max	4800	313	4800	4161
Min	104	0	128	610
Stddev	1304	43	1300	660

Figure 66



Wind and Sun Power Variation per Hour, Day, Week and Month

Tabel 34

Average, Max and Min, Wind, Sun and (wind + Sun) power. Denmark 2017.						
	Per Hour			Per Day		
	Wind	Sun	Wind+sun	Wind	Sun	Wind+sun
Average MW	1687	90	1777	1687	90	1777
Max MW	5487	673	5487	4419	247	4492
Min MW	3,5	0	11	54	3,5	188
Stddev MW	1212	145	1214	1075	65	1062
Max/Min	1568	∞	503	82	71	24
	Per Week			Per month		
Average MW	1687	90	1777	1687	90	1777
Max MW	3403	213	3425	2306	164	2323
Min MW	315	8,4	443	1159	17	1265
Stddev MW	625	56	608	405	55	375
Max/Min	11	26	7,7	2,0	9,8	1,8

It is well known that wind and sun varies from hour to hour and from day to day. It may be less realized that there are significant variations over longer periods.
For instance the wind power per hour varies with a factor 1568, the daily average varies with a factor 82, (between 4419 and 54 MW), the weekly average with a factor 11 (between 315 and 3403 MW) and the monthly average with a factor 2,0 (between 1159 and 2306 MW)

For instance wind + sun yielded 334 GWh in week 3+4 and 948 GWh in week 8+9. **The difference is 612 GWh. This corresponds to 6000 of Elon Musk's much praised battery in Southern Australia and a cost of 300 billion US$! Or about 55000 US$ per capita.**

334 GWh/2weeks corresponds to 994 MW and 948 GWh in to weeks to 2821 MW.
Denmark's total (total not only electricity) effect consumption in 2016 was 25.200 MW. The total electricity consumption is a little less than 4 GW.

So it may be concluded, that a fossil free society based on wind power is a distant dream.

Figure 67

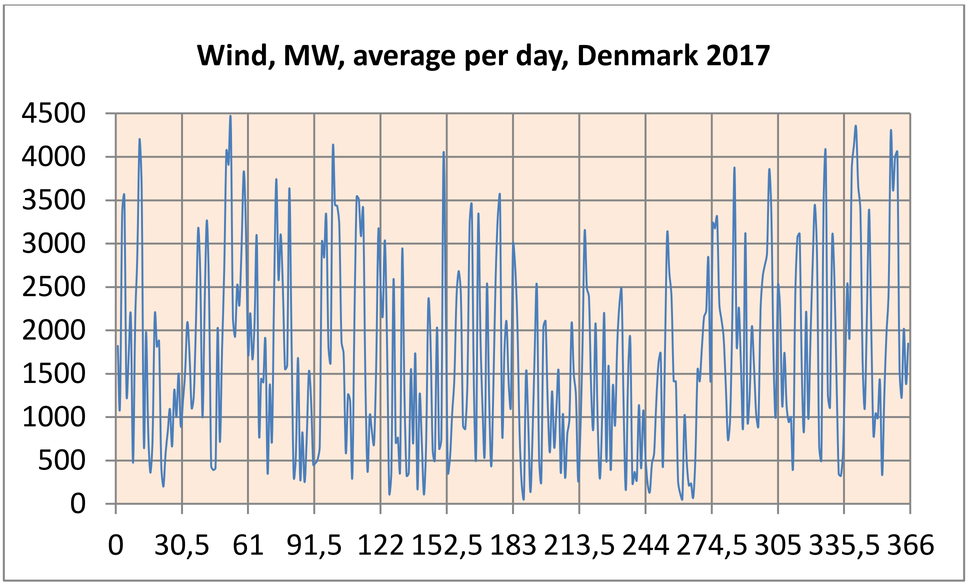


Figure 68

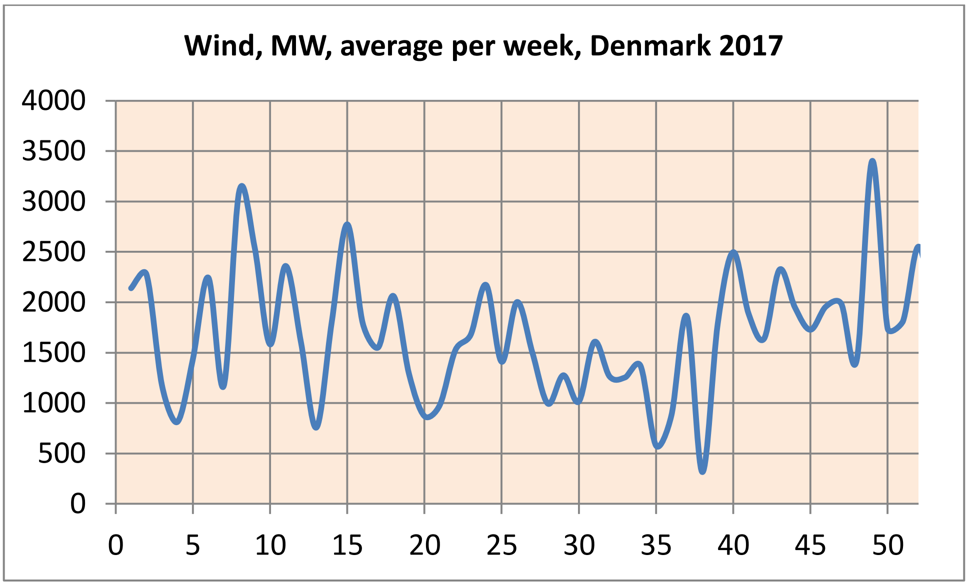


Figure 69

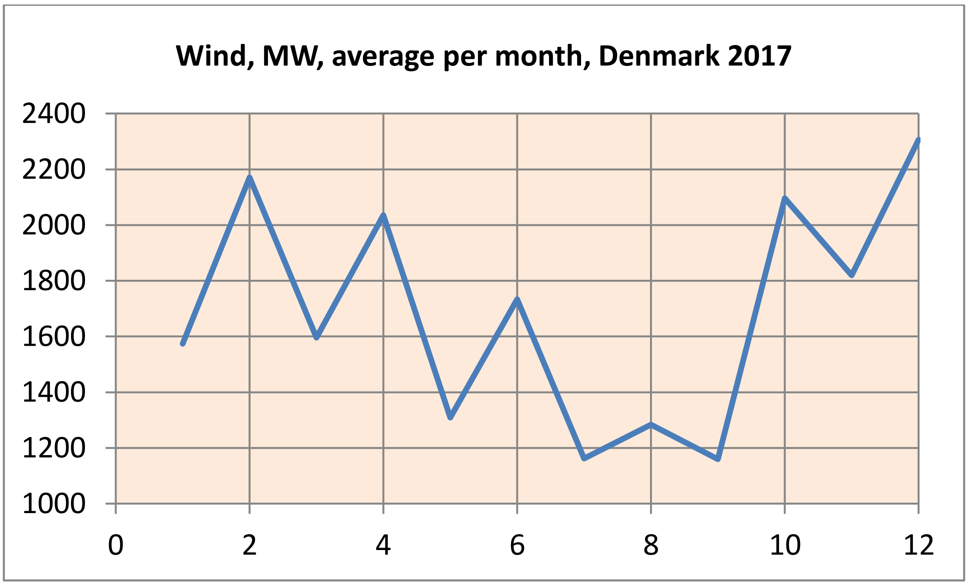


Figure 70

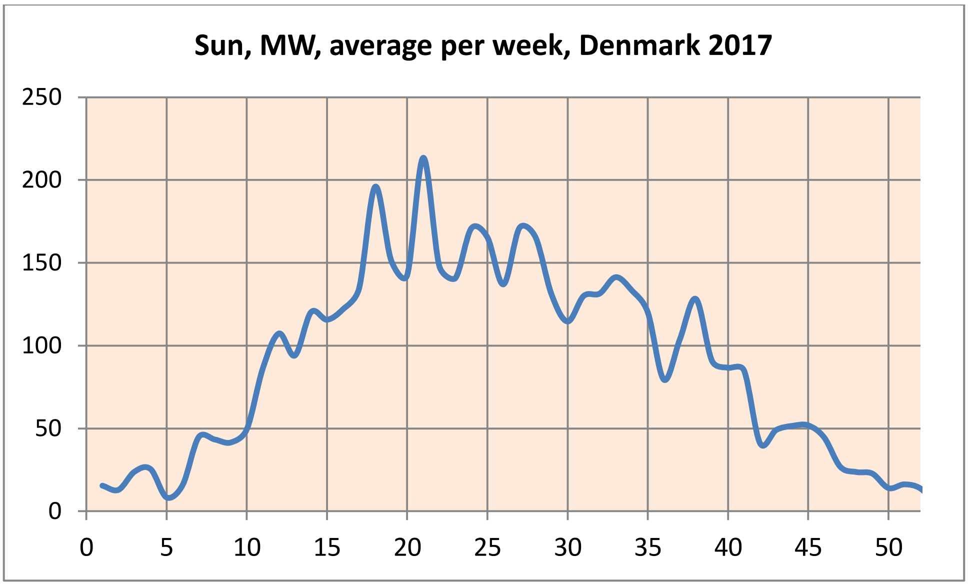


Figure 71

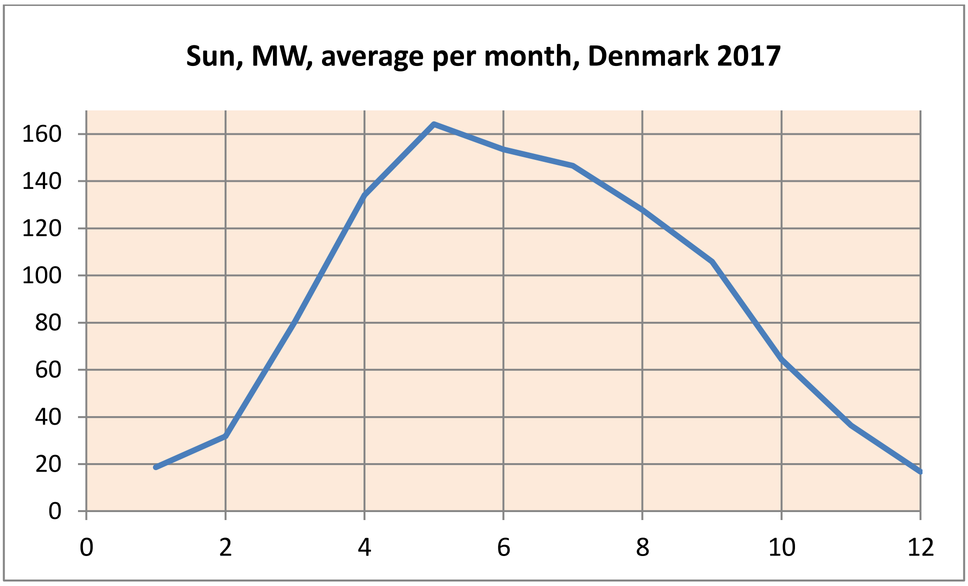
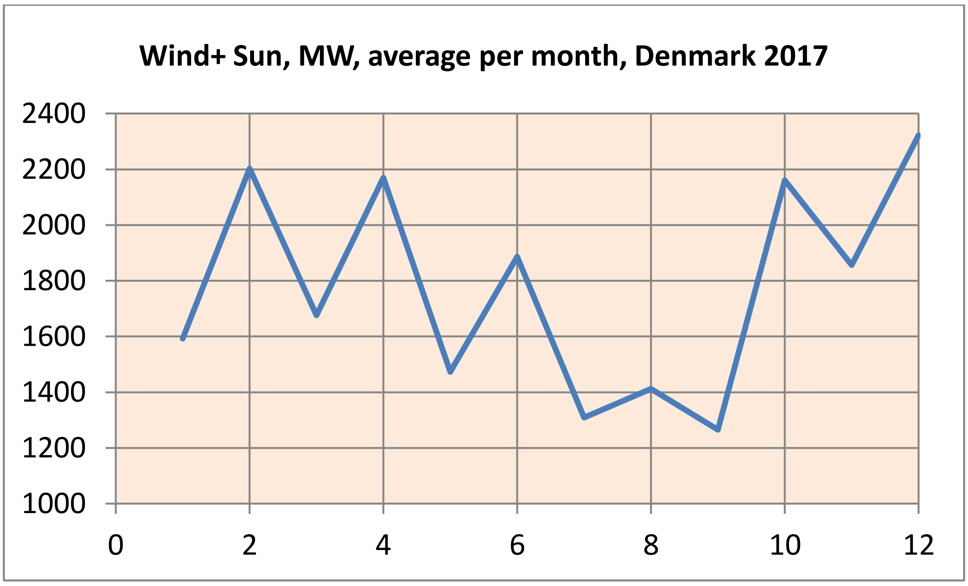


Figure 72



It is interesting to compare the Danish curve showing averages per week with the corresponding curve for Germany + United Kingdom +France.

However, the German system is much larger than the British and the French, so a direct comparison does not make sense. But if you divide the single figures for the wind effect with the yearly average and multiply by 1000 you get the value W/kW average production, and then you can compare.

Tabel 35

Wind Power, in Germany, Uk and France in 2016

	MW				Normalized W/kW average				
	DE	GB	FR	Sum	DE	GB	FR	Sum	Sum/3
Average	8765	2412	2232	13408	1000	1000	1000	3000	1000
Max	33626	7833	8050	45053	3837	3248	3607	9081	3027
Min	135	66	330	887	15	27	148	302	101
Stddev	6865	1578	1583	8680	783	654	709	1721	574
Observations	*8784*	*8784*	*8784*	*8784*	*8784*	*8784*	*8784*	*8784*	*8784*
Stddev % of av.	*78*	*65*	*71*	*65*	*78*	*65*	*71*	*57*	*57*

Figure 73

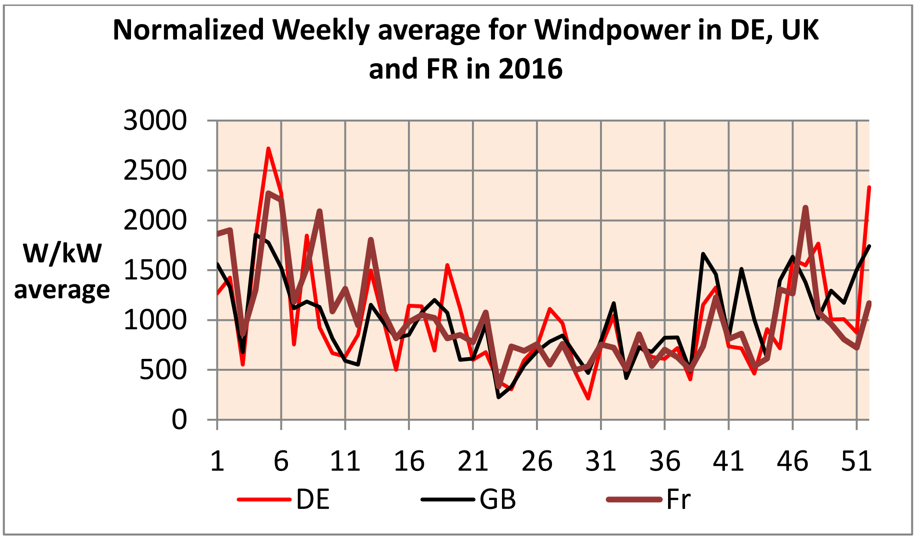
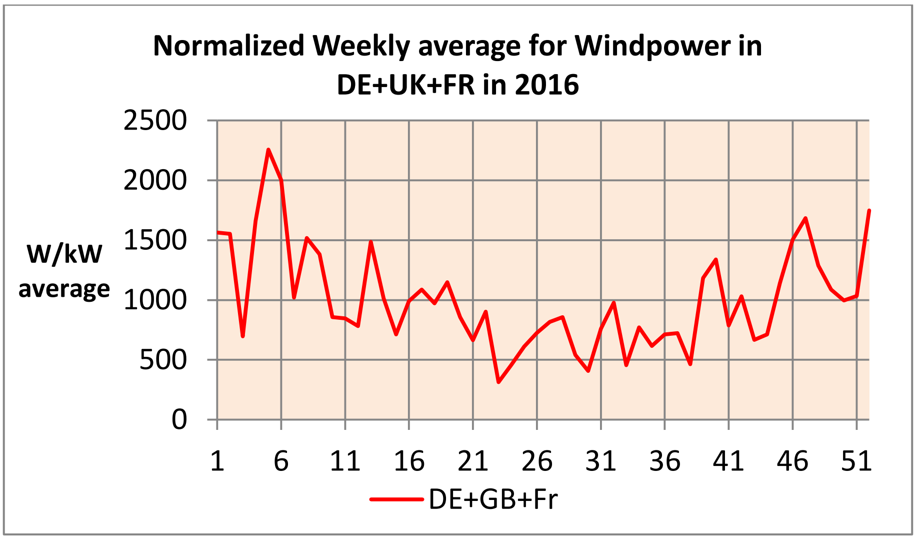


Figure 74



It should be very easy to see, that it is not true, that “it always blows somewhere”. This is illustrated by the following considerations concerning a cable between Denmark and England.

Storage of Wind energy

When we wish to calculate the magnitude of a storage for the fluctuating wind energy, it is necessary to choose the conditions for this calculation.
We have chosen a model where the output from the wind power+storage is kept constant. Not very realistic of course. As long as we have other options for producing electricitythe building of large storages is definitely not preferable. Nevertheless the matter is frequently discussed, so it gives meaning to try to create an idea of the magnitude of the task.
The calculations are performed under the following condition:

1. When the wind power is higher than the yearly average times a constant **F t**he wind energy above this level is brought to the storage.

2. When the wind power is lower than the yearly average times the constant **F** the storage delivers electricity back to the system.

3. The constant **F** depends of the loss by storing and recovering. If there was no loss the Constant would have the value **1.**

4. The contents of the storage at start shall equal tee storage at the end.

5. The contents of the storage has a minimum of 0.

Given these conditions the excel program calculates **F**, the storage contents at any time and the input to and the output from the storage.

The results are shown in the table 35 and 36 below.

Tabel 36

Wind Denmark 2017		To Reservoir	To reservoir after losses	From Reservoir	Regene-rated Power	Resulting Power	Reservoir content GWh
	MW	MW	MW	MW	MW	MW	GWh
Average	1687	536	509	509	484	1635	807
Max	5487	3852	3659	1718	1632	1635	1409
Min	4	0	0	0	0	1635	0
Stddev	1212	797	757	592	562	0	372
Observations	8760	8760	8760	8760	8760	8760	8760

On average 536 MW are transferred to the storage. The variation is considerable, between 0 and 3852 MW. It must be added, that the loss by limiting the transfer capacity are so small that this capacity can be reduced.

The variation in the transfer from the storage varying between 0 and 1718 MW is much lower.

Tabel 37

Loss by storing	**Wh/kWh input**	***50***
Loss by reproduction		***50***
Loss totally		97,5
Storage Efficiency		902,5
	MW	52
Loss	%	3,1
	GWh/year	455
Storage capacity	Future reservoir	Vianden in Luxem-bourg
GWh	**1409**	**5**
hrs of average production	**835**	**3,0**
Max input MW	**3852**	1040
Max Output MW	**1632**	1290
Condition 1: To reservoir - From reservoir =		**0**
Condition 2: Minimum storage content =		**0**
Calculated factor		**0,9692**
Storage Start of Period	**GWh**	**899**

Tabel 37 shows that the calculated loss is 455 GWh/year. By an electricity price of 100€/MWh this amounts to 45,5 Mio €/year. A loss of 19 % is more realistic and results in a loss of 934 GWh/year corresponding to 93,4 Mio €/year.

A lower efficiency gives a lower total output, but it will not require a larger storage. Some say that it would be cheaper to build more wind turbines than to establish a storage. That is true.But as in seen from table 36 showing the Danish Wind power in 2017 this could impossibly solve any problem since even an unlimited amount of wind turbines would not guaranty a power supply sometimes being approximately zero.

We would need a storage capacity of about 1400 GWh corresponding to 4% of the Swedish hydro system. This storage could surely not be found in Denmark.

And a capacity of 280 times Vianden in Luxemburg, the largest pumped storage system in Europe.

Some may wonder that the loss is only 3 % of the produced wind power. That is because only a part of the produced wind power is stored.

Figure 75

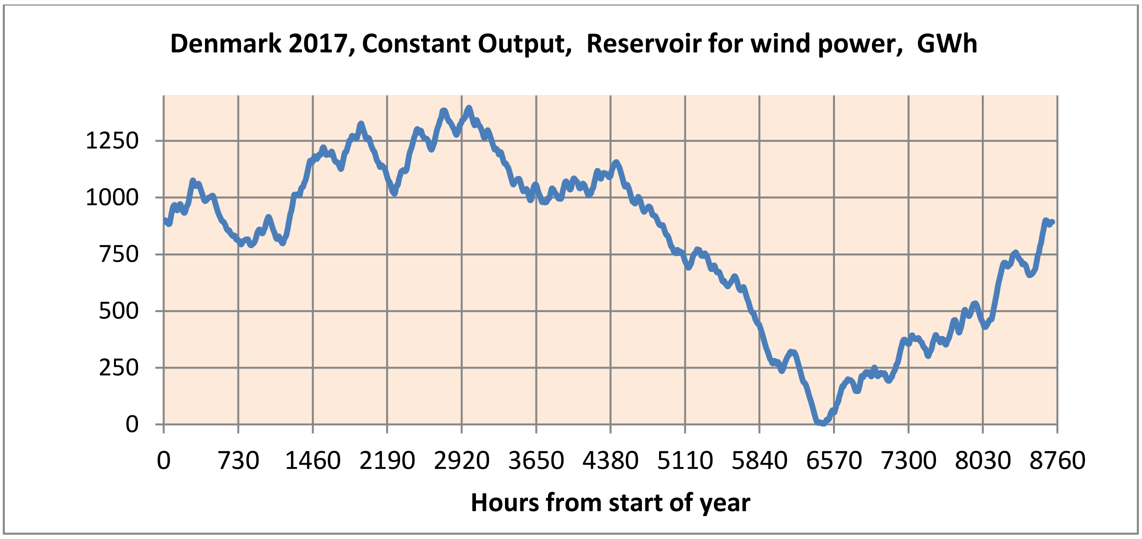


Figure 75 illustrates the variation of the storage contents

Figure 76

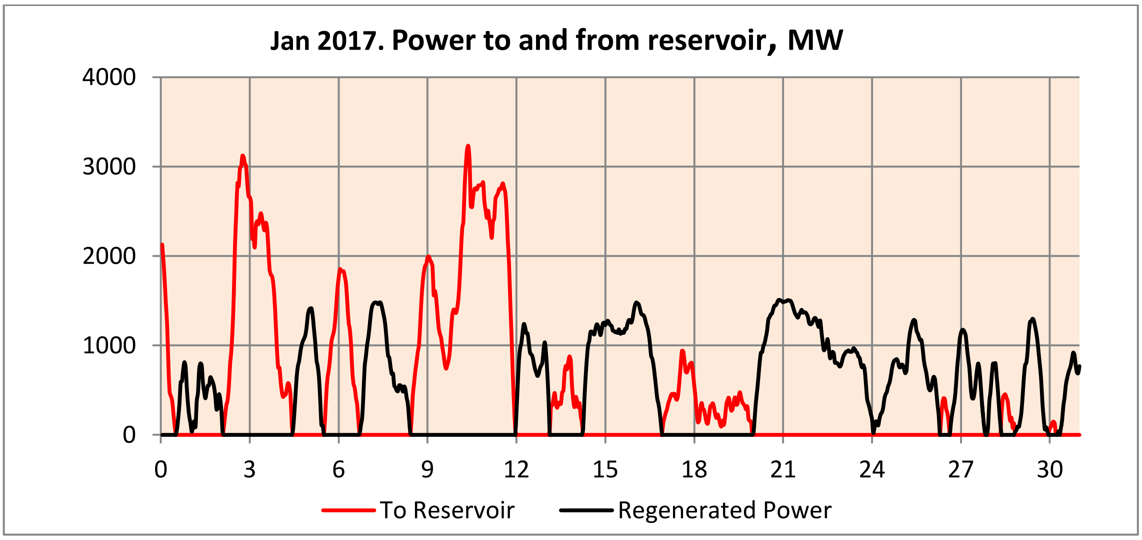
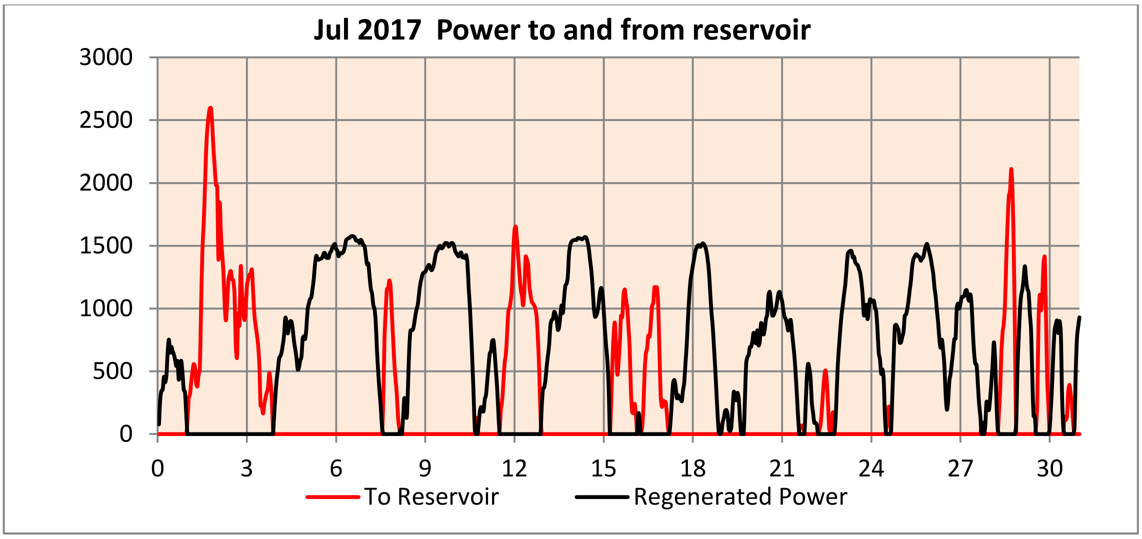


Figure 77



The figures76 and 77 show that the size of the storage is not the only problem. The demands to the input and output capacities are considerable too.

Tabel 38

Comparison with Elon Musk Battery South Australia				
Denmark 2017 Estimated loss by storing 19%		Battery South Australia	Danish Demand	Times Elon Musk
Capacity	MW	100	1.577	16
	MWh	129	1.396.412	10.825
Price	Mio US$	50	541.245	
	Mio €	40	434.305	

Tabel 38 shows the relation between capacity and cost for Elon Musk's battery delivered to South Australis. A Danish storage system would need only 16 times more effect capacity, 1577 MW against 100 MW in South Australia. But the needed storage capacity would be 10825 times larger than the Australian battery to ensure a stable electricity supply. Roughly 100000 US$ per capita.

And then it must be remembered that the wind power represented only 7% of the Danish effect or energy demand.

The conclusion is that it is nonsense to talk about storing of wind energy.

Some talk about an electrochemical storage by using the power to produce hydrogen, which thereafter should react with carbon dioxide to produce methanol. Every skilled chemical engineer will know that this I nonsense too.

We have seen phantasies about building an island at the Dogger Bank in the North Sea and then build the production facilities for production of Methanol by means of "cheap and plentiful wind power" used to produce hydrogen at that location.

This hydrogen should then react with carbon dioxide to form methanol.

It is a relevant question question:
"Where should the carbon dioxide come from."

It is well known how to extract it from the smoke from a power station. Alas it is well known too, that this process is very energy demanding, expensive to operate and capital demanding. Not to speak of a pipe for transporting carbon dioxide from onshore coal fired power stations.

And in no way compatible with a **fossil free society!**

North Sea Cable.

On October 30, 2017 the Danish Periodical **Energy Supply** described a plan for a cable between England and Denmark with the following data:

Capacity:	1400	MW
Length:	750	km
Price:	11	Billion DKK
corresponding to	1,47	Billion €.
Economy: Revenue over 40 years	4,7	Billion DKK

The authors calculations:

Investment	11000	mio DK
Pay back time	30	years
Interest	3%	per year
Cost per Year	561	mio DKK
Assumed average load	150	MW
Exchange per year	1314	GWh
Capital cost per MWh	**427**	**DKK/Mwh**
Capital cost per MWh exchange		
At full capacity	48	DKK/MWh

Conclusion

The system price for electricity in the Nordic countries was 200-220 DKK/MWh in 2017. So the project can't even be justified by the building of new off shore parks whose production has no market in Denmark. The politicians have given a license for 1350 MW of new off shore wind parks with an estimated average output of max 700 MW.

It is not explained why Denmark should build off shore wind parks to supply the British with wind power.

We have tried to quantify the benefits looking at the wind power data from England and Denmark in 2016, (Source: www.PFBach International Time Series) 2016).

We assume that export of electricity can be interesting when the wind power output is larger than a certain constant times the yearly wind power average, and that the import may be interesting when the wind power is less than this constant times the yearly average.

This is surely not a precise description of a future reality, but it may help an interested public to ask our politicians if they use our money in a sensible way.

The idea is the very undocumented assumption that the wind comes 24 hours later to Denmark than to the United Kingdom, and that we therefore will be able to support each other with wind power.

So let us look at the wind power graphs for Denmark and UK. The curves do not follow each other exactly, but they show too that you can't say that it blows in the UK when it does not in Denmark and vice versa.

Figure 78

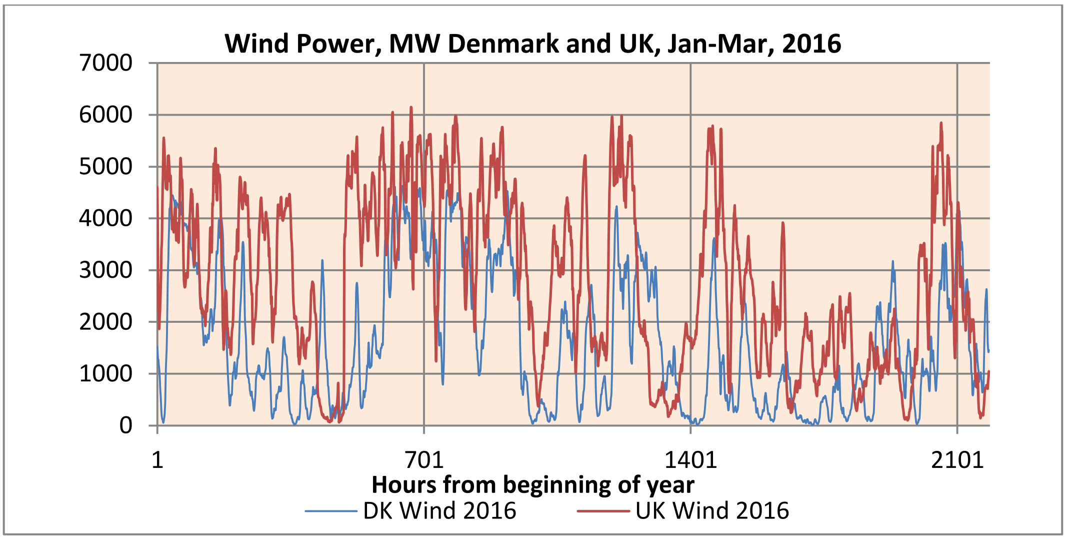


Figure 79

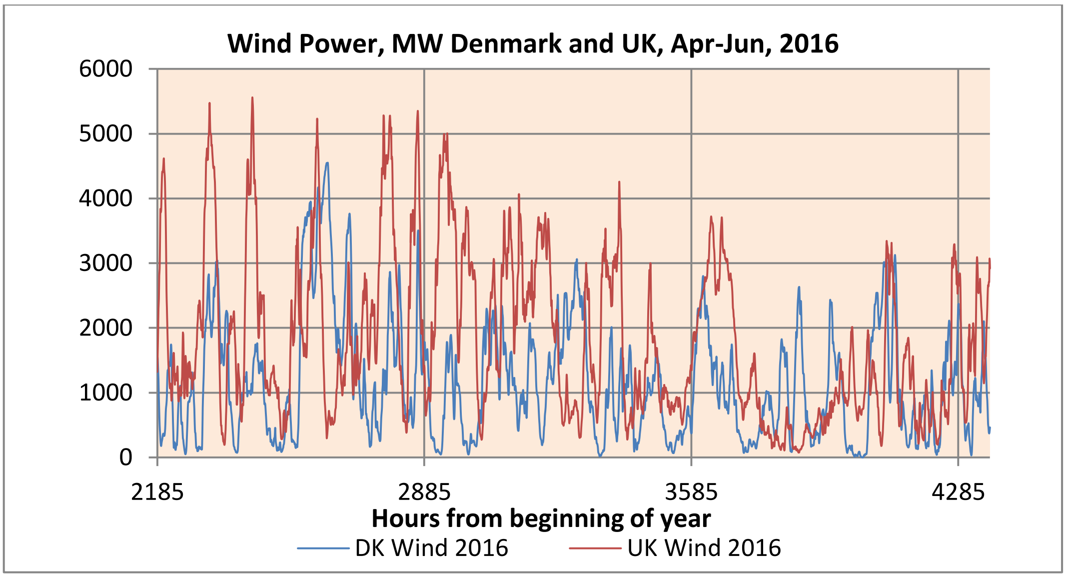


Figure 80

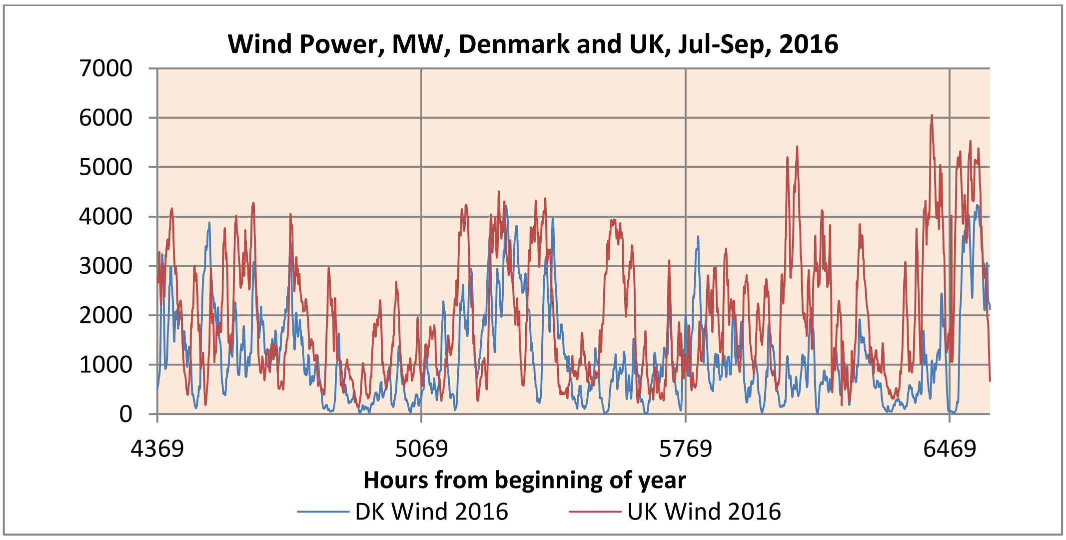
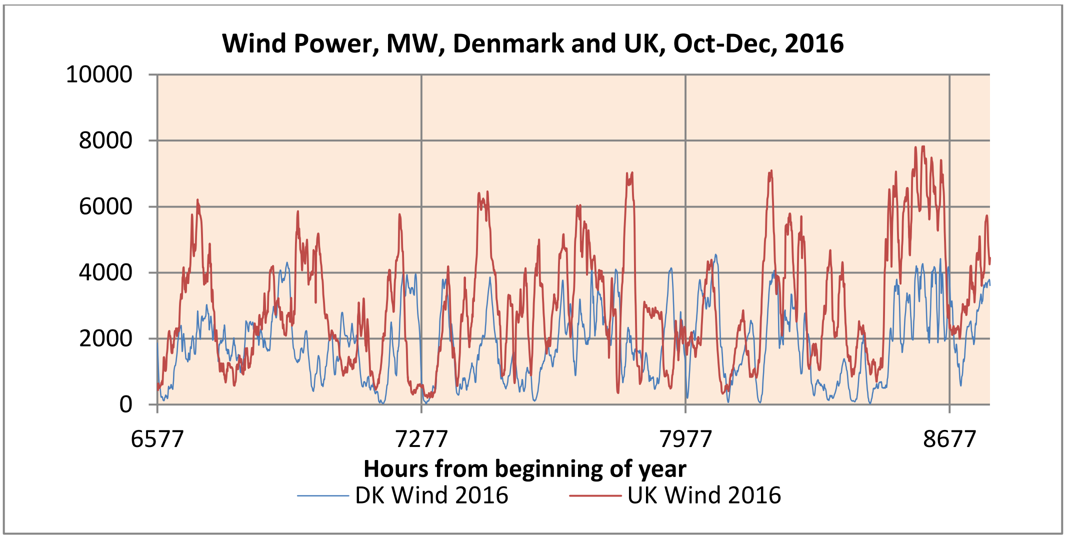


Figure 81



Tabel 39

		Year 2016							
		Wind		Export potential		Import potential		Possible Exchange	
		DK	UK	DK	UK	DK	UK	DK to UK	UK to DK
Average	**MW**	1454	2412	229	256	956	1462	77	62
Max	**MW**	4662	7833	2482	4216	2180	3551	2369	1941
Min	**MW**	1	66	0	0	0	0	0	0
Stddev	**MW**	1133	1578	516	615	761	1168	268	216
Stddev	**W/kW Avr.**	779	654	2253	2400	796	799	3490	3458
	Hours	8784	8784	**2164**	**2101**	**6620**	**6683**	**1131**	**1068**
Factor		***1,50***	***1,50***						
Wind Power limit for im/export	**MW**	**2181**	**3617**						

The figures 78-81show the wind effect in Denmark and UK in 2016. On average they were 1454 MW in Denmark and 2412 MW in the UK.
In Denmark the effect varied between 1 and 4662MW and in UK between 66 and 7833 MW.

The standard deviations are 779 W/kW average wind in Denmark and 654 W/kW in UK and indicate that the wind power in UK is a little more stable than in Denmark. This is no wonder since the wind turbines are spread over much larger distances in UK than in Denmark.

In the second last line we find the chosen **"Factor" 1,5** indicating that **export** from either Denmark or UK may be interesting when the wind power is higher than 1,5 times the yearly average respectively **2181** MW in Denmark and **3617** MW in the UK.
Import may be interesting when the wind power in Denmark is less than **2181** MW and in England less than **3617** MW.
We then find that export might be interesting for Denmark in **2164** hours per year and for UK in **2101** hours per year. And import in respectively **6620** and **6683** hours per year.

Alas no exchange can be made unless both countries see an interest in this. So export from Denmark to the UK might be possible in **1131** hrs per year and from UK to Denmark in **1068** hrs per year.
The average export from Denmark would amount to 77 MW and from UK to 62 MW, in total 139 MW.
This is 10 % of the capacity of the proposed cable!

So to justify the project it will be necessary to build new wind parks. The financing should be no problem. The tax payer and electricity consumers will have to pay the bill.

Tabel 40

Calculated Exchange, MW average, per month 2016 and 2017				
	DK to UK	UK to DK	DK to UK	UK to DK
	2016		2017	
Jan	66	148	46	61
Feb	89	87	194	151
Mar	45	53	114	86
Apr	156	67	301	52
May	31	42	105	18
Jun	31	0	193	33
Jul	49	2	52	4
Aug	111	20	37	6
Sep	10	111	23	68
Oct	140	82	71	185
Nov	142	72	83	316
Dec	54	67	42	190
Average	77	62	104	97
Sum DK +UK		139		201
Wind average MW	DK	UK	DK	UK
	1454	2412	1687	3689

Table 40 shows the calculated monthly averages in MW for the exchange of electricity between Denmark and the UK in 2016 and 2017.

Provided that export may be interesting when the wind power in each of the two countries is higher than 1,5 times the annual average, and import may be interesting when the wind power is less 1,5 times the average.

Due to the hi8gher wind power output in 2017 than in 2018 the calculated exchange for 2017 is higher than for 2016. But sill a very long way from 1400 MW.

Other factors than 1,5 might be chosen. Table 41 shows the resultsfor 2016 with varying factors.

Tabel 41

Sum of exchange, MW average in 2016, between Denmark and UK									
		Factor Danmark							
		1,2	1,3	1,4	1,5	1,6	1,7	1,8	1,9
Factor UK	1,2	**181**	179	180	183	187	192	200	207
	1,3	176	**171**	167	165	166	168	172	177
	1,4	174	164	**156**	151	148	147	149	152
	1,5	173	159	148	**139**	134	131	130	131
	1,6	173	156	142	132	**124**	119	116	114
	1,7	178	159	143	130	120	**112**	106	102
	1,8	186	165	147	131	119	108	**100**	94
	1,9	198	175	154	136	121	108	98	**89**

The maximal obtained figure is 207 MW exchange on average in a cable with a capacity of 1400 MW.

It must be added that the wind power was higher in 2017 than in 2016. In UK much higher.

Figure 82

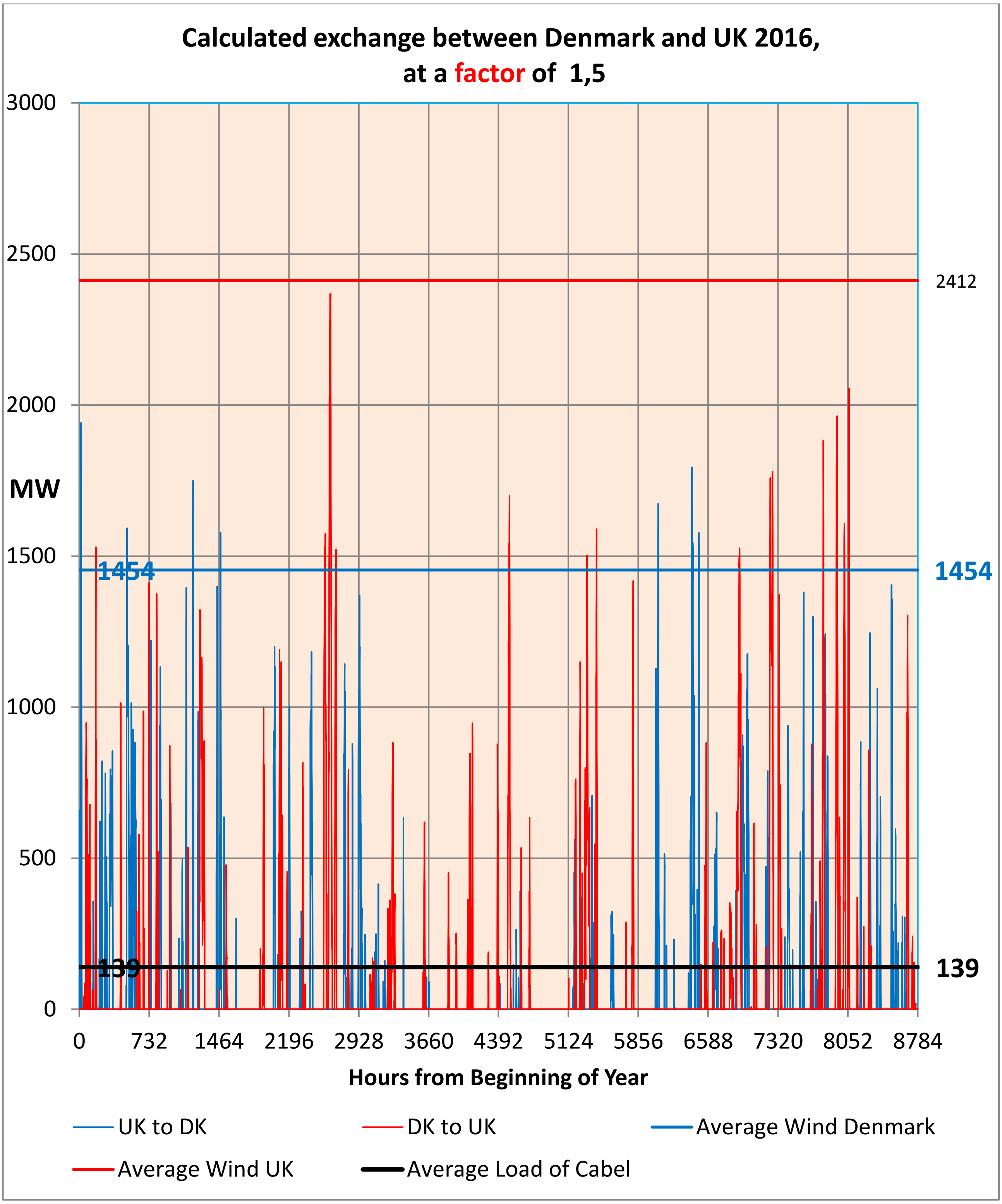


Figure 82 shows the intermittent load of the proposed cable under the chosen conditions. It should be observed that the cable is dimensioned for a load of 1400 MW, and that the calculated average load is as low as 139 MW.

When Sweden Rejects Nuclear Power[iv]

We have seen that the Danish Electricity supply is deeply dependent of cooperation with Norway and Sweden.

The Swedish production of electricity is shown as MW average for the mentioned periods in table 42.

Tabel 42

Swedish electricity production 2017. MW	Gastur-bine Diesel	Nuclear	Other thermal	Other	Sun	Hydro	Wind	Sum
				The year 2017				
Average	1	7.202	634	0	8	5.579	1.836	15.260
Max	162	9.141	2.026	42	86	12.769	5.524	25.561
Min MW	0	3.097	8	0	0	779	34	5.667
Stddev	4	1.771	543	1	15	2.571	1.165	4.290
Observations				***8.760***				
				Januar – March				
Average	2	8.975	1.442	1	3	7.832	2.347	20.602
Max	78	9.141	2.026	20	59	12.769	5.524	25.561
Min MW	0	7.882	946	0	0	2.268	177	14.055
Stddev	5	333	178	2	8	2.539	1.134	2.582
Observations				***2.160***				
				April – June				
Average	1	7.462	727	0	16	6.240	1.767	16.212
Max	59	9.007	1.383	42	81	10.605	5.221	23.464
Min MW	0	5.451	284	0	0	2.099	116	10.305
Stddev	4	1.091	294	2	21	1.888	1.061	2.471
Observations				***2.184***				
				July – September				
Average	1	5.017	214	0	11	4.989	1.197	11.428
Max	53	6.701	460	3	86	10.418	3.593	17.401
Min MW	0	3.097	83	0	0	896	56	5.667
Stddev	3	940	91	0	17	2.054	725	2.736
Observations				***2.208***				
				October - December				
Average	1	7.395	173	0	1	3.313	2.043	12.926
Max	162	8.644	529	1	22	5.853	5.417	18.440
Min MW	0	3.802	8	0	0	779	34	7.550
Stddev	5	1.525	90	0	3	1.135	1.331	2.006
Observations				***2.208***				

Tabel 43

Electricity Production , Sweden . January to March 2017, MW									
	Gastur-bine Diesel	Nucle-ar	Other Ther-mal Produc tion	Hydro	Wind Swe-den	Sum Produc -tion	Future Wind Power	Future Hydro Power	Den-mark WInd
				January 2017					
Average	2	9.005	1.472	7.912	2.665	21.057	13.119	6.463	1.563
Max MW	78	9.131	2.026	12.769	5.375	25.342	26.459	20.329	4.812
Min MW	0	8.317	1.076	2.268	303	15.018	1.493	-7.691	71
Stddev MW	5	204	143	2.622	1.110	2.566	5.462	5.668	1.169
Observations					**744**				
				February 2017					
Middel MW	2	9.113	1.535	8.224	2.039	20.917	10.038	9.338	2.183
Maks MW	66	9.141	1.900	12.767	4.131	25.561	20.336	19.707	4.795
Min MW	0	8.736	1.299	2.642	218	16.086	1.072	-4.005	84
Stdafv MW	6	47	144	2.509	1.000	2.468	4.920	5.241	1.256
Observations					**672**				
				March 2017					
Middel MW	2	8.821	1.328	7.398	2.307	19.862	11.358	7.168	1.692
Maks MW	58	9.129	1.896	11.889	5.524	24.813	27.192	18.488	4.392
Min MW	0	7.882	946	2.648	177	14.055	873	-9.001	31
Stdafv MW	5	487	176	2.415	1.190	2.539	5.859	5.838	1.203
Observations					**744**				

By observing table 43 above it will be seen that the standard deviation for the **nuclear power** in the months January, February and March is 204, 47 and 487 MW or **2,3 and 0,5 and 5.5 %** of the average production.

For the **wind power** the corresponding figures are **41 and 49 and 52%,** and the wind power output varied between 5524 MW and 177 MW.

Nuclear power is reliable. Wind power absolutely not.

Sweden is expanding the wind power, and for many influential persons the goal is to abandon nuclear power completely and replace it by wind power.

So we have tried to calculate the consequences, assuming that wind power should replace nuclear power, **and that the hydro power should yield the necessary regulation of the output and asuming that gas, diesel and other are kept unchanged.** In 2017 nuclear power yielded on average 7202 MW and the Wind Power 1836 MW. So in the future Wind Power should yield 9038 MW, which means that the wind power must be increased by a factor of **4,923.**The consequences are shown in the columns “Future Wind power” and “Future Hydro power” in the table 43 above, And in the Figures 83-91below.

Figure 83

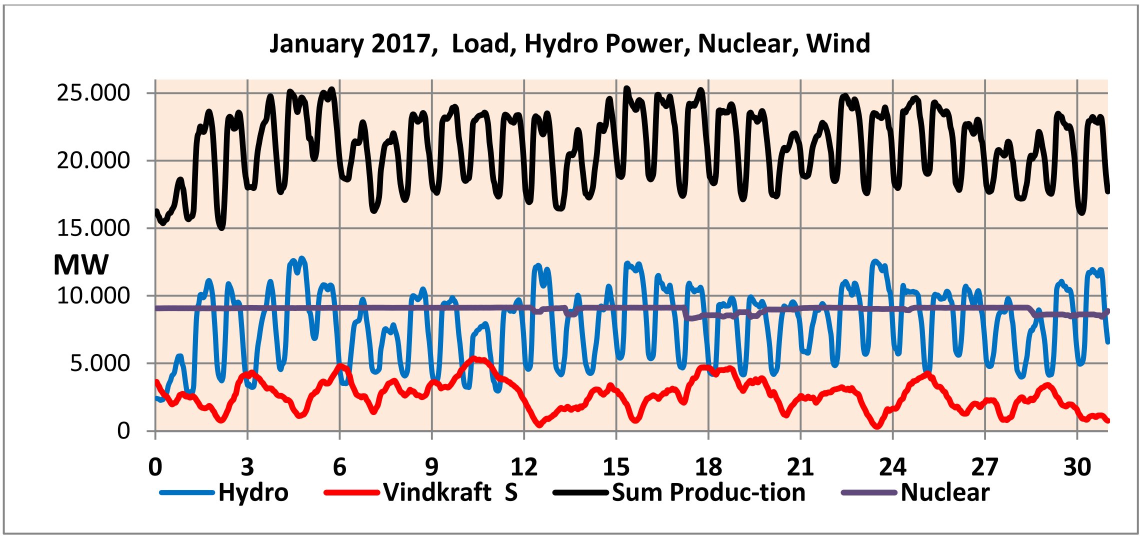


Figure 84

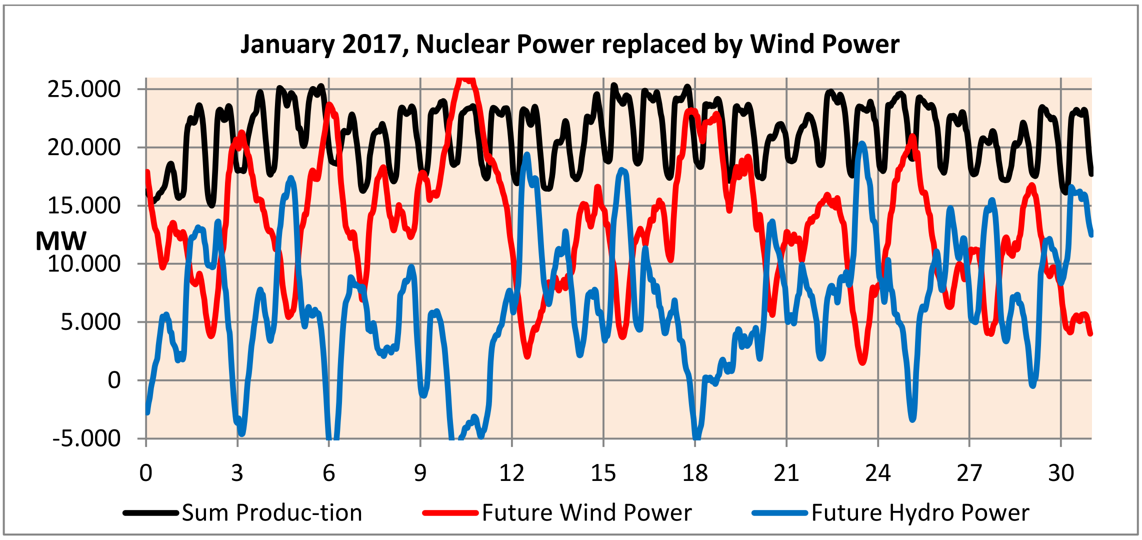
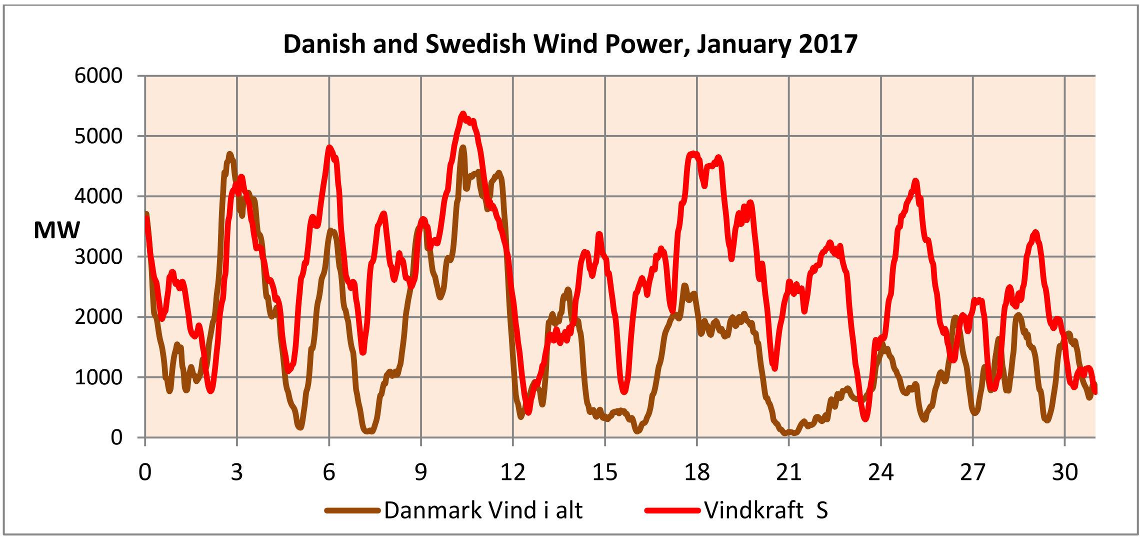


Figure 85



You might wonder how the hydropower can be negative. However that means that water should be pumped back to the reservoirs. Possibly this is not necessary. But about 5 TWh/year of windpower would be lost, unless you find a way to use a lot of extra electricity when it blows.

Figure 86

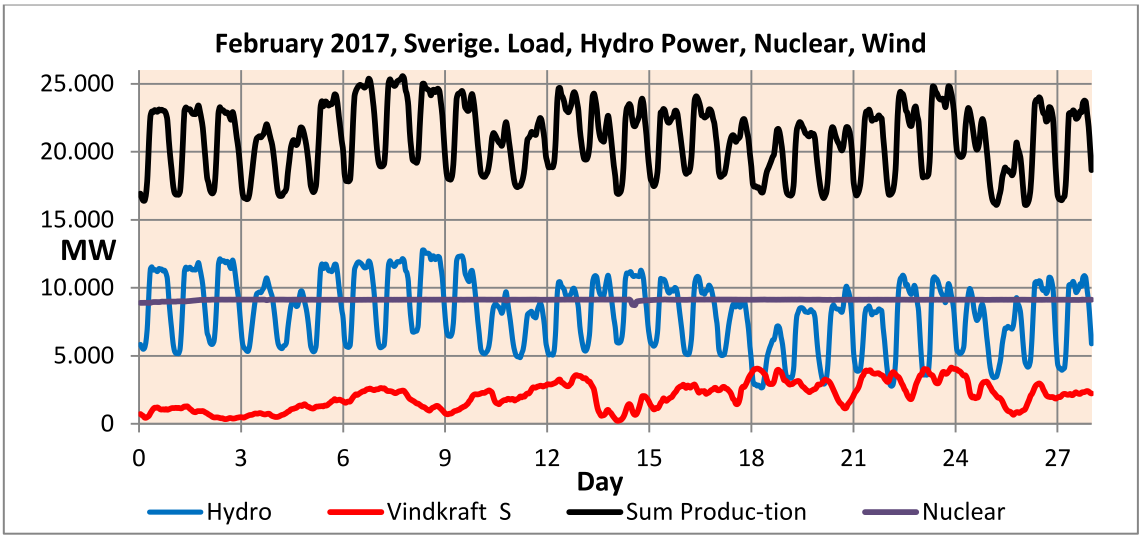


Figure 87

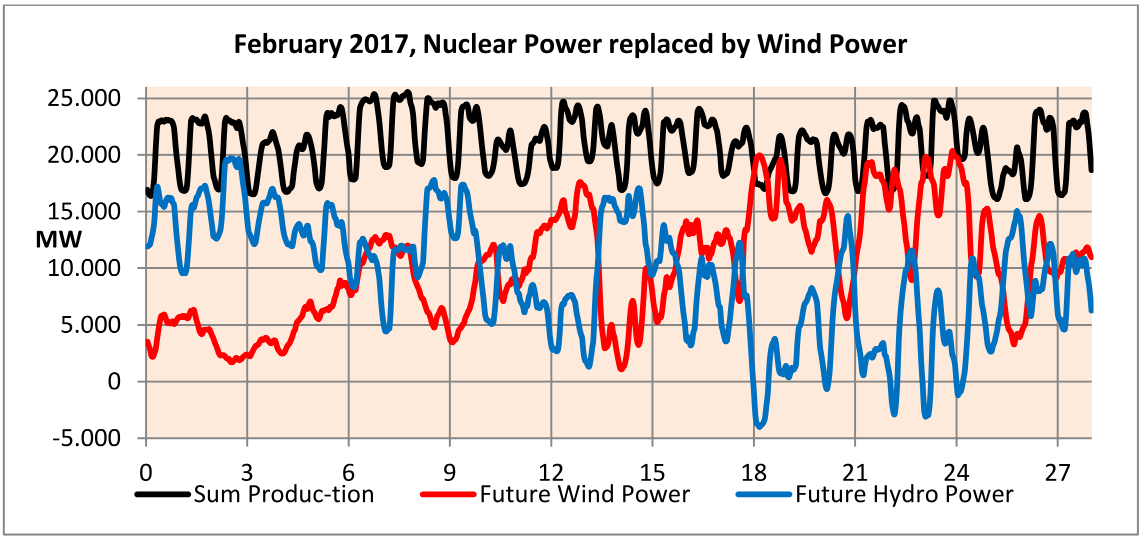


Figure 88

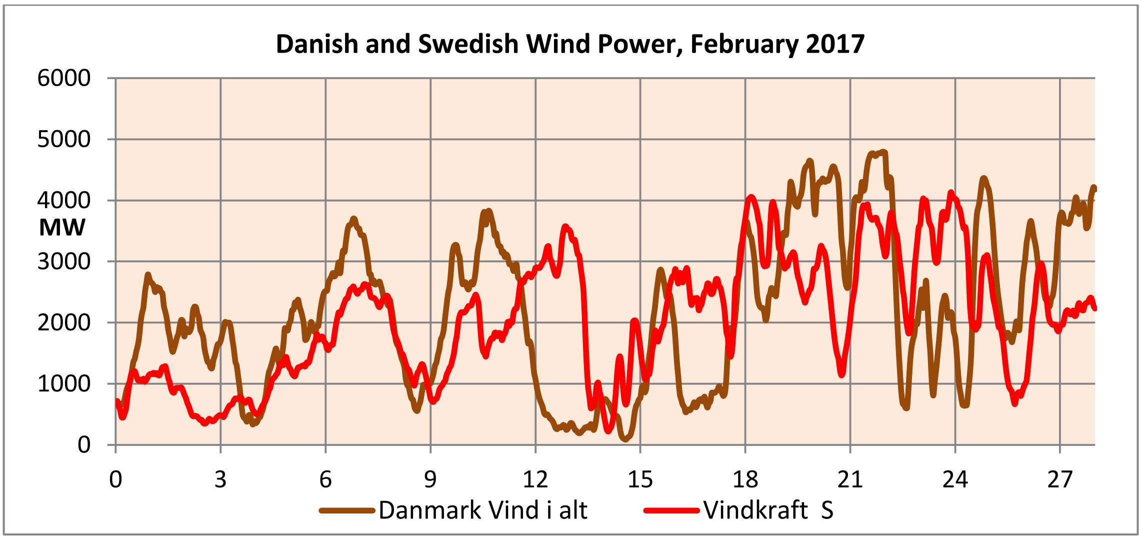


Figure 89

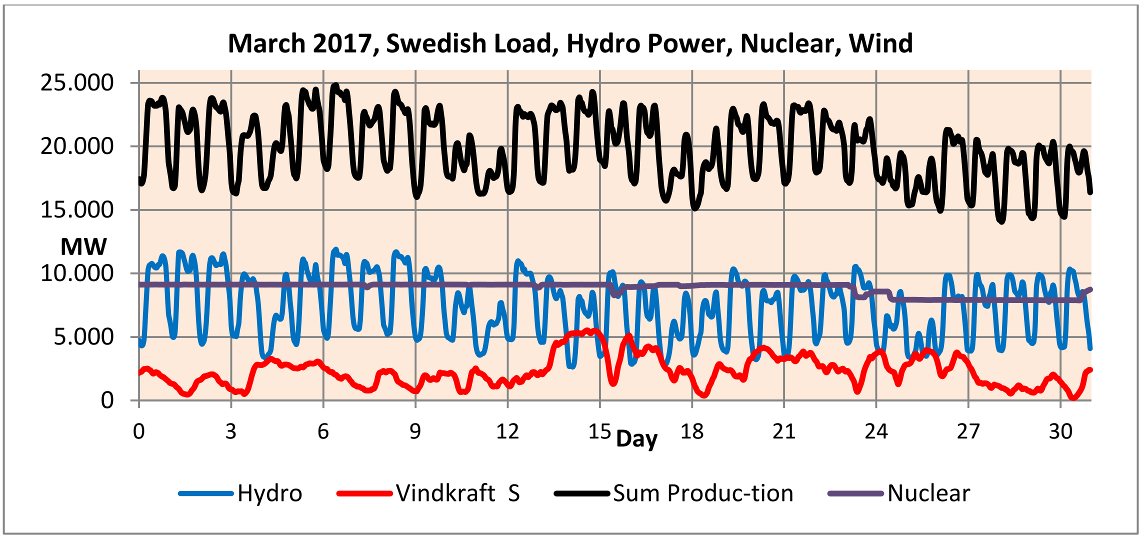


Figure 90

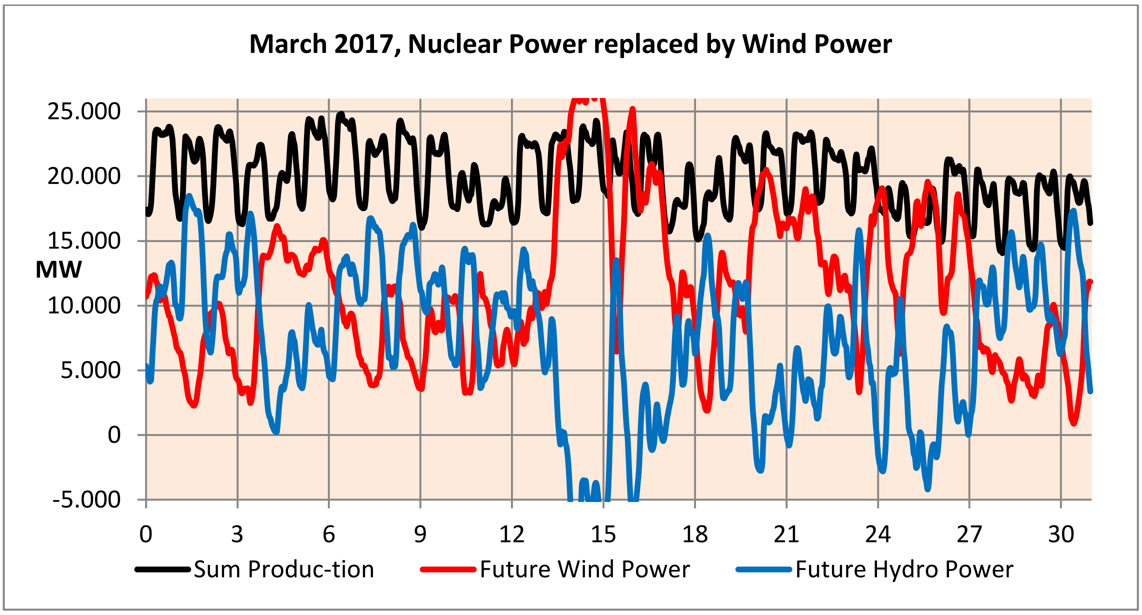
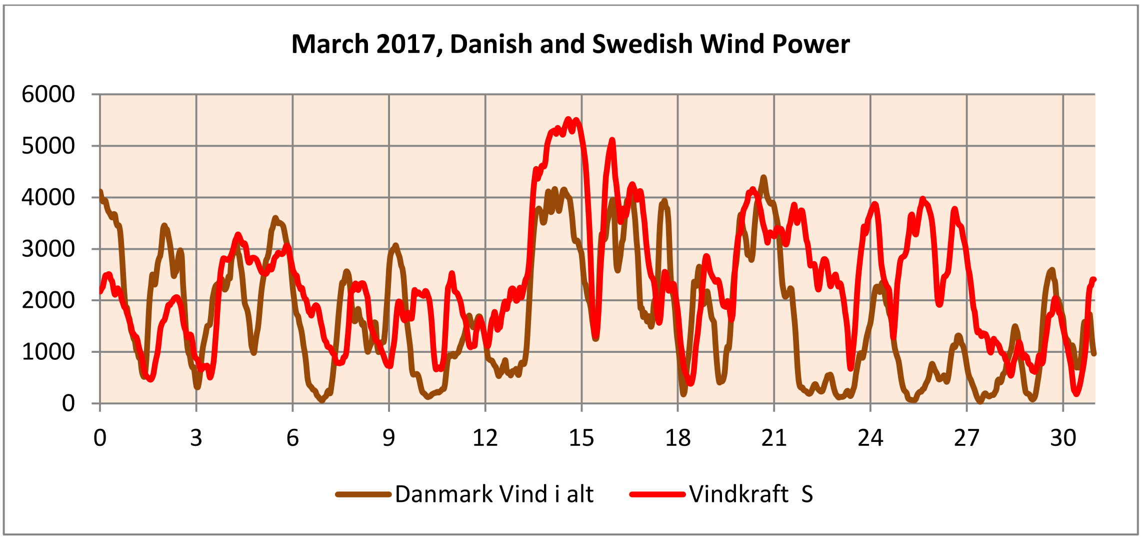


Figure 91



You see from figure 85, 86 and 91 Danish and Swedish wind power to a high degree varies synchronously. So it would be very unpleasant for Denmark if Sweden abandons nuclear power.

Production data per Month.

Energistyrelsen supplies production data for every wind turbine for every month[v].

Tabel 44

Denmark 2014-2017. Wind Power average per month and year													
Year	Jan	Feb	Mar	Apr	Maj	Jun	Jul	Aug	Sep	Okt	Nov	Dec	Year
2014	2.727	2.098	1.612	1.426	876	884	777	1.367	1.033	1.505	1.688	1.932	1.491
2015	2.107	1.780	1.529	1.485	1.692	1.377	1.443	1.085	1.354	1.259	1.703	2.520	1.611
2016	1.943	1.816	1.097	1.444	1.111	930	1.087	1.371	1.032	1.730	1.870	1.933	1.469
2017	1.541	2.160	1.675	1.897	1.351	1.748	1.193	1.248	1.151	2.076	1.829	2.276	1.675

Table 44 and figure 92 illustrate the necessity of back up.

Figure 92

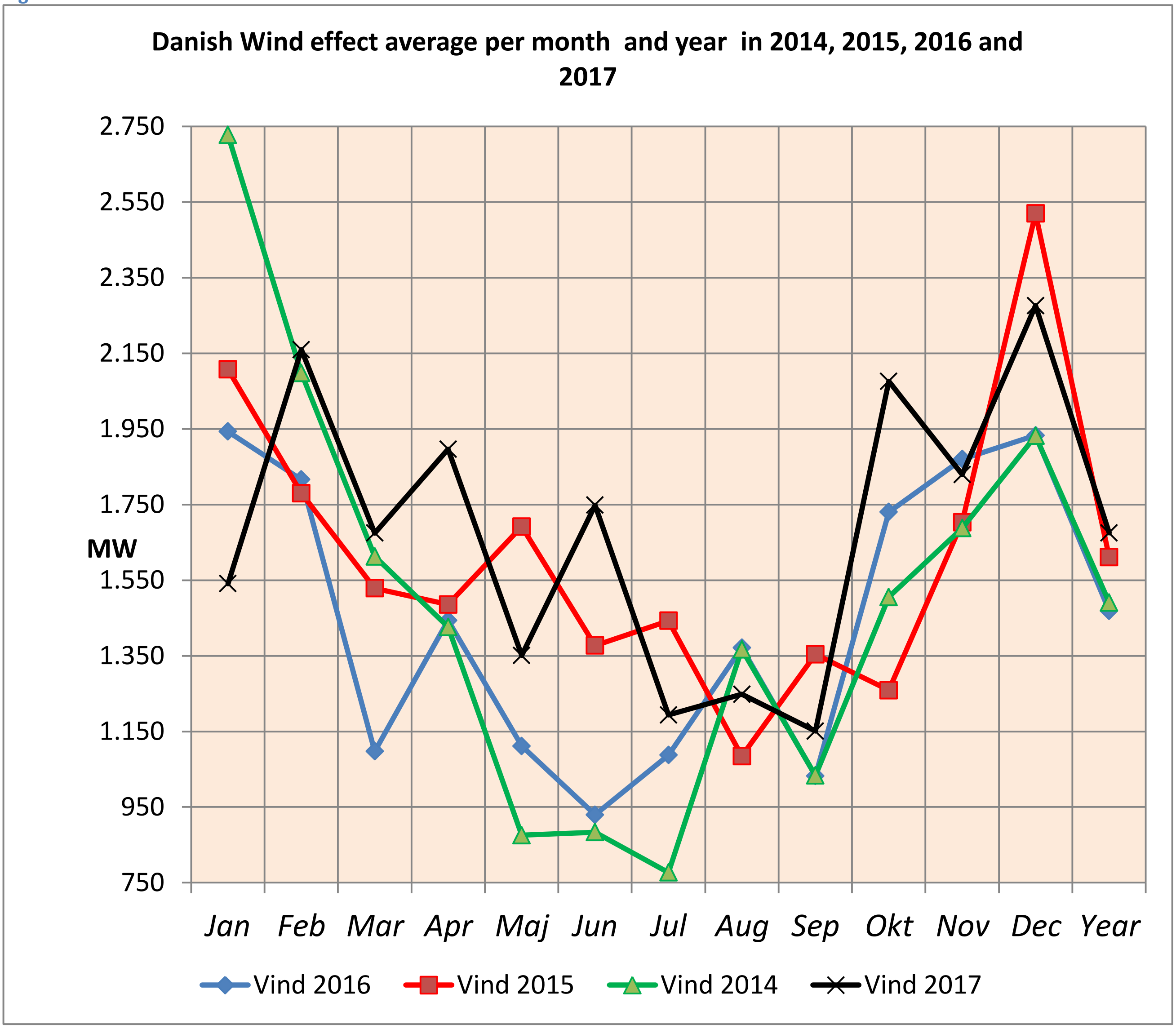


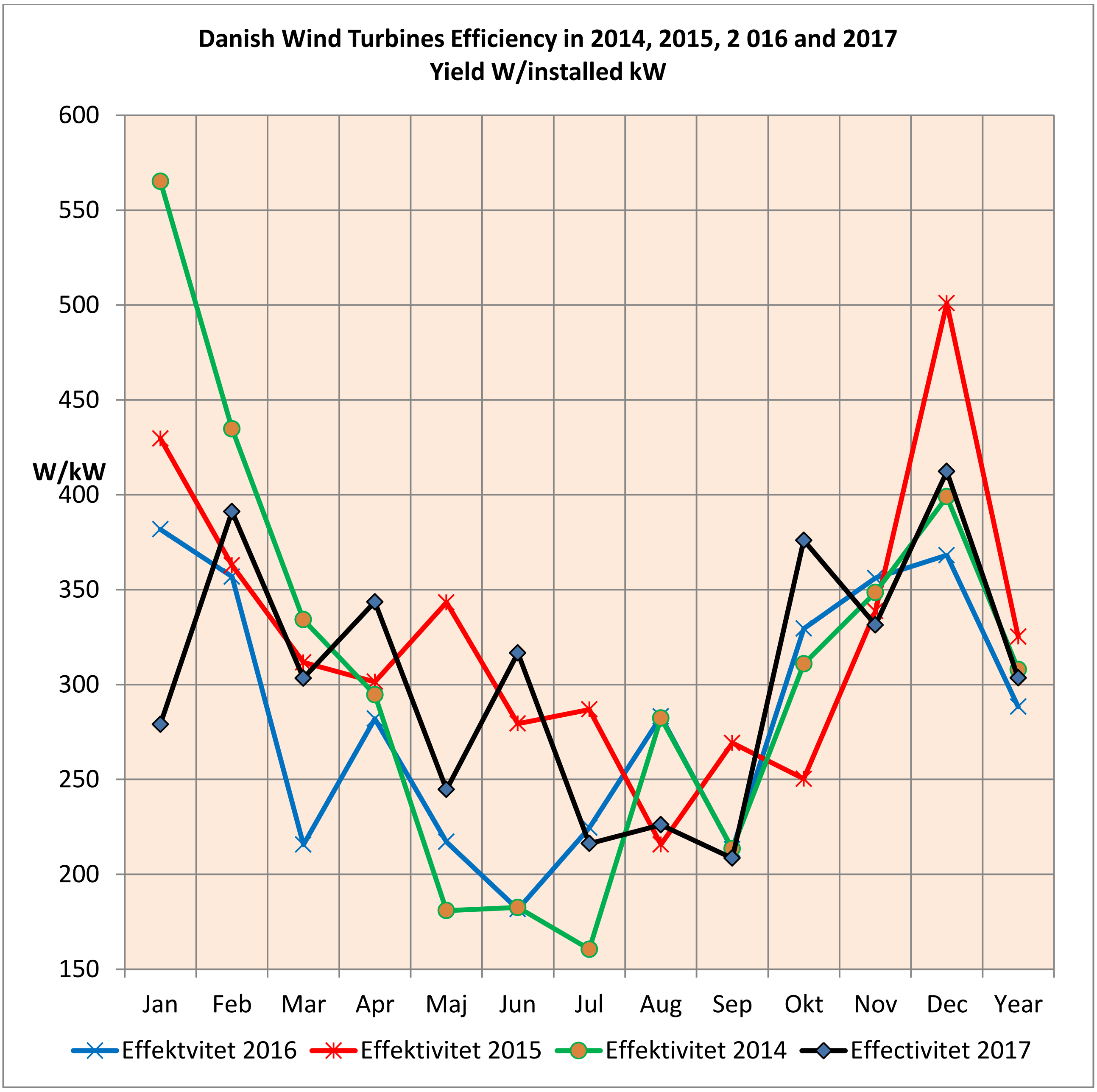
Table 45 and 46 and figure 93 and 94 illustrate the varying output per installed effect. On average the wind turbines yield about 30% of the nominal capacity.
What a waste of steel, concrete, copper, neodym and other materials. The (nominal) 3,6 MW wind turbines in "Norddjurs" weigh: 3 Turbineblades 54 tons, Tower 200 tons (steel), Turbine house 195 tons(Steel copper, neodym etc.) and the basement about 500 tons.

Tabel 45

Danish Wind turbines average efficiency. Yield W per installed kW capacity, 2014-2017.

Year	Jan	Feb	Mar	Apr	Maj	Jun	Jul	Aug	Sep	Okt	Nov	Dec	Year
2014	565	435	334	295	181	183	161	282	213	311	349	399	308
2015	430	363	312	301	343	279	287	216	269	250	339	501	325
2016	382	357	216	282	217	182	225	283	213	329	356	368	288
2017	279	391	303	344	245	317	216	226	208	376	331	412	303

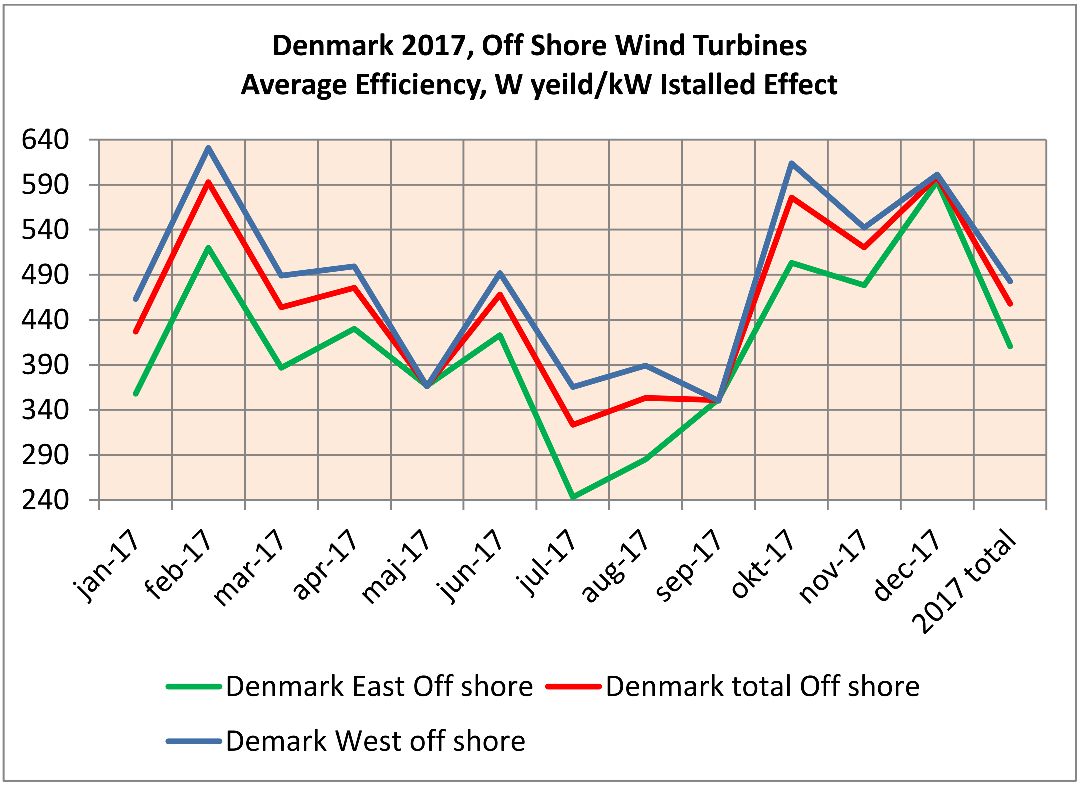
Figure 93



Tabel 46

Denmark 2017. Efficiency. On and off shore Wind Turbines. W yield/kW installed effect													
	jan	feb	mar	apr	maj	jun	jul	aug	sep	okt	nov	Dec	2017
East Off shore	358	520	387	430	367	423	243	285	352	503	478	594	411
West off shore	463	631	489	499	366	492	365	389	350	614	542	601	482
Total Off shore	427	593	454	475	366	468	323	353	351	576	520	599	458
East On shore	201	293	214	264	203	257	152	184	201	331	296	384	248
West On shore	241	337	267	312	208	273	190	188	157	312	269	349	258
Total On shore	234	330	257	303	208	270	183	187	165	315	274	355	256
Denmark total	279	391	303	344	279	317	216	226	208	376	331	412	303

Figure 94



The off shore wind turbines are just as unreliable as the onshore turbines but it must be admitted, at a higher level. In 2017 they yielded on average 458 W per installed kW, against 256 W per kW for the on shore turbines.

Figure 95

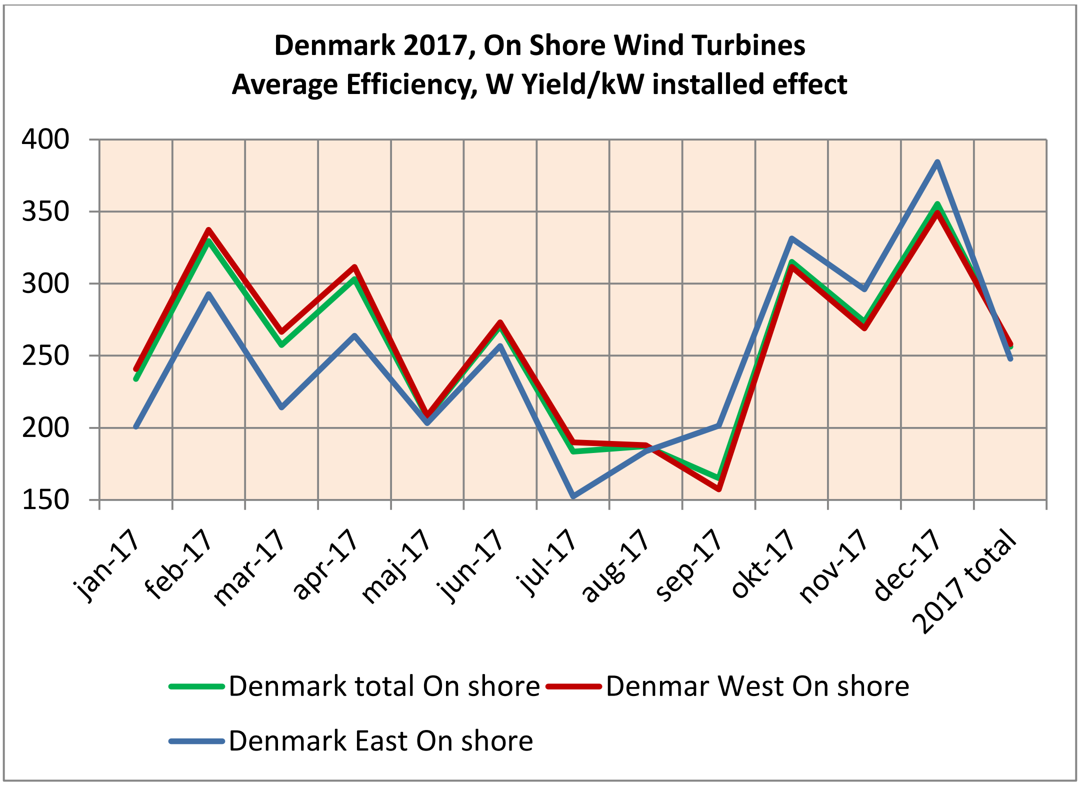


Table 47 below shows the development in installed wind power capacity in the period 2012-2017. The off shore capacity increased by 370 MW and the onshore capacity by 989 MW.

Tabel 47

Denmark 2012 – 2017, Installed Wind Power Capacity

	2012	2013	2014	2015	2016	2017	2012-17
	Installed Capacity MW						Increase
Off Shore	922	1271	1271	1271	1266	1292	370
On Shore	3240	3799	3634	3799	3985	4229	989
Total	4162	5070	4906	5070	5251	5521	1359
	Number of Turbines						Increase
Off Shore	419	516	519	516	505	508	89
On Shore	4591	5260	4753	5260	5562	5649	1058
Total	5010	5776	5272	5776	6067	6157	1147

Sören Kjärsgaard
May 31, 2018.

Sources

[i] https://ens.dk/service/statistik-data-noegletal-og-kort/maanedlig-og-aarlig-energistatistik Grunddata

[ii] https://ens.dk/service/statistik-data-noegletal-og-kort/maanedlig-og-aarlig-energistatistik Grunddata

[iii] https://esa.un.org/unpd/wpp/Download/Standard/Population/
Total Population - Both Sexes (XLSX, 2.42 MB)

[iv] https://mimer.svk.se/ProductionConsumption/ProductionIndex

[v] https://ens.dk/service/statistik-data-noegletal-og-kort/data-oversigt-over-energisektoren Data for eksisterende og afmeldte møller