Report about Danish and European Production and Consumption of Electricity, mainly Wind and Solar energy

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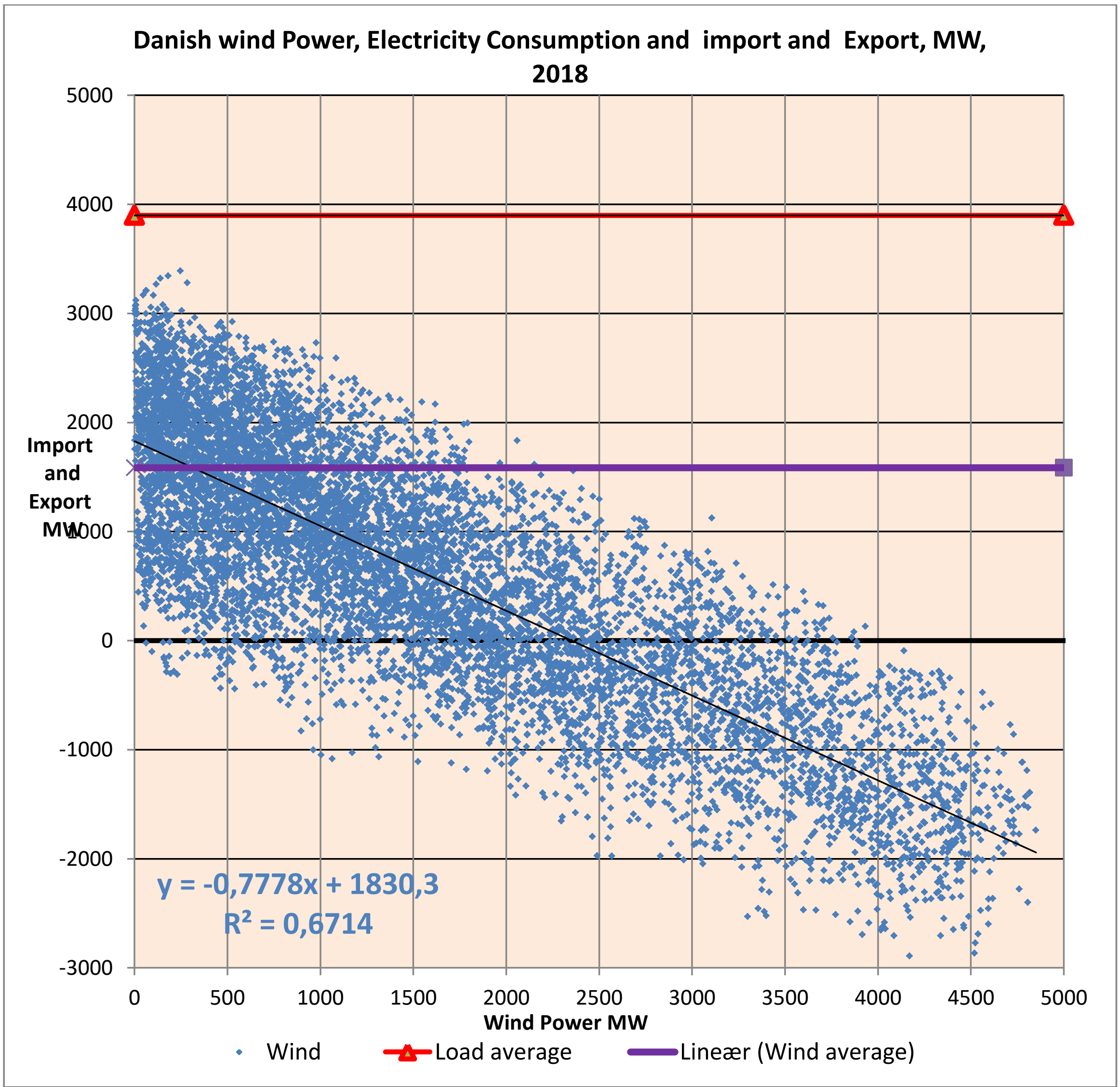

The graph above shows how dependant Denmark has become of electricity exchange with our neighbours. When the wind power is less than about 1500 MW we import a lot of our electricity, and when the wind power is higher than 4000 MW about a third of the wind power is exported. *(Import is positive, and export negative. The graph contains 8760 points, one for every hour in the year) It will be shown later that the exchange with Germany is very weak. Germany can neither use nor store Danish wind power.*

INTRODUCTION

The report is based on data open to the public among others from Danmarks Statistik, Energistyrelsens Stamdata for Vindmøller, Energinet.dk, BP.s Yearly Energy Statistics, and others mentioned at the end of this report.

It has been the author's purpose with the report to enlighten the consequences of the present political and public wish to create a "Green Society".

According to the Authors opinion a "Green" energy system will at first have the consequence that industrial production will be transferred to other parts of the world who don't care about green energy. This will be followed by an enormous waste of money in an experiment which impossibly can lead to the goal: A "green" society. And finally will follow a deep impoverishment of Europe.

At the same time the rest of the world will for many years to come continue to use more fossile energy. So even if the hypothesis that carbon dioxide plays an important role for the climate should be true our efforts to reduce carbon dioxide emissions will have no measurable effect at all.

According to data given by Vattenfall and the weekly periodical "Ingeniøren" it is even shown that off shore **wind power costs more than nuclear power**. Not to speak of what wind power would cost if the price for the necessary storages for the uncontrollably varying wind power were included in the price.

The report is divided in sections (See "Contents" page 3) containing 49 tables and 104 figures. Before each of the sections the reader will find a "Summary".

The main conclusions from each section are shown immediately after the list of Contents (p.4-8)

Thereafter follows an over view of the most important definitions and a short curriculum vitae for the author.

The author wants already at this place to draw the reader's attention to the much used word **"Load"** which means consumption of electricity.

The author has chosen – where possible - to use the unit Watt (joule/second) instead of the unit Joule/Year. The change is made by dividing the number of joule/year by the number of seconds per year.

Contents

Summaries

A condensed summary for each of the sections is shown below. It is the author´s hope, that these summaries will ease the reading and that they will be an appetizer for those wishing to look at the details.

World Energy and Population

The World's population is increasing steadily, in the years 2006-2017 from 6600 million to 7550 million i.e. ca. 80 million per year and the growth rate seems to be surprisingly constant.

The energy or effect consumption is increasing steadily too, from 14,9 TW in 2006 to 17,9 TW in 2017. The growth rate is on average 0,254 TW/year or 254 GW/year. In 2017 wind and solar power delivered 179 GW. Less than the yearly growth in consumption.

In 2006 Oil, Coal and gas supplied 90,5 % of the Worlds energy consumption, in 2017 the figure was 88,5 %.

It should be evident, that the idea of a World without fossil fuels is nonsense, at least until a drastic reduction of the World's population has taken place.

Danish Energy Production 2000-2017

The total Danish energy production rose from 36845 MW (1162 PJ) in the year 2000 to 41603 MW (1316 PJ) in 2005 and fell to 20879 MW (660 PJ) in 2017.

In 2017 wind + solar power yielded on average 1847 MW corresponding to 8,2 % of our gross energy consumption.

Danish Consumption of Energy 2000-2017

It is remarkable, that the net energy consumption is practically constant (table 6), whereas the loss in the transformation sector has decreased from 18% to 10% of the total energy consumption. It should be observed too that the population has increased by 6% in the period.

Imported biomass including imported garbage is the largest single contributor to the Danish green energy. How sustainable this is is for the reader to wonder.

Sustainable Energy

Contrary to what most people seem to think wind power so far isn't the dominant part of the "sustainable" energy. The "sustainable" energy has grown from 12 to 37% of the gross energy consumption in the period from 2000 to 2017. (The wind power fell from 1687 MW in 2017 to 1587 MW in 2018).

Domestically produced biomass and heat pumps yielded 9,6% in 2000 and 18,2% in 2017.

According to "Energistyrelsen" the potential for Danish bioenergy is 162 PJ/Year corresponding to 5100 MW so there remains 1300 MW to be used. **Far from enough.**

Increasing Wind Power, Increasing Import and declining Electricity consumption

It is generally accepted, that a fossil free society presupposes a very much increased use of electricity.
It seems, however, that Denmark is moving in the wrong direction. We import much more electricity today than 18 years ago, and the consumption falls.

How do we get our electricity

It is generally accepted that a fossile free society means much more electric power produced from lasting resources like solar, wind and hydropower. The wind and even the solar power have increased from 2000-2018, and so has the population (by 6,5%). Wind power is even told to be cheap. Why is it then that the electricity consumption has fallen by 2% and the import, which was close to zero 18 years ago in 2017 and 2018 was 13 % and 15 % of the consumption?

Thermal Electricity Production

The average production from thermal power stations was 1607 MW in 2015, and the maximal production was 4922 MW. So the capacity is exploited only by about 30%. It must be justified to ask who should pay for this back up capacity. The wind power has a privileged access to the market and the wind power can't function without back up, then the cost for the back up must be added to the price for wind power,

Danish Wind Energy 2012-18

In 2018 the wind power amounted to **7,1%** of the Danish energy consumption. However this is not quite true, because a lot of the wind power must be exported when it blows. According to the author's calculations he wind power share of the Danish energy is then reduced to **5,9%.**

On and Off Shore Wind Denmark East and West 2018

Off shore wind power is nearly just as variable as on shore wind power, and often comes very close to zero. Thus off shore wind needs just as much back up as on shore wind.

Off shore wind parks

The age, number of turbines, capacities, production for each of the 6 off shore parks in East Denmark and the 8 parks in West are shown in table 20 and 21. The author suspects that the efficiency is declining with time but has not been able prove it.

Variation Wind Power 2018

The graphs 44-47 below illustrate the wind power variation from hour to hour.

It must be admitted, that there is an - although unclear - pattern in the variations form month to month (Table 22 and figure 48). Anyway it seems that you can't rely on a car powered by wind power for your summer holiday tour to Italy.

Wind Power and Load

It should be observed that we import up to 88 % of the load and export up to 83% of the load. These high figures are caused by the large amount of wind power in the Danish system, and are surely a special case. Other countries are not so lucky that they can draw on the abundant water power from their neighbours.

Useful Wind Power

The wind power was on average 1586 MW in 2018 and the load 3900 MW, so a rough calculation indicate that **40,8% of our electricity** is supplied by wind power. After correction for export and the fact that the wind power is sometimes higher than the load, the figure is reduced to **34% of the average load.**

Wind Power and Exchange.

There is a clear relation between wind power and export. When the wind power surpasses 2500 MW we begin to export wind power. By a wind effect of 3000 MW about 16% of the wind power is exported and by 5000 MW 40%. You may wonder what will happen when the wind power according to plans will increase to on average 7000 MW and maximum 17000 MW.

Power Exchange with Norway, Sweden and Germany

There is a clear correlation between the wind power and the exchange with Norway and Sweden and only a very weak correlation between the wind power and the exchange with Germany. That is no wonder. Germany has plenty of wind power and there is a high degree of simultaneousness between the wind in Denmark and in Germany.

Wind and Solar Power in Denmark, Germany, Norway and Sweden

Generally speaking neighbours can't assist each other to secure a stable supply of wind and solar power, because the wind follows the same pattern over very large distances. The sun of course too.

Expanding and Storing off Shore Wind

The political system talks about adding 12000 MW to the present abt. 1700 MW of off shore capacity. This will result in a wind power with an average effect about 7000 MW varying between approximately zero and 17000 MW, whereas the average Danish load was 3900 MW in 2018.

We have been presented for numerous ideas about storing superfluous wind power. But for very good reasons we never see a calculation of the costs.

North Sea Cable. Viking Link

Justification for the Viking Link.

The author has seen reports assuming that there in the future will be a price difference for electricity between Denmark and the UK and that these assumed differences in a distant future could make the Viking Link profitable.

The author has chosen another assumptions reasoning:

When the wind power in a country is higher than a constant times the average wind power, export might be interesting, and import might be interesting if the wind power is less than the constant times the average wind power.

The Viking Link will have a transfer capacity of 1400 MW. No matter which wind power level is chosen for import/export we can't get higher than an average transfer of about 20% of the capacity. The Viking Link seems to be a **Waste of Money.**

Die Energiewende

Germany has during the last 10 years expanded her wind and solar power dramatically, so that wind and solar power in 2018 accounted for 29,5% of the electric load. However that is only partly true. It seems that Germany must export on average about a third of her wind and solar power. At very low and often negative prices, and mainly to Poland and Holland, which should not surprise anybody since Holland and Poland have a wind power share in their electricity supply of only 9,4% and 7,2% respectively. **The Poles and the Dutch get a good laugh.**

It always blows and the sun shines somewhere

Alas, that is not true. The author has compared the wind power in Belgium, Germany, Spain, France, UK and the Netherlands based on hourly registrations of the wind power in each of the six mentioned countries.

Wind + Solar Power % of load in Belgium, Germany, France, Spain, UK and the Netherlands

The proportion of wind and solar power in these countries varies between 3% and 43% with an average of 19%. The demand for back up decreases not very much by adding wind and solar power in this huge area.

Some Data from Belgium, Germany, Spain, France, United Kingdom and The Netherlands

It is remarkable that Germany in spite of **Die Energiewende** and in spite of the highest proportion of wind and solar energy in the energy consumption has both the highest carbon dioxide emission per produced unit of energy (kWyear) and per capita. France has the highest share of nuclear power in her energy supply, 14,5 % and by far the lowest carbon dioxide emission both per capita and per consumed kWyear.

Storing of Green Energy

It is evident that the most severe limitation for usage of wind and solar power is their instability and that this limits their usefulness until a storage method has been found.

If the present production of wind and solar power in Germany + France + Spain + Belgium + Great Britain + The Netherlands should be kept stable you can calculate a storage need of 18 TWh. Corresponding to 180 million Tesla Batteries or 3600 pumped storage units at the same capacity as Europe's largest pumped storage system, Vianden in Luxembourg with a storage capacity of 5 GW. **To support an energy system delivering 2,3% of the total energy in the mentioned countries.**

Wind and Nuclear Power.

Most politicians, journalists and a large majority among common people seem to believe that nuclear power is prohibitively expensive.

Vattenfall informs that the cost for the latest Danish of shore wind power park Horns rev 3 commissioned by the end of 2018 was 9 billion DKK and that the production is expected to be on average 194 MW. I.e. **46 million DKK/MW capacity**.
"Ingeniören" informed us on April 15, 2019 that the still not commissioned Finnish Reactor Oulkiluoto 3 will cost 41 billion DKK and on average deliver 1484 MW. I.e. **27 mio DKK/MW capacity**.

The operational costs for off shore wind power can impossibly be lower than for nuclear power. So nuclear power even from a new and still unpaid reactor is inevitably much cheaper than off shore wind power, and it is reliable, which means that we will not have to build still not invented storage systems with low efficiency and at an unpayable price

Danish plans and Swedish nuclear power.

Swedish nuclear power is reliable, Wind power is not. Danish wind power plans will give us much more wind power than we could possibly use before huge and unknown investments have been made.

The author finds it completely impossible to understand that the wind power lobby has been able to sell the idea of building a huge off shore wind capacity without having presented any sensible idea of how to use this wind power.

Conclusion.

We will give the word to the Swedish chancellor Axel Oxenstierne whose son worried if he was qualified to be Sweden´s chief negotiator at the "Westphalian Peace" in 1648:

"My son, if you knew with how little wisdom the World is governed."

Fore word

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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.

The author was 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. The author was 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 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.

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/year).**

1 PJ roughly corresponds to **25.000 tons of oil** and a **TJ** to **25 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**

World Energy and Population

Summary

The World's population is increasing steadily, in the years 2006-2017 from 6600 million to 7550 million i.e. ca. 80 million per year and the growth rate seems to be surprisingly constant.[i]

The energy or effect consumption is increasing steadily too, from 14,9 TW in 2006 to 17,9 TW in 2017, an increase of 3042 GW or 254 GW/year. For comparison the Danish effect consumption was 22 GW in 2017.[ii]

So the increase in the World's energy consumption per year is about 11 times the Danish consumption.

Wind + Solar power grew from 16 GW in 2006 to 179 GW in 2017. A growth rate of about 14 GW/year, which should be compared with a growth rate for the World effect consumption of about 250 GW/year!

In 2006 oil, coal and gas supplied 90,5 % of the Worlds energy consumption, in 2017 the figure was 88,5 %.

It should be evident, that the idea of a World without fossil fuels is nonsense, at least until a drastic reduction of the World's population has taken place.

The sources for this section are UN.s population statistics and BP.s yearly energy statistics.

Tabel 1

World Energy Consumption 2006-2017												
Source: BP 2017	***2006***	***2007***	***2008***	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***	***2015***	***2016***	***2017***
						GW						
Total World	14.896	15.385	15.542	15.334	16.090	16.482	16.668	17.032	17.198	17.339	17.554	17.938
Oil+coal+naural gas	13.021	13.493	13.580	13.355	14.000	14.362	14.511	14.768	14.842	14.907	15.010	15.280
Nuclear	320	314	312	308	316	303	281	284	290	294	297	301
Hydro	910	925	978	977	1.032	1.052	1.100	1.141	1.168	1.169	1.209	1.220
Solar	1	1	1	2	4	7	11	16	23	30	37	51
Wind	15	19	25	31	39	50	60	74	81	95	109	128
Geotermal, Biomass, Other	82	88	94	102	114	119	129	139	152	162	167	176
Biofuels	37	50	66	74	85	87	89	96	106	106	108	112
Sum	14.385	14.890	15.056	14.850	15.590	15.981	16.181	16.518	16.661	16.762	16.938	17.267
Wind+solar	16	20	27	34	43	57	71	90	104	125	147	179
Sum Non fossile	1.365	1.397	1.477	1.495	1.589	1.619	1.670	1.750	1.820	1.855	1.928	1.987
Increase fossile		472	87	-225	645	362	149	257	74	65	103	270
Increase Wind +Solar		5	6	7	9	14	14	18	14	21	22	32
Total World increase		489	157	-208	756	392	186	365	166	141	215	384
						EJ						
Energy influx	470	485	491	484	507	520	527	537	542	547	555	566

It is observed, that the consumption is increasing steadily by about 260 GW/year, and that Wind and Solar increased with 31 GW/year in 2017.
It is observed too, that there is a slight discrepancy between the sum for the total world in the first line of the table and the sum for the singles fuels. The most of this difference is due to the fact, that the energy from nuclear power is calculated in two different ways. 1. The heat developed in the reactors is part of the "Total World, whereas in the line "Nuclear Power" contains the output of electricity only. I.e. ca. 38% of the energy developed by the nuclear reactors.

BP's statistic give the energy consumptions in different units for each type of energy, and the author has chosen to transform all these units to watts i.e Joule/second.

Tabel 2

Population	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
World Energy Consumption and population 2006-2017												
					% of World Energy Consumption							
Oil+coal+naural gas	90,51	90,62	90,19	89,93	89,80	89,87	89,68	89,40	89,08	88,93	88,62	88,49
Nuclear	2,22	2,11	2,07	2,07	2,03	1,89	1,74	1,72	1,74	1,75	1,76	1,74
Hydro	6,33	6,21	6,49	6,58	6,62	6,59	6,80	6,91	7,01	6,97	7,14	7,06
Solar	0,00	0,01	0,01	0,02	0,02	0,05	0,07	0,10	0,14	0,18	0,22	0,29
Vind	0,11	0,13	0,17	0,21	0,25	0,31	0,37	0,45	0,49	0,57	0,64	0,74
Geotermal, Biomass, Other	0,57	0,59	0,63	0,68	0,73	0,75	0,80	0,84	0,91	0,96	0,99	1,02
Biofuels	0,26	0,33	0,44	0,50	0,54	0,55	0,55	0,58	0,64	0,63	0,64	0,65
Total World Population Mio	6600	6682	6764	6846	6930	7013	7098	7182	7266	7349	7467	7550
Increase per year Mio		81	82	83	83	84	84	84	84	84	117	83
Consumption per capita kW	2,26	2,30	2,30	2,24	2,32	2,35	2,35	2,37	2,37	2,36	2,35	2,38
Pop Growth* kW/capita GW		187	189	185	193	197	197	200	199	197	276	198

The consumption per capita is surprisingly constant 2,35 - 2,38 kW, but by a population growth of about 85-90 million per year the growth in the global energy consumption is about 250 -300 GW/year.
Wind and Solar increased with 32 GW/year in 2017.

However, it may be argued that 1 kW of wind or solar effect replaces about 1/0,38 = 2,6 kW fossil fuel, so you may say that the yearly increase in wind and solar power replaces about 2,6*32 = 83 GW of fossil effect. ***Still only about a third of the increase in the World's effect consumption.***

Figure 1

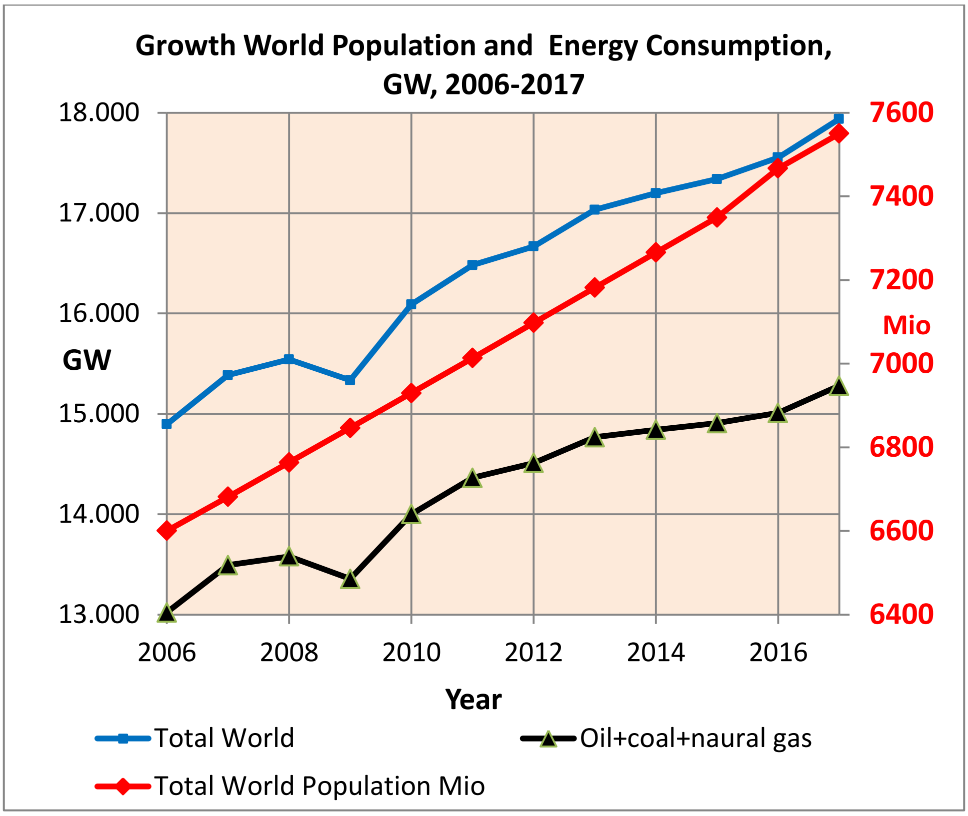


Figure 13 above illustrates the growth in population and energy consumption.
The World's population is growing steadily by about 85 million per year.
The consumption of energy is growing steadily too14.900 GW in 2006 to nearly 17.900 GW in 2017 i.e. by 250 GW/year.
The consumption of fossil fuel is growing a little slower, by 2300 GW in the same period. But it is still growing considerably. On average 188 GW/year.

A fossil free World seems to be very far away.

Figure 2

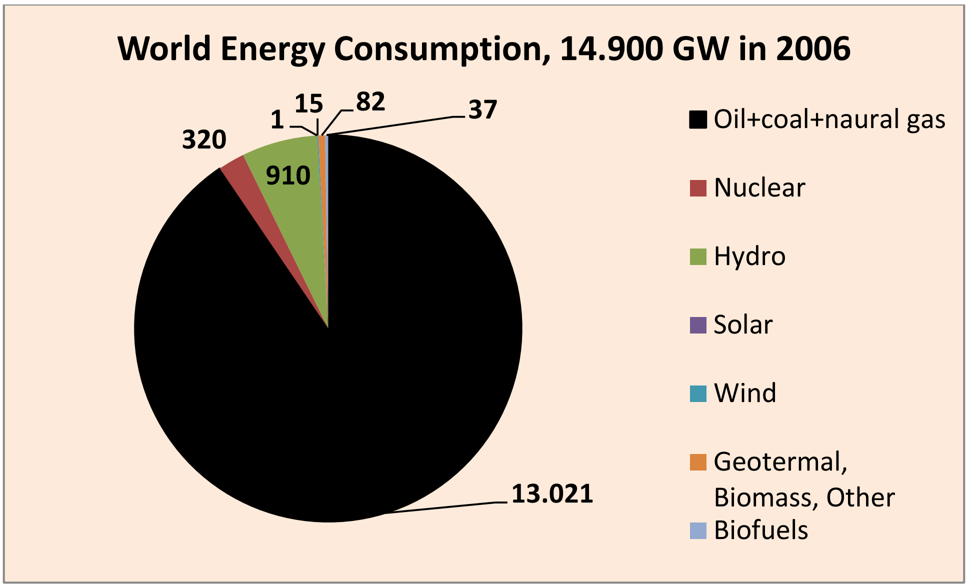


Figure 3

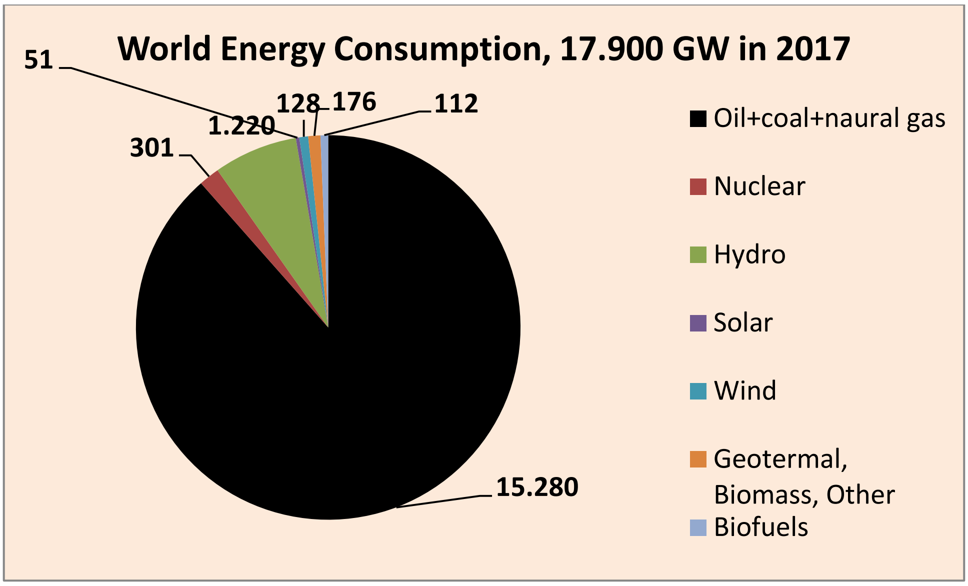


Figure 14 and 15 above illustrate the World Energy Consumption in 2006 and 2017. There has been a considerable increase in the consumption of fossil energy. 2259 GW. This could also be expressed: In 2017 the World consumes nearly 1,7 billion tons oil equivalents of fossil fuel more than in 2006 . (1 GW = 0,75 mio tons of oil equivalent per year)

Figure 4

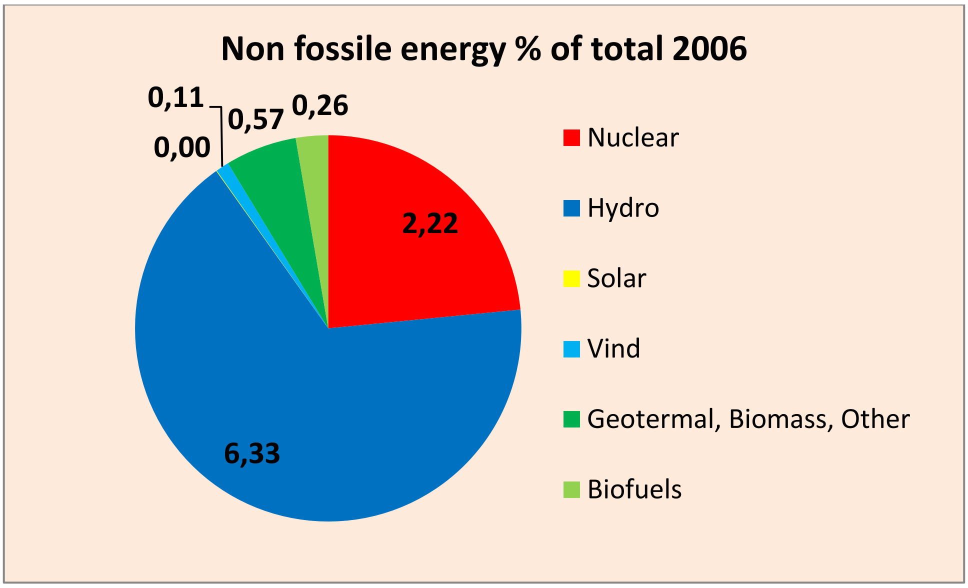


Figure 5

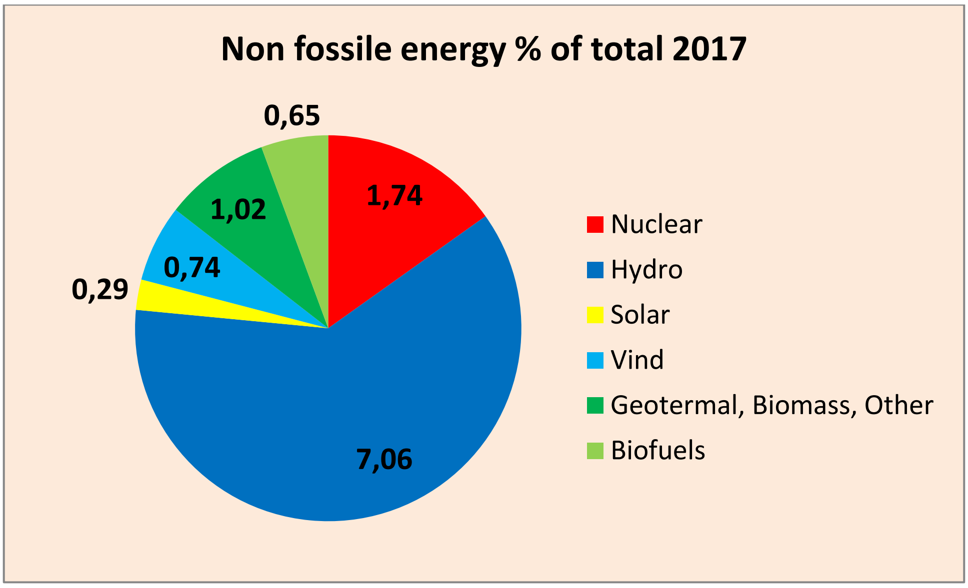
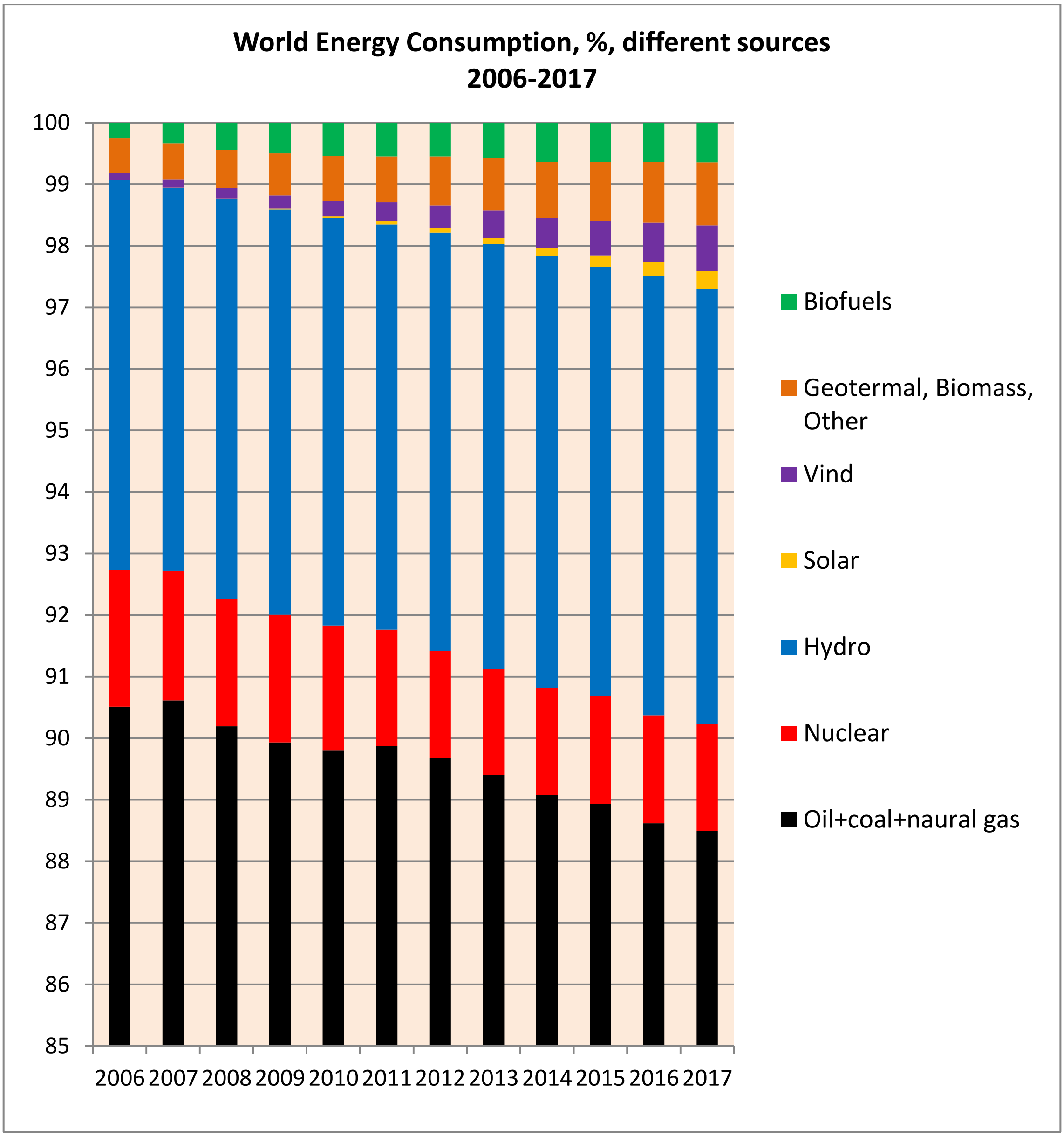


Figure 16 and 17 illustrate the increasing role of non fossil energy. Wind+solar supply only a little more than 1%, of the World's energy supply.

Figure 6



World Energy Consumption, %, different sources
2006-2017
100
99
98
97
96
95
94
93
92
91
90
89
88
87
86
85
2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
Biofuels
Geotermal, Biomass, Other
Vind
Solar
Hydro
Nuclear
Oil+coal+naural gas

Figure 7

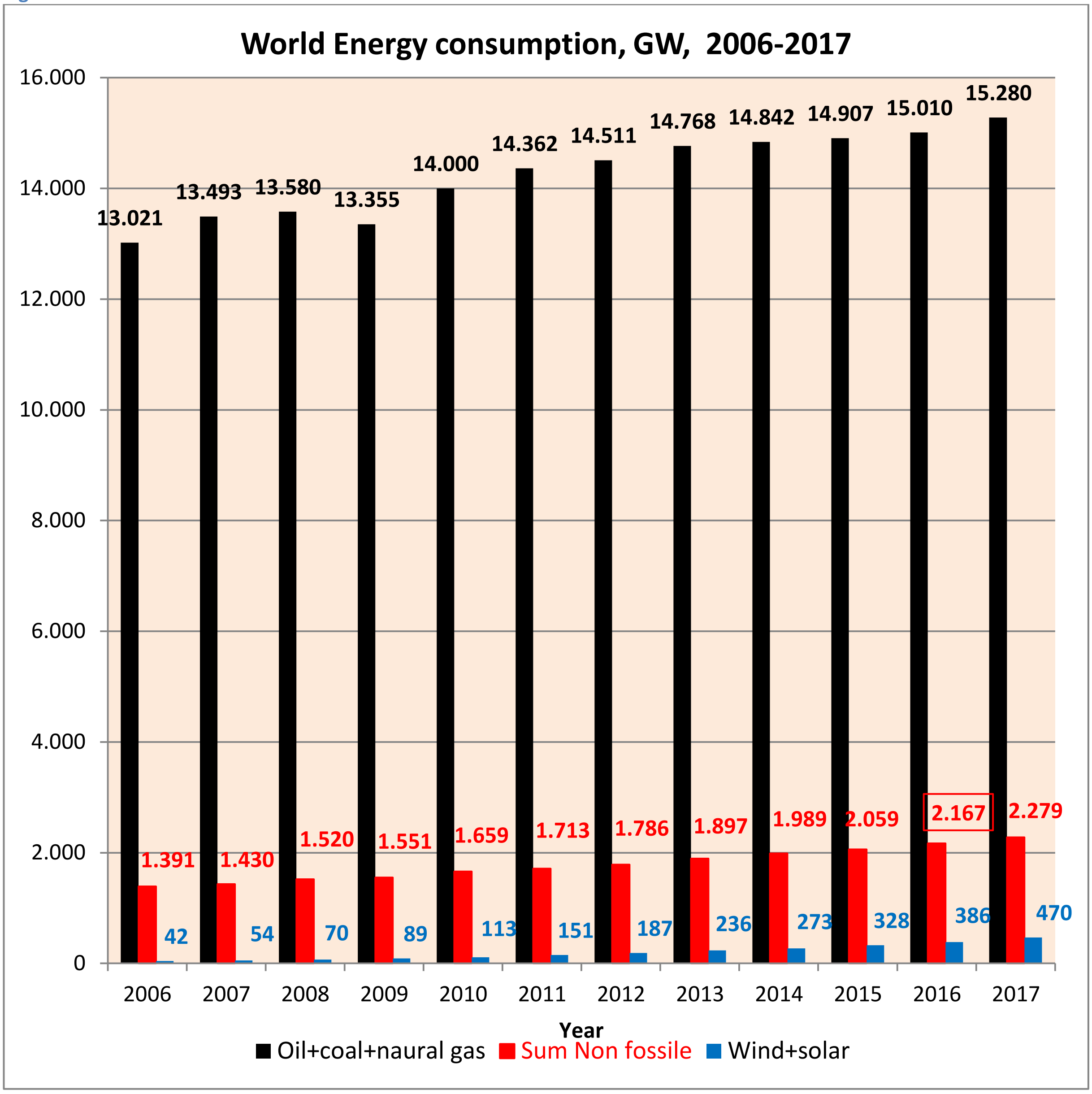


Figure 7 illustrates the distribution of energy types in another way. It must be admitted, that the alternative energy is an increasing part of the energy consumption. But the progress is slow, and it can't keep pace with the increase in demand.

Danish Energy Production 2000-2017[iii]

Summary

The total Danish energy production rose from **36845 MW** (1162 PJ) in the year 2000 to **41603 MW** (1316 PJ) in 2005 and fell to **20879 MW** (660 PJ) in 2017.

The production in 2000 corresponded to 151% of the consumption, 167 % of the consumption in 2005 and only 93 % of the consumption in 2017.

However, this is still a high degree of self-sufficiency which in Western Europe is only surpassed by Norway. And with the planned investments in the North Sea oil and gas fields we will probably regain more than 100 % self-sufficiency.

This presupposes of course that the political system realizes that our energy demand can't be covered by wind power.

In 2017 wind + solar power yielded on average 1847 MW corresponding to 8,2 % of our gross energy consumption.

It is planned to build 12 GW new off shore wind power capacity so we can expect an average wind power of about 7 GW (table 27) corresponding to a little more than 25% of the Danish energy demand. It should be remarked too that the average Danish electricity load was only 3900 MW in 2018. However, most people seem to have forgotten that the output will vary uncontrollably between zero and 17 GW. So unless we can obtain a very good – and unlikely – cooperation with the Norwegian hydro system, or which is absolutely unlikely invent and build new storage systems for electricity we will in the foreseeable future still be dependant of fossil energy.

Tabel 3

Danish Energy Productio, MW, 2000- 2017, Detailed																		
MW	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Crude Oil	24177	23025	24738	24738	26193	25248	22960	20683	19085	17593	16576	14918	13571	11839	11087	10485	9416	9186
Waste Oil	19	22	22	13	9	10	12	5	2	1	1	1	1	1	0	2	1	1
Natural Gas	9813	10076	10094	9562	11243	12458	12378	10976	11939	9988	9748	7819	6831	5685	5494	5502	5368	5776
Solar	11	11	11	12	12	13	14	15	16	19	21	25	40	92	109	118	147	160
Wind	483	492	557	635	749	755	697	819	789	767	891	1116	1169	1270	1493	1613	1455	1687
Hydro	3	3,2	3,6	2,4	3	2,6	2,7	3,2	3	2,2	2,4	1,9	2	1,5	1,7	2,1	2	2,0
Geothermal	2	2,3	2,7	2,6	3	5,5	9,1	9,1	8	7,7	6,7	5,3	9	7,3	5,3	4,4	7	4,8
Straw	386	434	496	535	567	586	588	595	501	550	740	641	579	644	589	627	622	641
Wood Chips	87	101	119	201	220	193	215	229	260	311	360	362	393	341	359	468	541	616
Firewood	393	420	413	471	495	560	603	793	760	731	754	649	622	623	567	696	711	713
Wood Pellets	94	97	93	98	104	103	74	78	76	77	76	77	55	58	61	85	89	89
Wood Waste	218	213	191	200	202	206	220	242	231	219	270	248	221	228	224	354	270	227
Biogas, Landfill	19	18	20	14	19	17	10	10	9	8	10	7	6	7	5	6	6	6
Biogas, Sludge	27	27	27	28	26	29	28	27	27	27	27	26	29	30	33	29	33	35
Biogas, Other	46	52	59	72	73	75	87	87	89	98	101	97	104	109	138	165	247	313
Wastes, Non-renewable	432	460	483	522	530	539	548	567	591	561	544	548	507	498	503	497	488	508
Wastes, Renewable	529	562	591	638	648	659	670	693	722	686	665	670	620	609	615	607	596	621
Bioethanol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biodiesel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biooil	2	6	4	13	21	24	36	38	57	51	62	25	30	28	23	20	9	6,0
Heat Pumps	104	107	108	109	110	118	132	141	153	166	179	192	205	219	230	254	280	288
SUM MW	36845	36128	38033	37868	41228	41603	39283	36011	35318	31865	31033	27428	24993	22289	21537	21532	20287	20879
Sum PJ	1162	1142	1199	1194	1300	1316	1239	1136	1114	1008	979	865	788	705	679	679	640	660

Tabel 4

Danish Energy Production, MW, 2000-2017																		
Year	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
Sum Fossile	34009	33123	34854	34314	37445	37715	35349	31664	31027	27583	26325	22738	20403	17525	16581	15989	14784	14962
Solar	11	11	11	12	12	13	14	15	16	19	21	25	40	92	109	118	147	160
Wind	483	492	557	635	749	755	697	819	789	767	891	1116	1169	1270	1493	1613	1455	1687
Hydro	3,4	3,2	3,6	2,4	3,0	2,6	2,7	3,2	2,9	2,2	2,4	1,9	2,0	1,5	1,7	2,1	2,2	2,0
Geothermal	2	2	3	3	3	5	9	9	8	8	7	5	9	7	5	4	7	5
Bio+ Heat Pumps	2338	2497	2605	2902	3016	3111	3211	3501	3475	3486	3786	3542	3370	3394	3347	3806	3892	4063
Sum	36845	36128	38033	37868	41228	41603	39283	36011	35318	31865	31033	27428	24993	22289	21537	21532	20287	20879
Sum Non Fossile	**2836**	**3004**	**3179**	**3554**	**3783**	**3887**	**3934**	**4347**	**4291**	**4282**	**4707**	**4690**	**4590**	**4764**	**4956**	**5544**	**5503**	**5917**

It can easily be seen from fig. 8 and fig. 9 here under that the increase in non fossil production is far less than the decrease in oil and gas production. It is remarkable too that the increase in wind power has only been about 1200 MW whereas the increase in other non fossile energy has been about 1700 MW from 2000-2017.

Figure 8

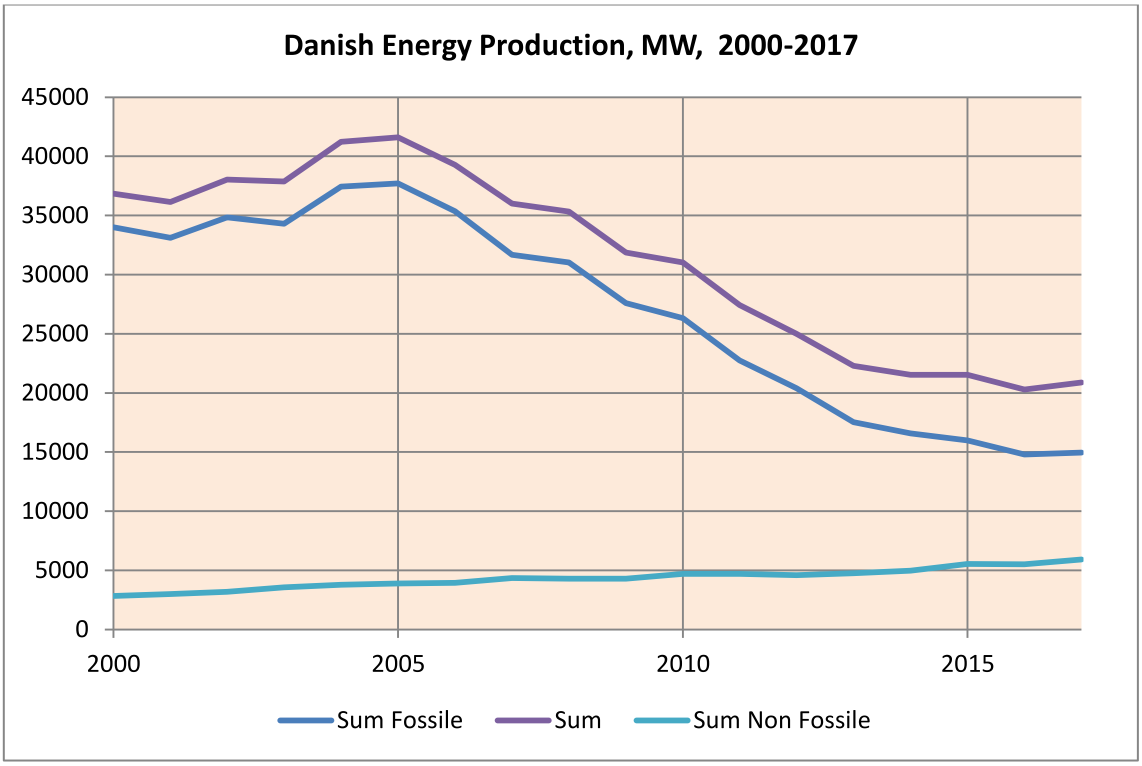
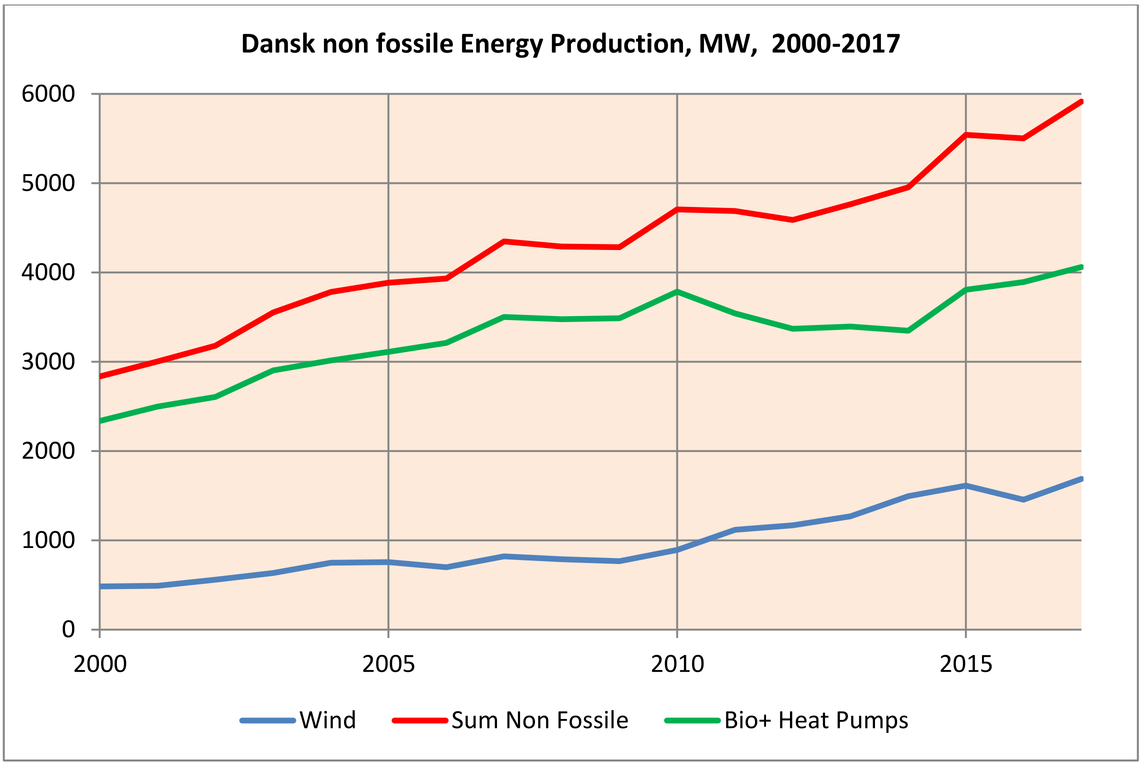


Figure 9

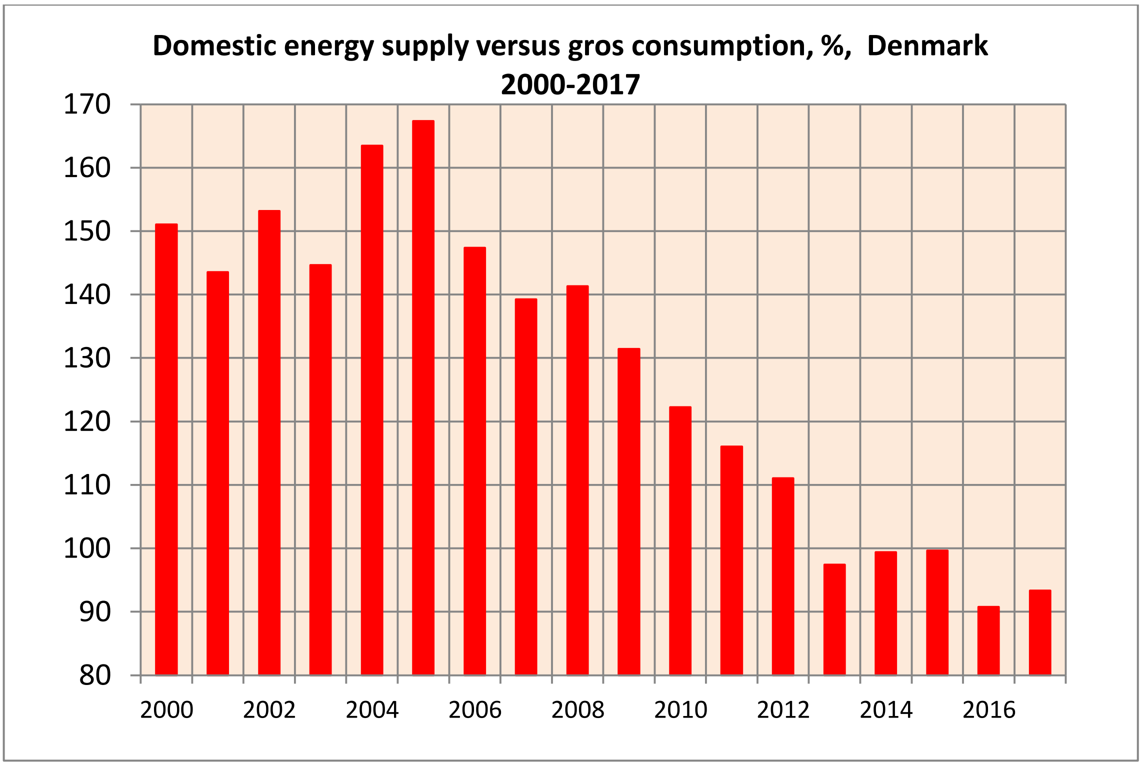


Production versus consumption

Tabel 5

Domestic Energy consumption and % self supply									
Year	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*
Gros Domestic Consumption	24462	25168	24826	26179	25287	24860	26651	25860	25064
Net Domestic Consumption	20003	20507	20019	20393	20660	20879	21100	21116	20773
Energy production % of gross domestic consumption	**151**	**144**	**153**	**145**	**163**	**167**	**147**	**139**	**141**
Year	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
Gros Domestic Consumption	24248	25382	23636	22567	22875	21666	21606	22349	22373
Net Domestic Consumption	19891	20921	20002	19557	19433	18718	19352	19769	20061
Energy production % of gross domestic consumption	**131**	**122**	**116**	**111**	**97**	**99**	**100**	**91**	**93**

Figure 10



Hardly any other European country, except Norway and Russia, enjoys such a high degree of energy self supply. The production is 20,9 GW and the gross consumption is 22,4 GW. So if we were smart enough to by the two 900-1000 MW nuclear reactors at Ringhals that the Swedes plan to shut down no energy crisis could harm us.

Figure 11

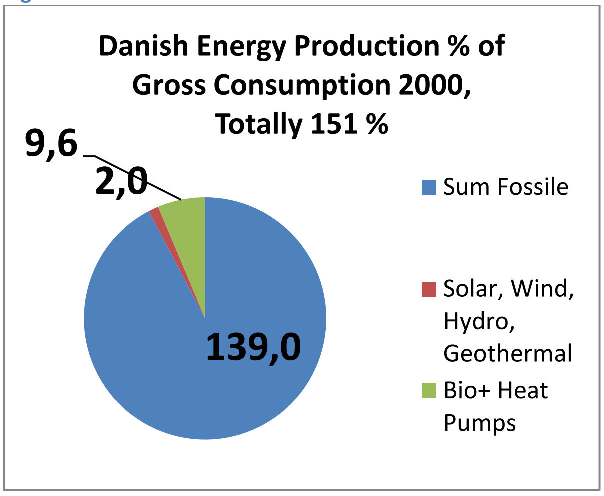
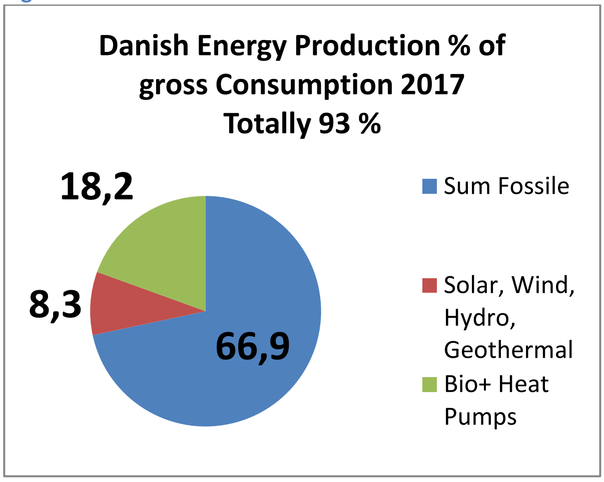
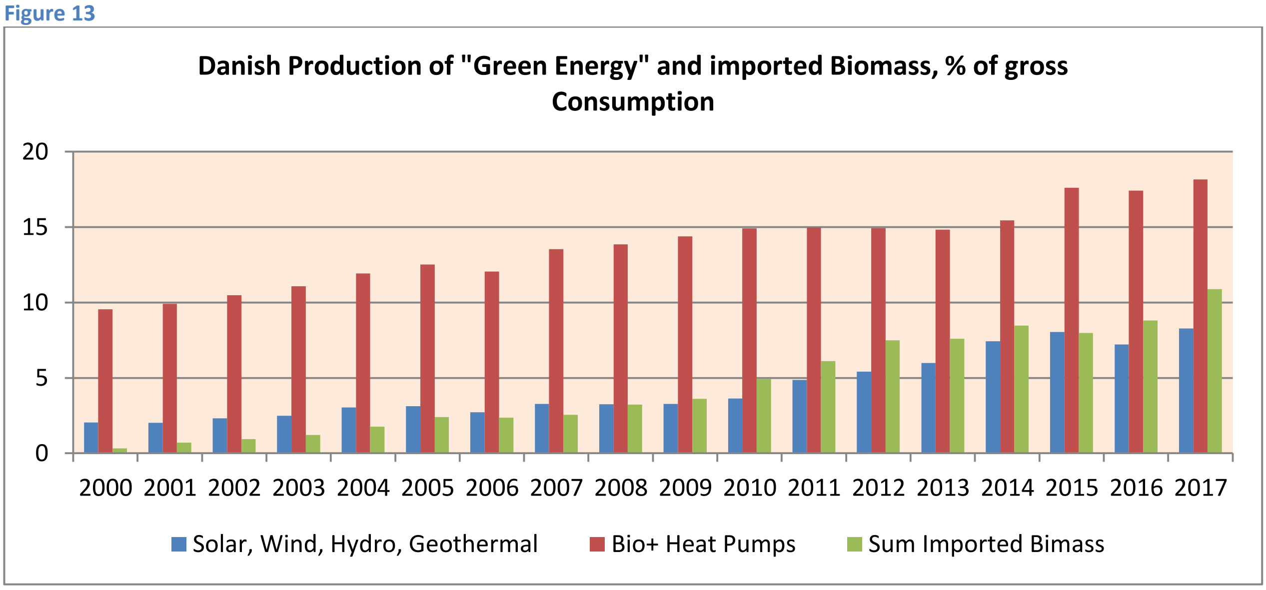


Figure 12



Denmark imports electricity and biomass and exports fossil fuels.

Figure 13



It must be justified to wonder how Denmark should be "fossil free" in 31 years. There is not much more domestic biofuel to exploit and no more hydro power so wind and solar must be extended by a factor about 10 unless we can count on forests around the World.

By the way Danish Wind and Solar Power varied between 11 MW and 5168 MW with an average of 1702 MW in 2018. So there is a not quite small energy storage task to perform too.

Danish Consumption of Energy 2000-2017

Summary

It is remarkable, that the net energy consumption is practically constant (table 6), whereas the loss in the transformation sector has decreased from 18% to 10% of the total energy consumption. (Figure 14)

It should be observed too that the population has increased by 6% in the period.

(Table 7 and Figure 15)

Imported biomass including imported garbage is the largest single contributor to the Danish green energy. How sustainable this is is for the reader to wonder. (Table 11 and Fig 16)

Transport (Table 8 and Figure 18). In 2000 the consumption was 6,3 GW and in 2017 it was 6,9 GW. An increase of 558 MW or an increase of 8,3%. Only slightly more than the increase in the population. The aviation increased by 239 MW, and the road transport by 325 MW.

Production (Table 9 and Figure 19) In 2000 the consumption was 5,2 GW and in 2017 it was 4,1 GW. A reduction of 1112 MW or 21%. **The most remarkable figures are the consumption for Agriculture, Forestry and Horticulture which fell from 985 to 823 MW or by 16% by an increasing production. The 823 MW corresponds to 3,7% of the gross energy consumption in 2017.**
It should be noted too, that agriculture and forestry delivers 2599 MW "green energy" back in the form of wood, straw and biogas. (Table 3)

However, it is a well known fact that the talking classes despise production and hate the famers, so they have invented the idea, that the gas produced by animals should be taken into account, although the only carbon slipping out from a cow or pig is the carbon in their food, which is taken out from the atmosphere by the plants eaten by cows and pigs.

The manufacturing industry has reduced its' energy usage from 3,68 GW to 2,89 GW or by 794 MW. The author is living in the small community Grenaa, which in the last 20 years has lost about 1000 work places in the energy intensive industry, chemicals, textiles and paper. They have been transferred to without any doubt less energy efficient countries. The former EU commissar for The Environment Connie Hedegaard in 2008 wrote a book "When the Climate became hot" page 115: "In China you use 6-7 times as much energy per produced item as in the USA or the EU."

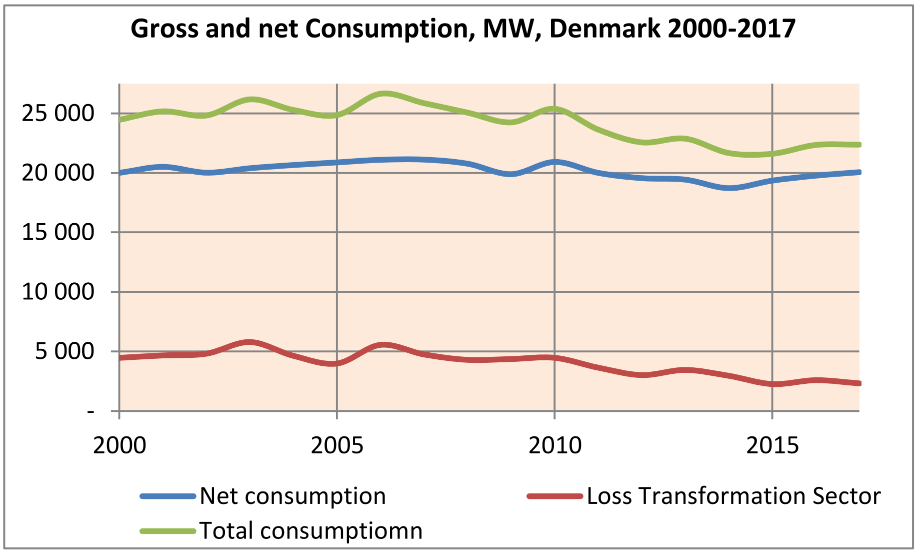
So you might think that our energy policy – by heavily taxation to get rid of energy intensive industries – is counterproductive.

Trade, Service and Housing. (Table 10 and Figure 20) The consumption has risen from 8,3 GW in 2000 to 8,9 GW in 2017, or by 672 MW corresponding to 8,1%, so the consumption per capita, 1,05 kW, is constant.

The author might save maximum 1 kW heat or 8,960 MWh per year by spending 250.000 DKK or 19.000 € for better insulation and new doors and windows.

The energy price without tax should not exceed 500 DKK/MWh. The saving would be max 9 MWh per year corresponding to 4500 DKK. So it would take 55 years to get the money back under the condition that you pay no interest for the investment. And that the investment will need no maintenance.

Figure 14



The net consumption is the gross consumption minus losses in power stations, refineries and district heating systems.

Figure 15

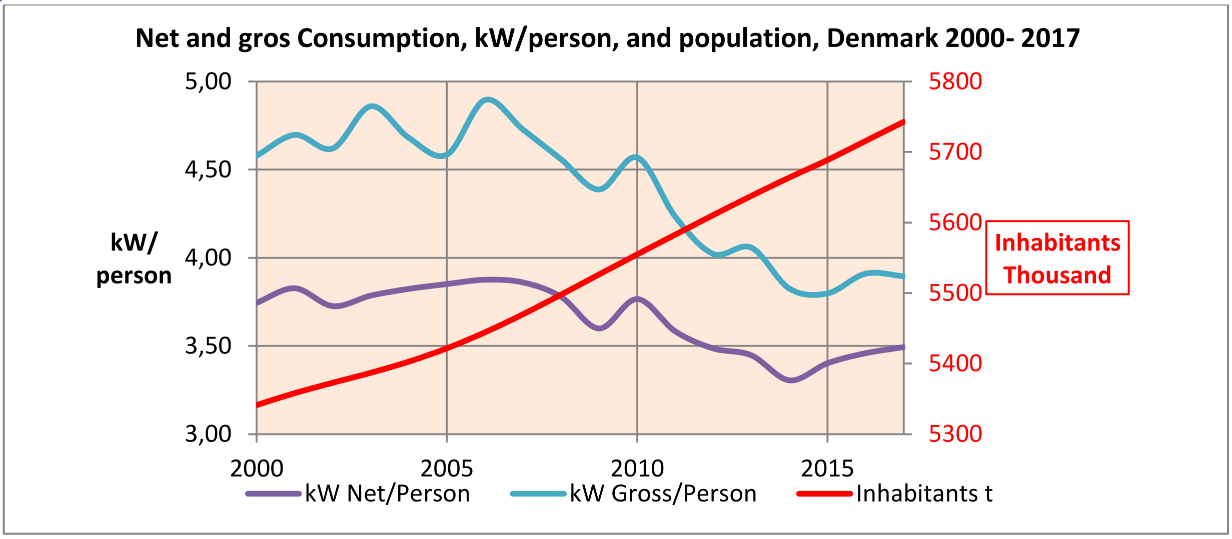
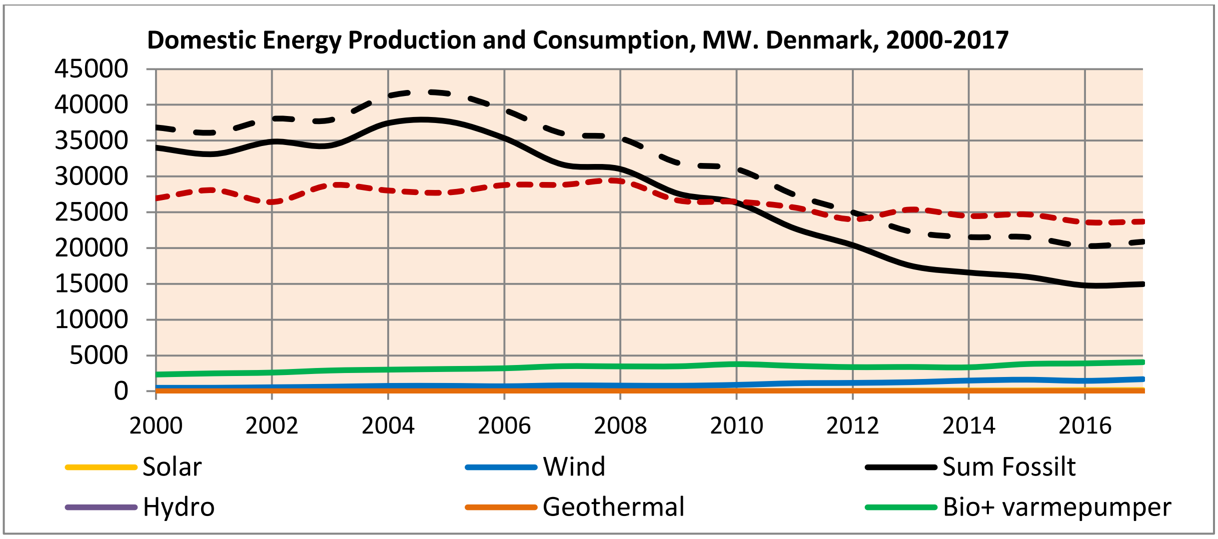


Figure 16



Domestic Energy Production and Consumption, MW. Denmark, 2000-2017
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
2000
2002
2004
2006
2008
2010
2012
2014
2016
Solar
Wind
Sum Fossilt
Hydro
Geothermal
Bio+ varmepumper

Usage of Energy

Tabel 6

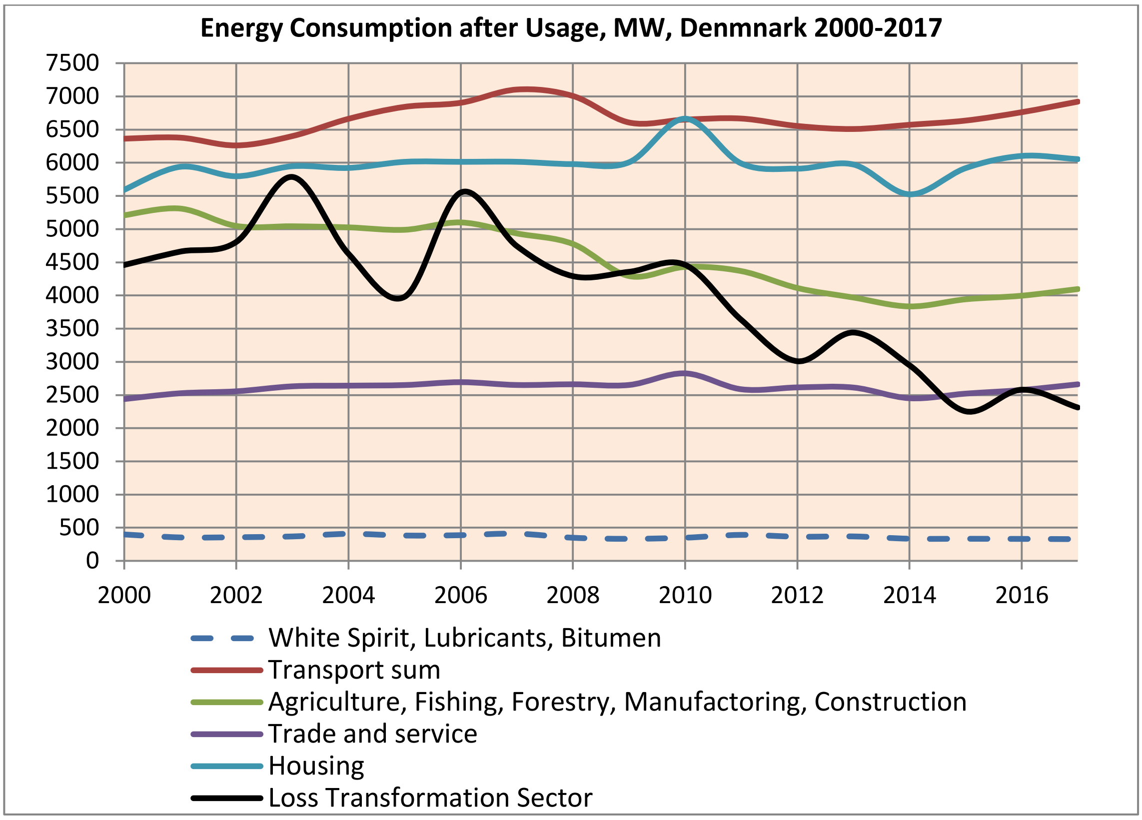
Consumption after Usages, MW

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
White Spirit, Lubricants, Bitumen	399	354	357	369	408	383	387	411	349	333	350	392	364	369	335	334	332	328
Transport sum	6363	6378	6261	6402	6662	6843	6904	7104	7006	6607	6651	6666	6554	6509	6572	6636	6762	6921
Agriculture, Fishing, Forestry, Manufactoring, Construction	5209	5310	5048	5043	5026	4990	5101	4935	4776	4293	4430	4367	4113	3969	3835	3943	3997	4097
Trade and service	2439	2526	2556	2631	2641	2650	2693	2651	2662	2651	2826	2587	2615	2613	2452	2521	2576	2661
Housing	5592	5939	5797	5948	5922	6014	6014	6015	5979	6007	6664	5990	5911	5974	5524	5919	6103	6054
Net consumption	20003	20507	20019	20393	20660	20879	21100	21116	20773	19891	20921	20002	19557	19433	18718	19352	19769	20061
Loss Transformation Sector	4460	4661	4807	5786	4627	3981	5552	4744	4291	4357	4461	3633	3009	3442	2948	2254	2580	2312
Gross consumption	24462	25168	24826	26179	25287	24860	26651	25860	25064	24248	25382	23636	22567	22875	21666	21606	22349	22373
Transformation sector delivery district heating	4002	4314	4297	4444	4465	4502	4489	4413	4523	4630	5290	4745	4859	4808	4468	4788	4921	5000

Tabel 7

kW/Inhabitant. Denmark 2000- 2017																		
Year	***2000***	***2001***	***2002***	***2003***	***2004***	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***	***2015***	***2016***	***2017***
*Inhabitants*1000*	***5341***	***5358***	***5373***	***5387***	***5403***	***5422***	***5444***	***5470***	***5498***	***5526***	***5555***	***5583***	***5611***	***5638***	***5664***	***5689***	***5716***	***5743***
White Spirit, Lubricants, Bitumen	0,07	0,07	0,07	0,07	0,08	0,07	0,07	0,08	0,06	0,06	0,06	0,07	0,06	0,07	0,06	0,06	0,06	0,06
Transport sum	1,19	1,19	1,17	1,19	1,23	1,26	1,27	1,30	1,27	1,20	1,20	1,19	1,17	1,15	1,16	1,17	1,18	1,21
Agriculture, Fishing, Forestry, Manufactoring, Construction	0,98	0,99	0,94	0,94	0,93	0,92	0,94	0,90	0,87	0,78	0,80	0,78	0,73	0,70	0,68	0,69	0,70	0,71
Trade and service	0,46	0,47	0,48	0,49	0,49	0,49	0,49	0,48	0,48	0,48	0,51	0,46	0,47	0,46	0,43	0,44	0,45	0,46
Housing	1,05	1,11	1,08	1,10	1,10	1,11	1,10	1,10	1,09	1,09	1,20	1,07	1,05	1,06	0,98	1,04	1,07	1,05
Net consumption	**3,74**	**3,83**	**3,73**	**3,79**	**3,82**	**3,85**	**3,88**	**3,86**	**3,78**	**3,60**	**3,77**	**3,58**	**3,49**	**3,45**	**3,30**	**3,40**	**3,46**	**3,49**
Loss Transformation Sector	0,83	0,87	0,89	1,07	0,86	0,73	1,02	0,87	0,78	0,79	0,80	0,65	0,54	0,61	0,52	0,40	0,45	0,40
Gross consumptiomn	**4,58**	**4,70**	**4,62**	**4,86**	**4,68**	**4,59**	**4,90**	**4,73**	**4,56**	**4,39**	**4,57**	**4,23**	**4,02**	**4,06**	**3,83**	**3,80**	**3,91**	**3,90**
Transformation sector delivery district heating	0,75	0,81	0,80	0,83	0,83	0,83	0,82	0,81	0,82	0,84	0,95	0,85	0,87	0,85	0,79	0,84	0,86	0,87

Figure 17



The most remarkable development is that the loss from the transformation sector has decreased significantly. The electricity production from thermal power stations has decreased significantly and thus the internal power consumption in these. The district heating systems have been improved and more homes are heated by natural gas.

The energy consumption in manufacturing, agriculture etc. has fallen drastically (table 6) from 5209 to 4097 MW.

Trade and service shows a small increase, so our civil servants and bureaucrats and the Chinese and other to whom we have transferred our production of textiles, paper, chemicals and steel can be satisfied. Housing is nearly constant, but until now the transport sector has had a slightly increasing energy consumption, so it is evident that it is a popular target for those who will save the World.
White spirit, lubricants and bitumen demands about 325 MW. 325 MW corresponds to about 244.000 tons of oil per year. *So the thoughtful reader may ask how we shall build and maintain our roads when the fossil free Paradise has come true.*

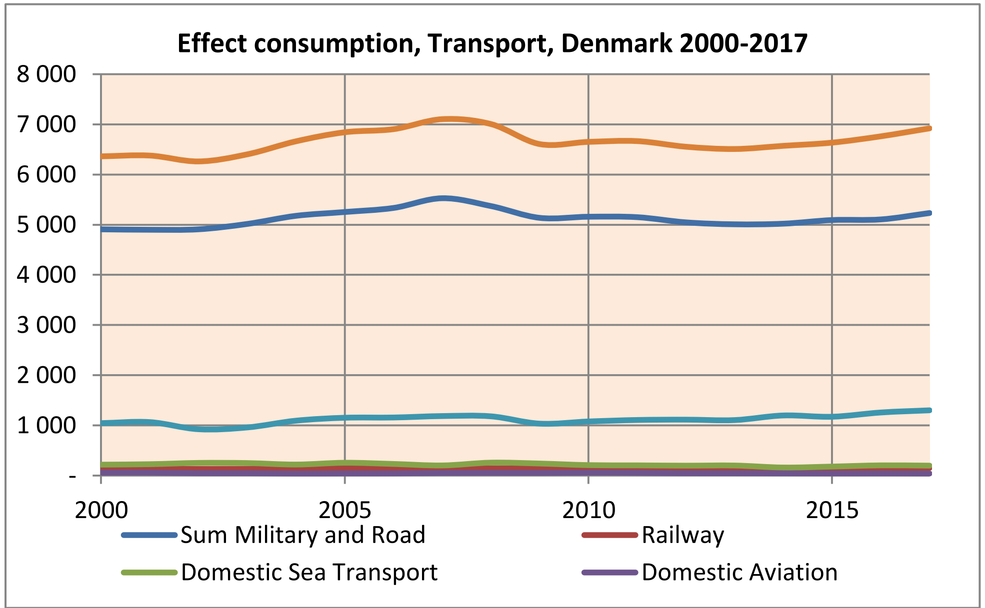
Consumption Transport

Tabel 8

Effect Consumption, Transport, MW, Denmark 2000- 2017

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Sum Military and Road	4 908	4 899	4 908	5 015	5 177	5 253	5 334	5 528	5 372	5 137	5 159	5 150	5 047	5 008	5 020	5 092	5 105	5 233
Railway	137	130	132	134	135	142	140	138	144	144	150	152	150	150	152	152	156	151
Domestic Sea Transport	217	226	251	248	219	255	230	201	257	239	207	202	197	200	159	179	202	197
Domestic Aviation	57	58	47	47	39	41	43	51	54	53	57	55	47	46	43	41	42	40
International Aviation	1 044	1 065	923	958	1 093	1 152	1 157	1 185	1 180	1 034	1 077	1 107	1 114	1 105	1 197	1 172	1 257	1 300
Sum	**6 363**	**6 378**	**6 261**	**6 402**	**6 662**	**6 843**	**6 904**	**7 104**	**7 006**	**6 607**	**6 651**	**6 666**	**6 554**	**6 509**	**6 572**	**6 636**	**6 762**	**6 921**
Road Transport per inhabitant MW	*878*	*825*	*847*	*843*	*874*	*873*	*887*	*919*	*898*	*855*	*774*	*860*	*854*	*838*	*909*	*860*	*836*	*864*

Figure 18



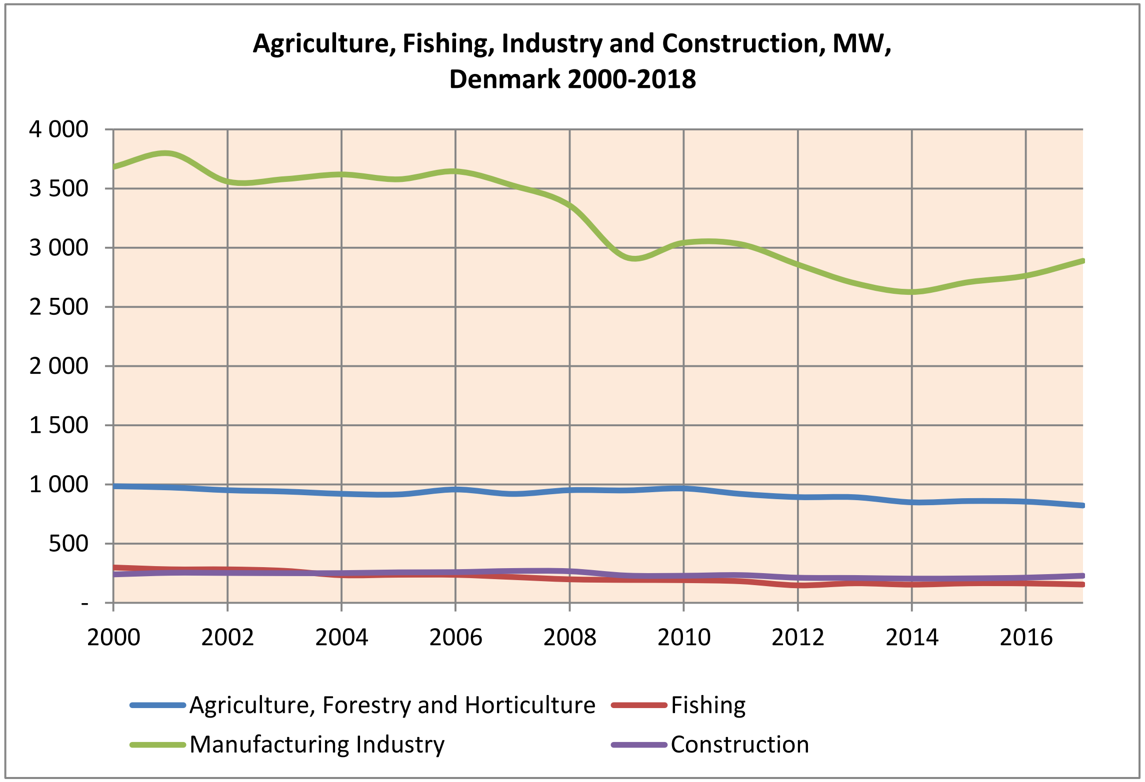
Road transport is the largest factor, so it is evident that all good people are eager to reduce it. The energy consumption for road transport has increased by 6%. So has the population. So if anybody wants to limit our energy consumption it is recommendable to put limits on the immigration.

Consumption Production

Tabel 9

Effect Consumption, Production, MW, Denmark 2000- 2017																		
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Agriculture, Forestry and Horticulture	985	975	952	941	921	916	958	920	952	950	967	920	894	893	850	860	855	823
Fishing	299	283	283	271	234	237	237	218	199	194	192	182	148	165	154	165	164	155
Manufacturing Industry	3684	3798	3560	3581	3620	3579	3646	3527	3358	2918	3043	3030	2859	2701	2627	2710	2764	2890
Construction	240	254	253	251	251	258	260	269	267	231	229	234	212	210	205	207	213	229
Sum	**5209**	**5310**	**5048**	**5043**	**5026**	**4990**	**5101**	**4935**	**4776**	**4293**	**4430**	**4367**	**4113**	**3969**	**3835**	**3943**	**3997**	**4097**

Figure 19



Agriculture, forestry and horticulture has reduced its' energy consumption from 985 to 823 MW. A reduction of 16% by increasing production. So it is evident that the farmers by the political establishment are considered to be severe climate sinners.

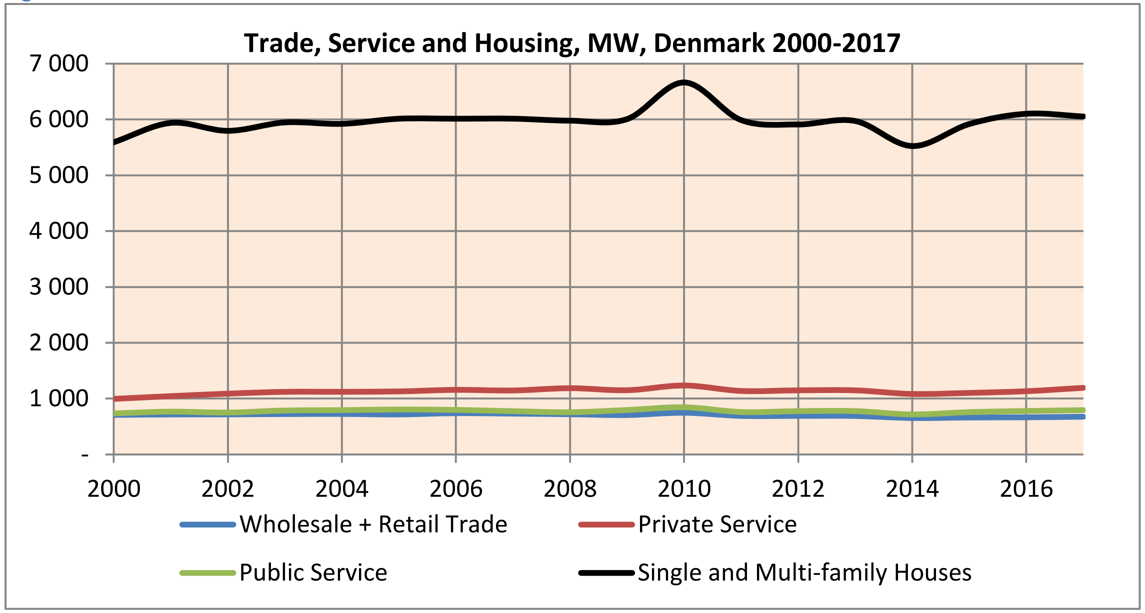
The decline in the consumption of energy in the manufacturing industry is considerable. The author is a former production manager and thinks: "Untergang des Abendlandes."

Trade, Service and Housing

Tabel 10

Trade, service and housing, MW, Denmark 200-2017																		
Year	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
Wholesale + Retail Trade	708	716	717	723	725	716	739	731	720	705	746	690	691	689	652	661	665	675
Private Service	996	1044	1089	1121	1122	1129	1157	1145	1187	1150	1235	1137	1148	1148	1083	1102	1132	1193
Public Service	735	766	750	787	794	805	797	775	756	796	845	760	776	776	717	757	778	793
Single and Multi-family Houses	5592	5939	5797	5948	5922	6014	6014	6015	5979	6007	6664	5990	5911	5974	5524	5919	6103	6054
Sum	8272	8719	8605	8830	8815	8922	8967	8935	8909	8889	9719	8811	8738	8797	8181	8647	8892	8944
Housing kW per inhabitant	1,05	1,11	1,08	1,10	1,10	1,11	1,10	1,10	1,09	1,09	1,20	1,07	1,05	1,06	0,98	1,04	1,07	1,05

Figure 20



Private and public service shows a slight increase. Single and multi-family houses show a significant increase from 5592 to 6054 MW.

But per inhabitant there is no significant increase.

Sustainable Energy

Summary

Contrary to what most people seem to think wind power so far isn't the dominant part of the "sustainable" energy (table 4 above, table 11 hereunder and figure 22.) The sustainable energy has grown from 12 to 37% of the gross energy consumption in the period from 2000 to 2017. (The wind power fell from 1687 MW in 2017 to 1587 MW in 2018, ref. table 13).

Wind, solar, hydro and geothermal rose from 2,0% of the gross consumption in 2000 to 8,3 % in 2017. Domestically produced biomass and heat pumps yielded 9,6% in 2000 and 18,2% in 2017.
These 18,2 % corresponds to 4063 MW. The heat pumps yielded 288 MW in 2018, so the biomass corresponded to 3845 MW in 2018.

According to "Energistyrelsen"[iv] the potential for Danish bioenergy is 162 PJ/Year corresponding to 5,1 GW so there remains 1,3 GW to be used.

At the moment there is much talk of bio fuel for aviation. In 2017 the aviation used 1,34 GW of fuel. So it can hardly be made by Danish biomass. (There will always be heavy losses by transforming straw or tree to liquid fuel, so we must hope that forests in Sibiria or Africa can supply the necessary biomass.)

Figure 21-23 below illustrate the development of sustainable energy. And it is illustrated that hydropower and geothermal hardly ever will obtain any great importance. Figure 23 and 24 illustrate the solar power. It must be admitted that this is increasing fast, and figure 24 illustrate it's problem. It yields practically nothing in half of the year.

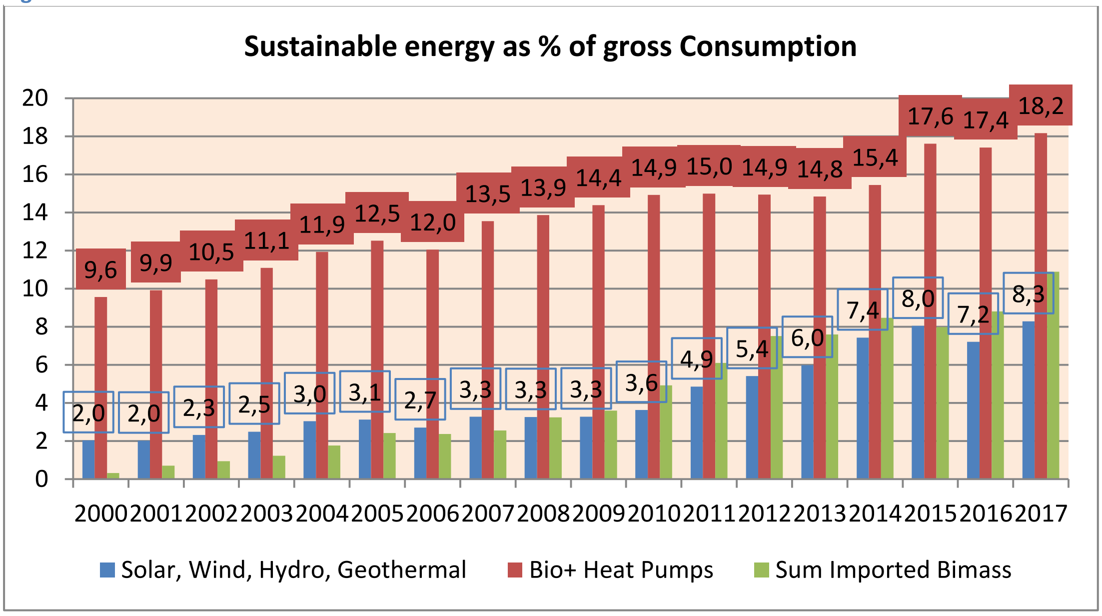
The remarks about **Bio Oil** illustrate that EU is in a hurry if the plans to cover up to 10% of the fuel used for transportation shall be fulfilled. But if the price is high enough we may of course to the benefit of the climate import it from USA or Brazil!

Tabel 11

Solar Wind Hydro Geothermal, Bio+ Heatpumps and imported biomass % of gross consumption																		
Year	***2000***	***2001***	***2002***	***2003***	***2004***	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***	***2015***	***2016***	***2017***
Solar, Wind, Hydro, Geothermal	2,0	2,0	2,3	2,5	3,0	3,1	2,7	3,3	3,3	3,3	3,6	4,9	5,4	6,0	7,4	8,0	7,2	8,3
Bio+ Heat Pumps	9,6	9,9	10,5	11,1	11,9	12,5	12,0	13,5	13,9	14,4	14,9	15,0	14,9	14,8	15,4	17,6	17,4	18,2
Sum Imported Bimass	0,3	0,7	0,9	1,2	1,8	2,4	2,4	2,6	3,2	3,6	4,9	6,1	7,5	7,6	8,5	8,0	8,8	10,9
Sum sustainable	12	13	14	15	17	18	17	19	20	21	23	26	28	28	31	34	33	37

Danish Energy Production, MW, 2000-2017																		
Sum Fossile	34009	33123	34854	34314	37445	37715	35349	31664	31027	27583	26325	22738	20403	17525	16581	15989	14784	14962
Solar	11	11	11	12	12	13	14	15	16	19	21	25	40	92	109	118	147	160
Wind	483	492	557	635	749	755	697	819	789	767	891	1116	1169	1270	1493	1613	1455	1687
Hydro	3,4	3,2	3,6	2,4	3,0	2,6	2,7	3,2	2,9	2,2	2,4	1,9	2,0	1,5	1,7	2,1	2,2	2,0
Geothermal	2	2	3	3	3	5	9	9	8	8	7	5	9	7	5	4	7	5
Bio+ Heat Pumps	2338	2497	2605	2902	3016	3111	3211	3501	3475	3486	3786	3542	3370	3394	3347	3806	3892	4063
Sum	36845	36128	38033	37868	41228	41603	39283	36011	35318	31865	31033	27428	24993	22289	21537	21532	20287	20879
Sum Non Fossile	**2836**	**3004**	**3179**	**3554**	**3783**	**3887**	**3934**	**4347**	**4291**	**4282**	**4707**	**4690**	**4590**	**4764**	**4956**	**5544**	**5503**	**5917**

Figure 21



It will probably surprise most of the readers how small a role the wind power plays. 7,5% of our energy supply in 2017, and somewhat less in 2018.

Figure 22

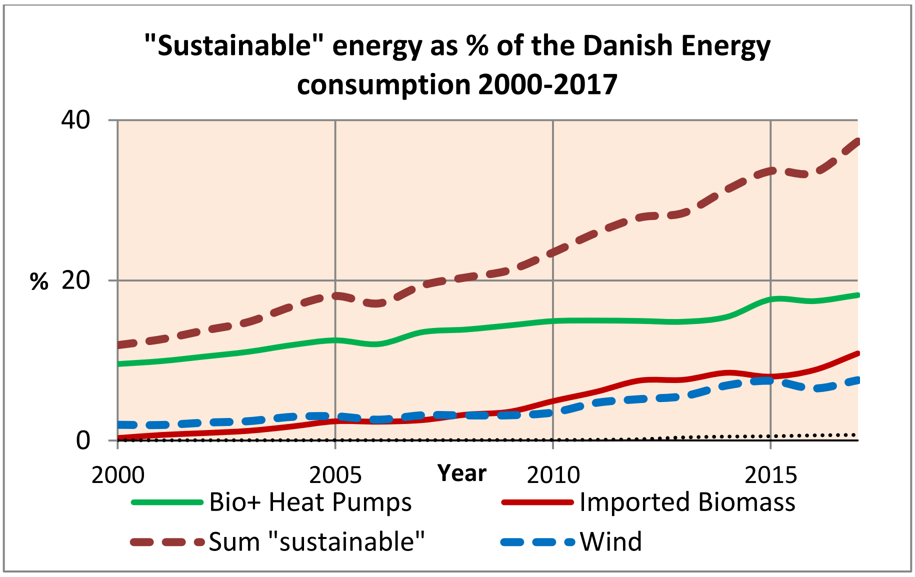
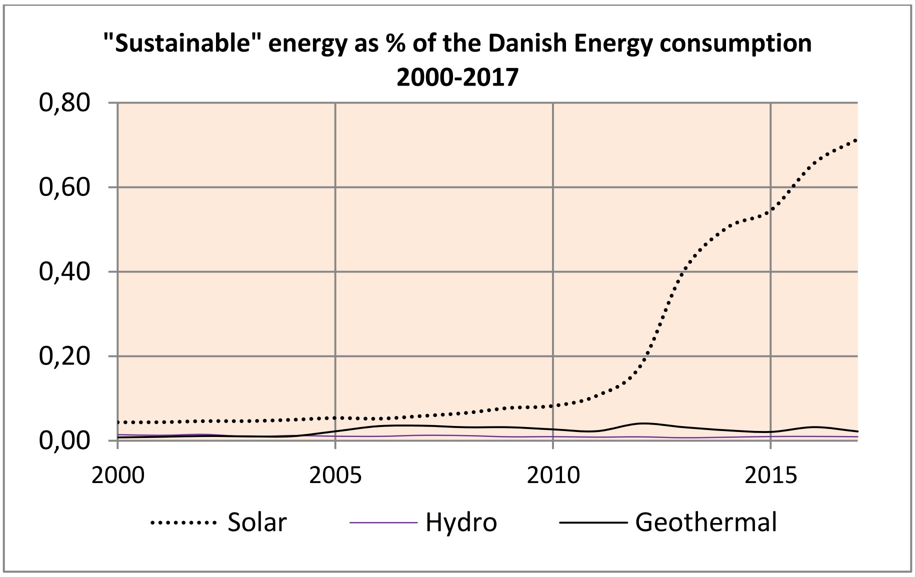
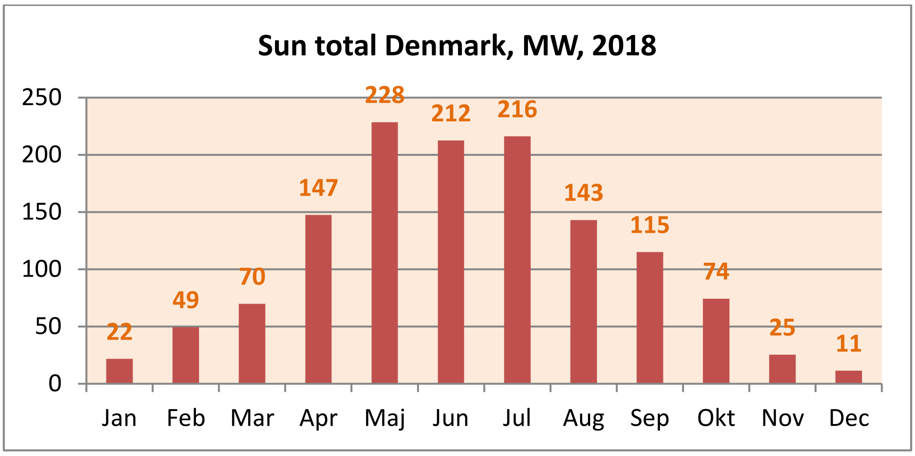


Figure 23



Solar Power may have a potential for an essential increase – in the summer months.

Figure 24



Contrary to wind power it is reasonably predictable but of no use half of the year. And the panels are ugly to look at.

Bio oil. About 10 years ago DONG, now Oersted, built a plant for producing ethanol from straw. Cost about 1 billion DKK, 135 million €. From the very scarce information given to the public, the involuntary investors, it can be concluded that it was a complete fiasco. However 6 MW of Bio oil was produced in 2017.

According to https://www.eia.gov/todayinenergy/detail.php?id=32152
The USA produced 1025 barrels of bioethanol/day in 2017

And according to
https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_The%20Hague_EU-28_6-19-2017.pdf table 3 the EU produced 5380 mio liter bieoethanol for fuel in 2017.

We can calculate the effect and get an American bioethanol effect of 39,8 GW and a European of 3,6 GW. So the American bioethanol production corresponds to about twice the Danish energy consumption, and the European production a tenth of that.

The figures talk for themselves. The Americans act, the Europeans talk. The European production of bioethanol corresponds to less than half of the Danish demand for energy for transportation. The American to about six times the Danish demand for transportation.

No wonder that the Europeans talk about abandoning diesel and petrol cars and talk a lot of electric cars. They seem to have forgotten that electric cars need a reliable electricity production, which the politicians seem to believe they can get from wind and solar.

Increasing Wind Power, Increasing Import and declining Electricity consumption [v]

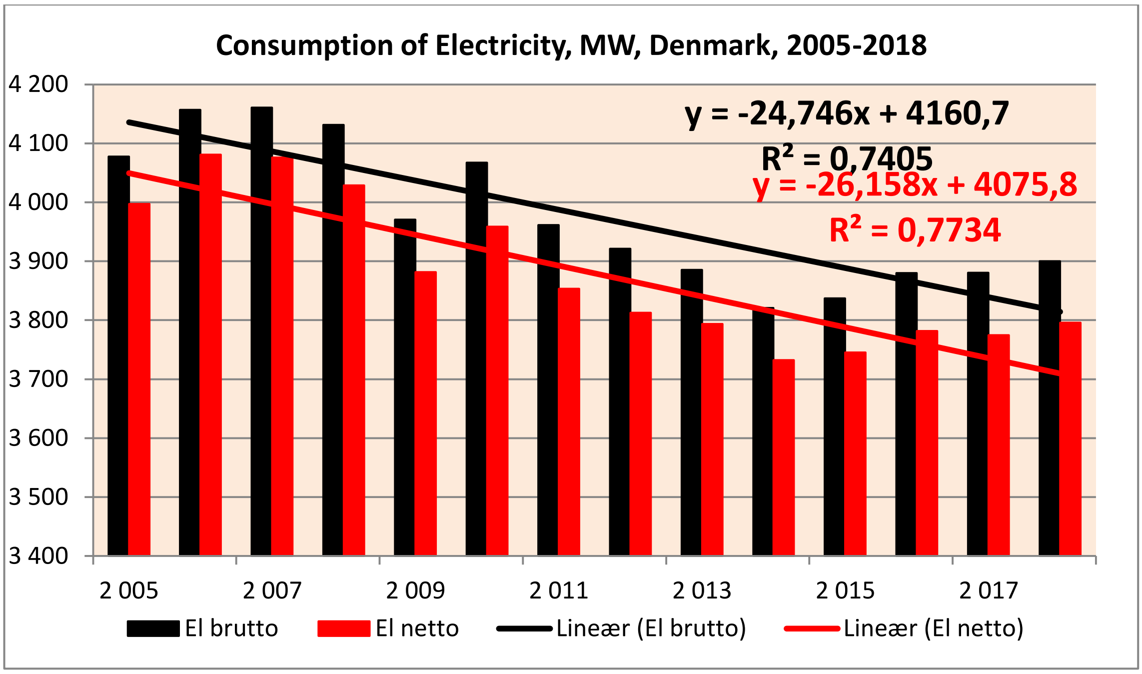
Summary

It is generally accepted, that a fossil free society presupposes a very much increased use of electricity.
It seems, however, that Denmark is moving in the wrong direction as illustrated in figure 25. The net consumption of electricity (i.e. the electricity supply exclusive the electricity consumed in power stations) was on average 4100 MW in 2005 and 3900 MW in 2018. The net consumption was reduced by 200 MW too in the period.
If we look at the consumption per capita (figure 26) we find a decline from 741 W to 680 W. It is remarkable that this development has taken place simultaneously with an increase in the wind power from on average 755 MW to 1587 MW in 2018.

Table 12 and figure 27 show the development in wind power and in im- and export of electricity. The author can't explain this development. But wonders, how an increasing amount of wind power can result in both a decline in the use of electricity and an increase in the import.

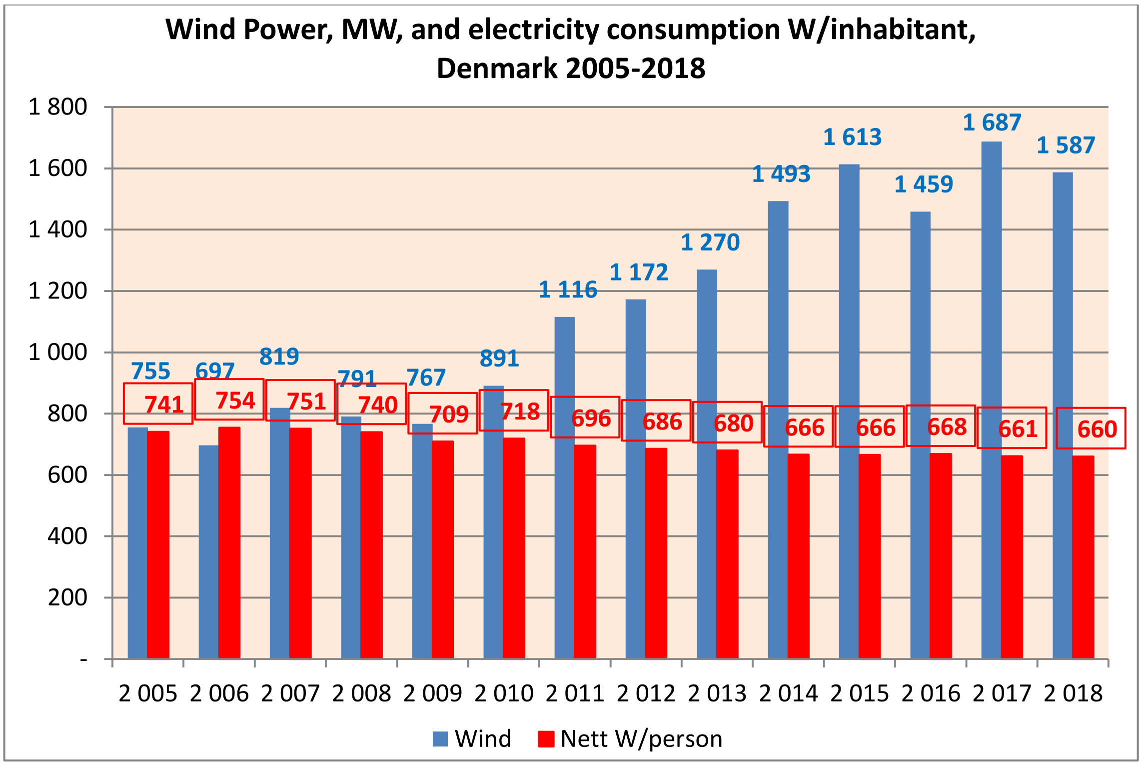
And wonders too how a drastic expansion of the off shore wind power will fit into the Danish system.

Figure 25



Denmark's population has due to uncontrolled immigration increased considerably in the period from 5398 t inhabitants in 2005 to 5749 in 2018 i.e. by 27 t per year.

Figure 26

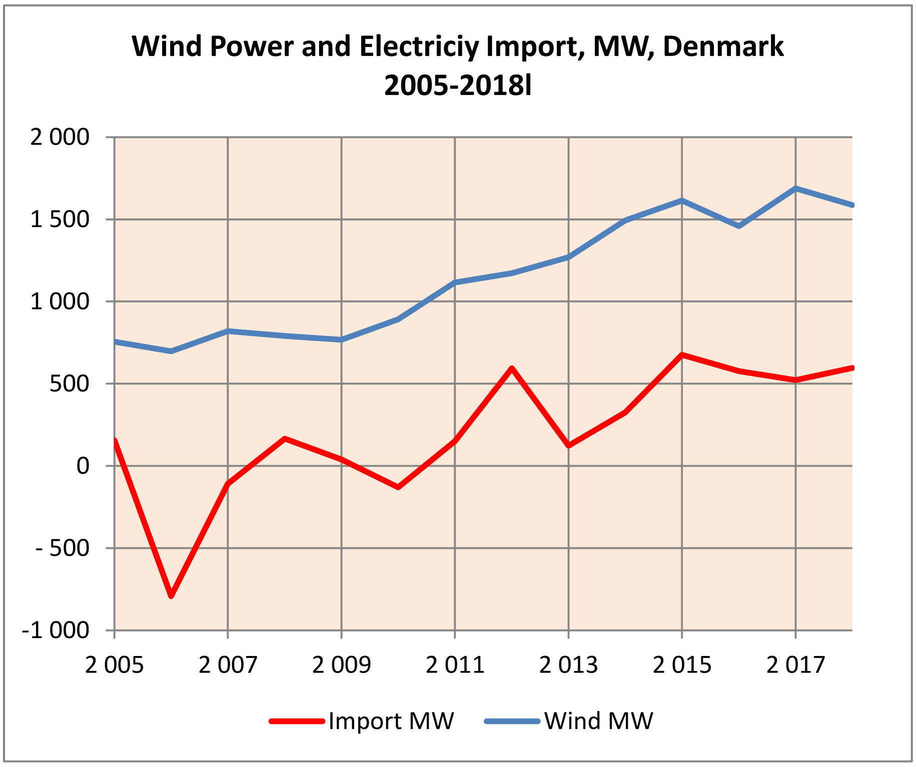


Increasing Wind Power and increasing Electricity Import

Tabel 12

Wind Power and Electricity Import, MW Denmark 2005-2018		
Year	Import MW	Wind MW
2 005	156	755
2 006	- 792	697
2 007	- 108	819
2 008	166	791
2 009	38	767
2 010	- 130	891
2 011	151	1 116
2 012	594	1 172
2 013	123	1 270
2 014	326	1 493
2 015	675	1 613
2 016	576	1 459
2 017	521	1 687
2 018	596	1 587

Figure 27



The Danish wind power was on average 1586 MW in 2018, The load 3900 MW and the import on average 569 MW. There may be many explanations, some of them even good. Still a little bit strange that the import has increased at the same time as the wind power has increased.

10 years ago the Danish coal fired power stations were the most efficient in the world. But they were hardly suited to operate as the wind blows, and most of them have been closed. The author finds it very risky to rely on imported electricity.

How do we get our electricity

Summary

It is generally accepted that a fossile free society means much more electric power produced from lasting ressources like solar, wind and hydropower. The wind and even the solar power have increased from 2000-2018, and so has the population (by 6,5%). Wind power is even told to be cheap. Why is it then that the electricity consumption has fallen by 2% and the import, which was close to zero 18 years ago in 2017 and 2018 was 13 % and 15 % of the consumption?

Figure 64 below illustrate, that Denmark has made herself very dependant of the import of electricity. That is not necessarily wrong. But since the suppliers are mainly Norway and Sweden it may be risky. Sweden plans to close her nuclear power stations and expand the wind energy. Thus Sweden will be unable to deliver electricity to Denmark, when there is no wind, and Norway build cables to England, The Netherlands and Germany which means that we will have to compete with other countries about the Norwegian hydropower.

Tabel 13

Electricity consumption and Supply, MW, Denmark 2000-2018

Year	Gross Pro-duc-tion	Use of Electricity in Electricity Generation	Net Pro-duc-tion	Cen-tral Power Sta-tions	Public Power Sta-tions	Indu-strial Auto-producers	Wind Turbi-nes	Hydro power	Solar Photo voltaic **	Net Ex-ports	Total Domestic Supply of Electricity		
											Total	West	East
2000	4074	174	3900	2410	632	371	483	3	0	-76	3976	2353	1623
2001	4293	182	4111	2538	714	364	492	3	0	66	4045	2383	1662
2002	4463	210	4253	2625	714	354	557	4	0	236	4017	2381	1636
2003	5250	255	4995	3289	706	363	635	2	0	975	4020	2402	1618
2004	4583	214	4369	2550	713	354	749	3	0	327	4042	2419	1623
2005	4113	192	3921	2152	629	382	755	3	0	-156	4077	2433	1644
2006	5204	256	4949	3289	621	339	697	3	0	792	4157	2488	1668
2007	4478	209	4269	2595	553	299	819	3	0	108	4160	2499	1661
2008	4145	191	3954	2339	563	261	789	3	0	-166	4120	2471	1649
2009	4133	200	3933	2393	527	244	767	2	0	-38	3971	2358	1613
2010	4403	206	4197	2406	647	250	891	2	0	130	4067	2421	1646
2011	3987	177	3811	1933	530	230	1116	2	0	-151	3961	2370	1591
2012	3473	156	3317	1527	398	209	1169	2	12	-594	3911	2341	1570
2013	3948	185	3762	1885	363	183	1270	2	59	-123	3886	2329	1557
2014	3642	147	3495	1481	269	182	1493	2	68	-326	3821	2300	1520
2015	3280	117	3163	1051	242	186	1613	2	69	-675	3837	2322	1516
2016	3425	132	3293	1270	298	183	1455	2	85	-576	3869	2338	1532
2017	3471	111	3360	1086	317	182	1687	2	86	-521	3881	2353	1527
2018	3424	120	3304	1093	336	178	1587	2	109	-596	3900	2392	1508

Figure 28

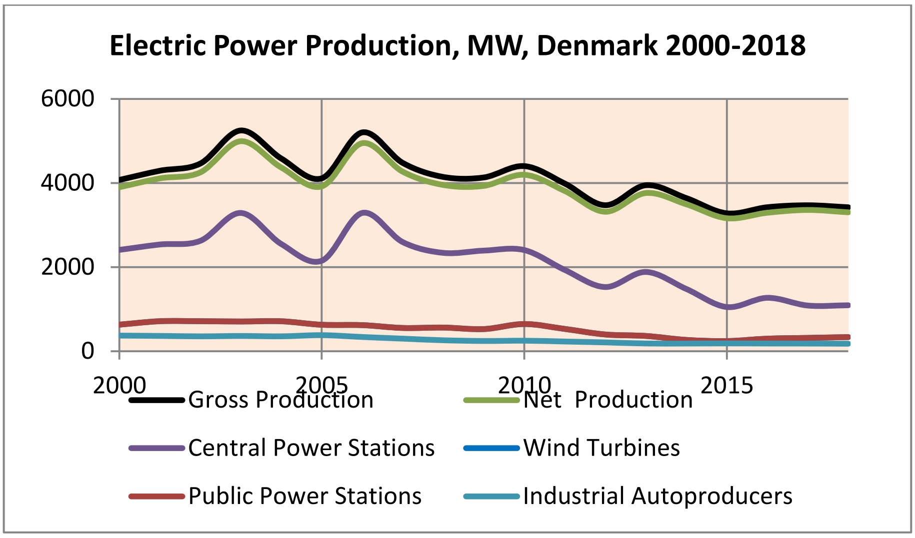


Figure 29

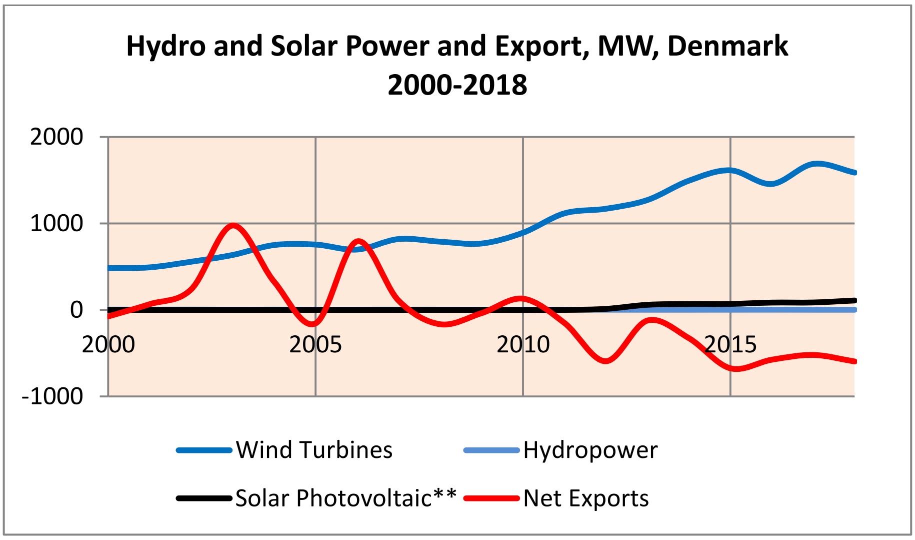
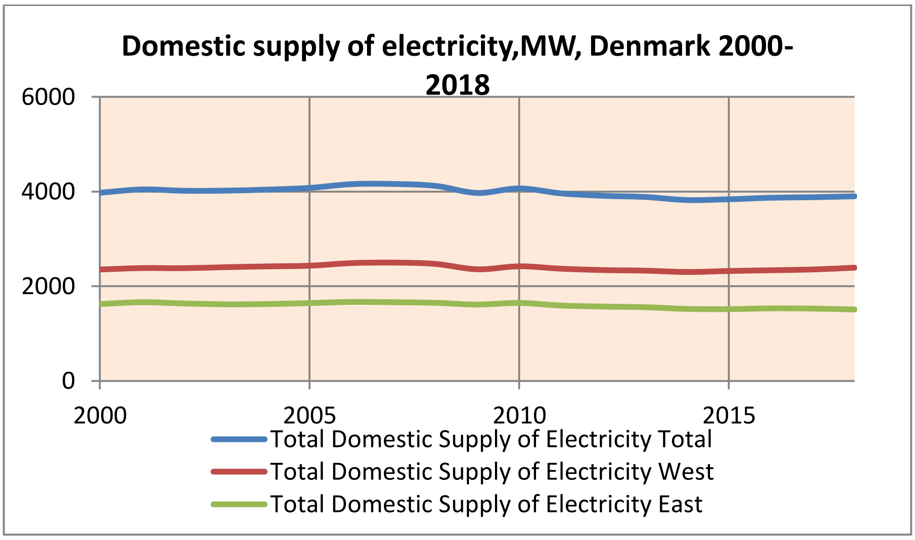


Figure 30



Variation in Consumption (Load) [vi]

This variation is seen from table hereunder.

Tabel 14

Load ,MW, Denmark 2018					
	2018	Jan Mar	Apr-Jun	Jul-Sep	Oct-Dec
Average	3900	4393	3610	3519	4085
Max	6076	6076	5126	4968	6015
Min	2294	2858	2391	2294	2632
Stddev	782	747	633	632	767
Stddev % of av	20	17	18	18	19

It is observed, that the load varies with a high degree of predictability, and that the load varies considerably from summer to winter.

Figure 31

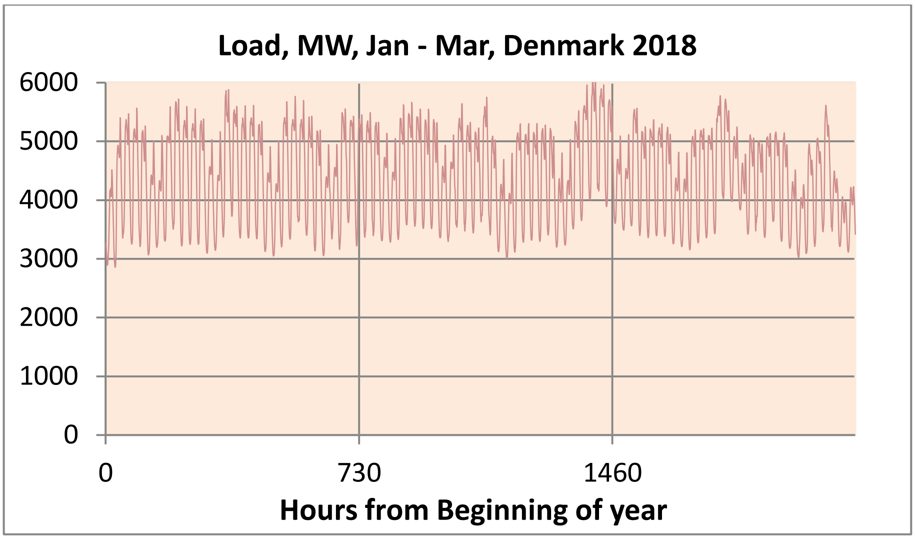


Figure 32

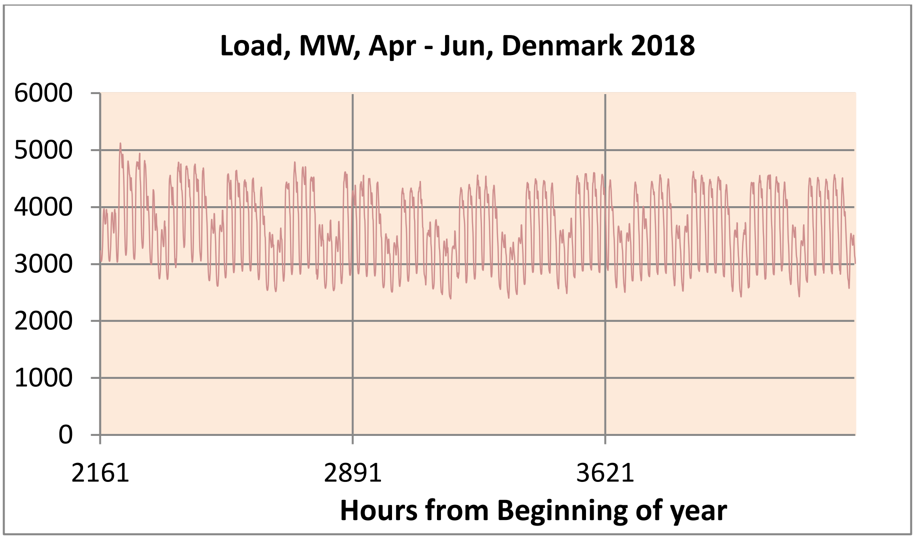


Figure 33

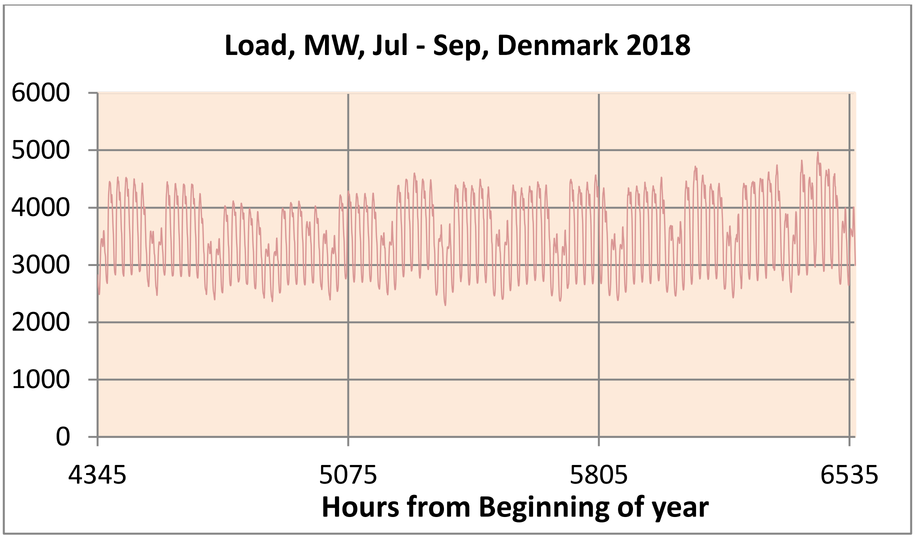
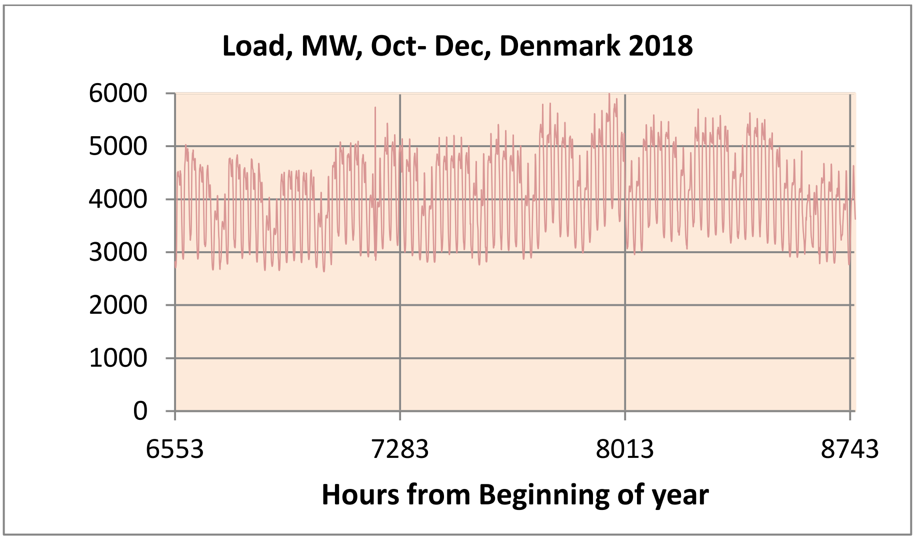


Figure 34



Thermal Electricity Production

Summary

Tabel 13 and fig 28 above shows that the consumption of electricity is slightly reduced since the year 2000. They show too that the production from central power stations, in the year 2000 Central, Public and Industrial producers yielded 2410, 632 and 371 total 3413 MW, and in 2018 only 1607 MW. Table 15 hereunder shows that the maximum output in 2018 was 4922 MW thermal power and the average only 1607 MW. So we have a capacity of about 5000 MW thermal and produce on average only 1607 MW. The capacity exploitation is only about 32%. From table 19 below we can see that the wind turbines capacity exploitation is only 27,6 % (276 kW/MW). **It costs an undisclosed but surely large amount of money to possess so much unused capacity.**

Tabel 15

Thermal Power MW, Denmark 2018

	2018	Jan Mar	Apr-Jun	Jul-Sep	Oct-Dec
Average	1607	2707	1073	812	1856
Max	4922	4922	3375	1945	3695
Min	292	933	292	323	627
Stddev	948	694	691	232	640
Stddev % of av	59	26	64	29	34

Table 15 above shows the variations in the thermal power production. The variations are considerable, which means that the operation of the power plants can't be efficient and on average less than 30% of the capacity is used. This will necessarily result in a higher cost than if the production more smooth. The variation is necessitated by the varying wind power. An honest calculation of the cost for wind power should take this into consideration.

The miserable operation of the thermal power stations are illustrated by the figures 30-33 below.

Figure 35

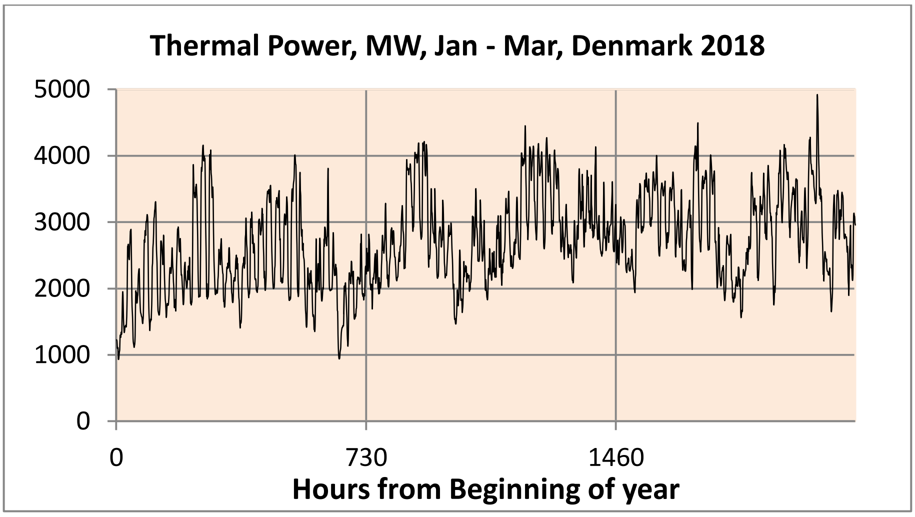


Figure 36

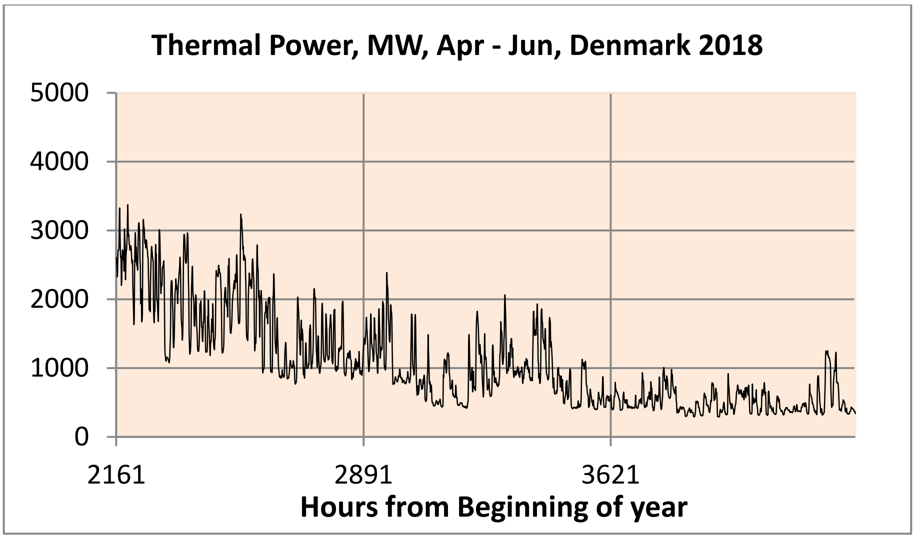


Figure 37

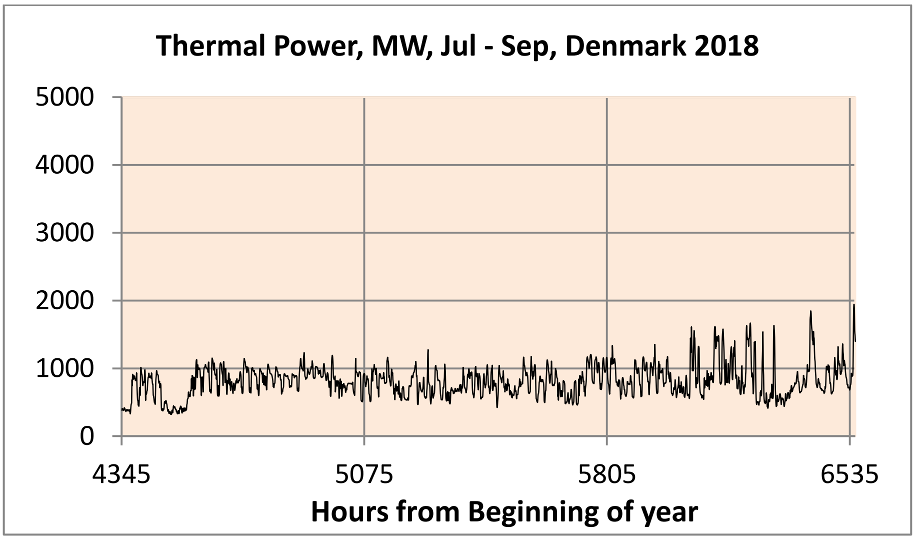
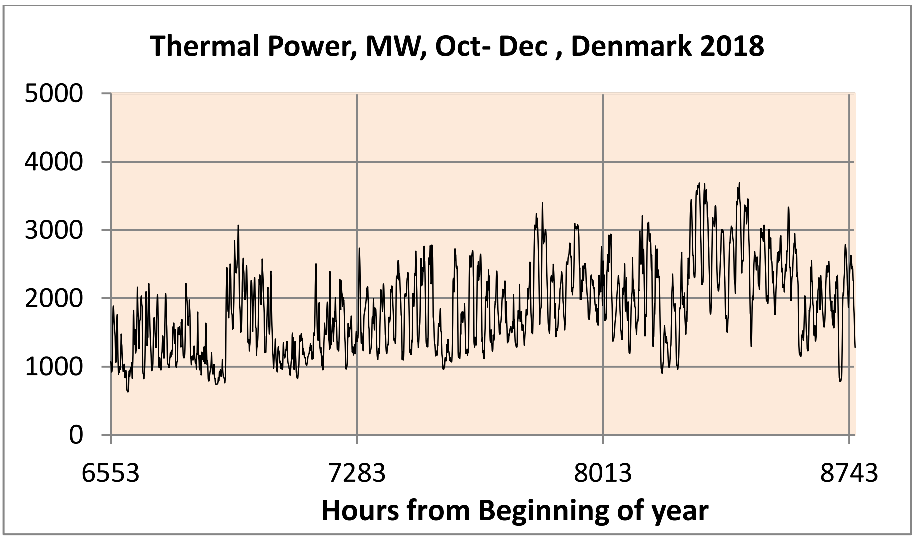


Figure 38



Danish Wind Energy 2012-18 [VII]

Summary

In 2009 the Danish prime minister Anders Fogh Rasmussen promised us a "Fossil free Society in 2050." Most people think that wind power should play an essential role in this process. So let us look at the realities.

Table 16 and figure 39 illustrate how small a part of our energy consumption we get from the windpower. In 2018 it amounted to 7,1 %. Which is even not quite true, because a lot of the wind power must be exported, when it blows. Table 25 below indicates that only 1337 MW of the produced 1586 MW in 2018 are useful for the Danish market, which reduces the wind power share of the Danish energy consumption from 7,1% to 5,9%.

The wind power variations from month to month are shown in the tables 17 to 21 below and in the figures 40-43. This fact should interest not only consumers and producers but even the gentlemen of the press and the political system

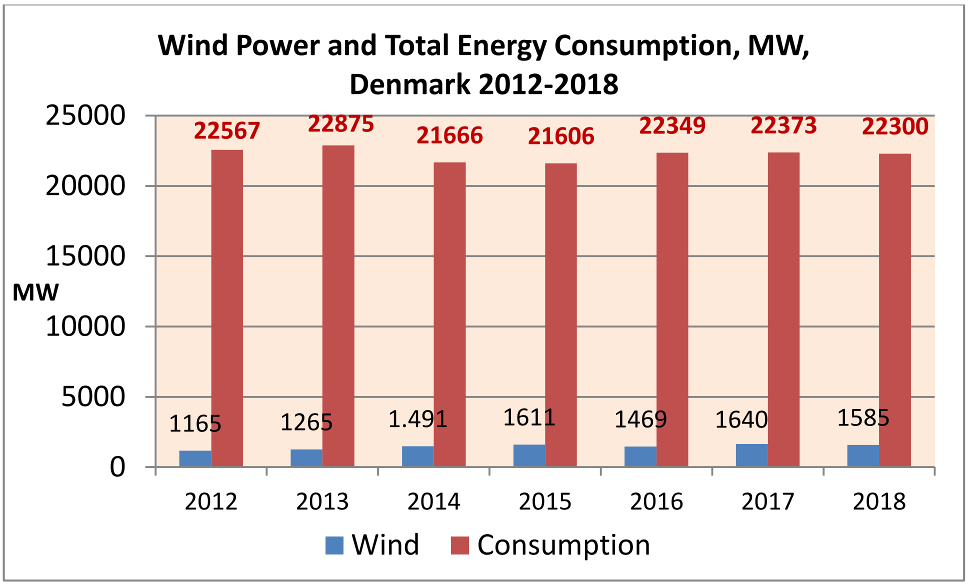
Table 20-21 and figure 40-42 below illustrate the performance of the different off shore wind parks. The planned increase of the off shore wind capacity by a factor of about 7, ought to be a nightmare for responsible planners.

Tabel 16

Danish Wind Power and Energy Consumption, MW, 2012-18

	2012	2013	2014	2015	2016	2017	2018
Wind	1165	1265	1.491	1611	1469	1640	1585
Consumption , gross	22567	22875	21666	21606	22349	22373	22300
% Wind	*5,2*	*5,5*	*6,9*	*7,5*	*6,6*	*7,3*	*7,1*

Figure 39



Wind Power Variation 2016-2018

Tabel 17

Danish Windpower, MW, 2018															
	Jan-Mar			Apr-Jun			Juli-Sep			Okt-Dec			Jan-Dec		
	On shore	Off shore	Total	On shore	Off shore	Total	On shore	Off shore	Total	On shore	Off shore	Total	On shore	Off shore	Total
Average MW	1192	585	1777	863	447	1309	944	465	1408	1233	618	1852	1058	529	1586
Max MW	3632	1206	4806	3545	1234	4730	3491	1239	4730	3759	1217	4850	3759	1239	4850
Min MW	2	3	12	1	0	5	2	0	4	1	1	1	1	0	1
Stddev MW	1028	384	1381	805	344	1123	801	350	1121	894	331	1195	900	360	1231
Stddev % of Average	**86,3**	**65,7**	**77,7**	**93,3**	**77,0**	**85,8**	**84,9**	**75,3**	**79,6**	**72,5**	**53,5**	**64,5**	**85,1**	**68,2**	**77,6**
GWh	**2575**	**1263**	**3838**	**1884**	**975**	**2860**	**2083**	**1026**	**3109**	**2723**	**1366**	**4088**	**9266**	**4630**	**13896**
PJ	**9,3**	**4,5**	**13,8**	**6,8**	**3,5**	**10,3**	**7,5**	**3,7**	**11,2**	**9,8**	**4,9**	**14,7**	**33,4**	**16,7**	**50,0**
Danish Windpower, MW, 2017															
	Jan-Mar			Apr-Jun			July-Sep			Okt-Dec			Jan-Dec		
Average MW	1170	630	1800	1115	563	1678	764	442	1206	1335	732	2067	1096	592	1687
Max MW	3609	1227	4812	3455	1222	4639	3014	1189	4177	5005	1216	5487	5005	1227	5487
Min MW	5	2	31	3	0	12	1	0	4	5	1	21	1	0	4
Stddev MW	895	373	1236	904	383	1253	652	332	953	916	347	1219	874	374	1212
Stddev % of Average	**76,5**	**59,1**	**68,7**	**81,1**	**68,0**	**74,7**	**85,3**	**75,0**	**79,0**	**68,6**	**47,4**	**59,0**	**79,7**	**63,2**	**71,8**
GWh	**2526**	**1361**	**3888**	**2436**	**1230**	**3666**	**1687**	**976**	**2664**	**2947**	**1617**	**4564**	**9597**	**5184**	**14781**
PJ	**9,1**	**4,9**	**14,0**	**8,8**	**4,4**	**13,2**	**6,1**	**3,5**	**9,6**	**10,6**	**5,8**	**16,4**	**34,5**	**18,7**	**53,2**
Danish Windpower, MW, 2016															
	Jan-Mar			Apr-Jun			Juli-Sep			Okt-Dec			Jan-Dec		
Average MW	1063	572	1633	724	443	1163	740	428	1167	1169	675	1844	924	530	1452
Max MW	3485	1220	4654	3331	1222	4541	3086	1202	4235	3338	1321	4557	3485	1321	4654
Min MW	1	2	9	1	0	1	8	0	18	9	1	26	1	0	1
Stddev MW	969	396	1331	638	321	921	658	322	951	803	356	1117	802	364	1131
Stddev % of Average	**91,1**	**69,2**	**81,5**	**88,2**	**72,6**	**79,2**	**88,9**	**75,2**	**81,5**	**68,7**	**52,8**	**60,6**	**86,8**	**68,8**	**77,9**
GWh	**2321**	**1250**	**3566**	**1580**	**967**	**2539**	**1633**	**944**	**2577**	**2582**	**1490**	**4072**	**8117**	**4651**	**12754**
PJ	**8,4**	**4,5**	**12,8**	**5,7**	**3,5**	**9,1**	**5,9**	**3,4**	**9,3**	**9,3**	**5,4**	**14,7**	**29,2**	**16,7**	**45,9**

The table is based on an observation every hour. **The total Danish energy consumption in 2017 was 660 PJ. (Table 4)**

On and Off Shore Wind Denmark East and West 2018[vii]

Summary

The main data are given in table 18 below. It is shown, that Denmark east of the great belt produces about 25 % of the wind power. It is seen too that the off shore wind power is 33% of the total. It may be surprising that the off shore wind power is nearly just as unstable as the on shore power. They can both go down to zero, and the standard deviation is high for both.

85% of the average for on shore wind and 68% for off shore wind. So wind power is of little use unless **back up** is provided for. Until now we have been able to count on the Scandinavian hydro power resources. But since both Norway and Sweden are expanding their wind power considerably, and build transmission lines to England, The Netherlands and Germany it seems very sanguine to take it for granted that this will be the case in the future too. Not to speak of the conditions when the Danish plans to expand the Offshore capacity by 12 GW, resulting in a wind power varying between zero and 17-18 GW against the actual figures varying between zero and 5 GW.

The variations per month are shown in the tables 18-21 hereunder and illustrated in the figures 40-43.

Tabel 18

Wind Power, MW, Denmark 2018									
						On shore		Off shore	
	East	West	Onshore	Offshore	Total	East	West	East	West
Average	340	1247	1058	529	1586	186	872	160	365
Max	1082	3845	3759	1239	4850				
Min	0	0	1	0	1				
Stddev	294	977	900	360	1231				
Stddev% of average	87	78	85	68	78				

Tabel 19

Capacities Efficiency and production On and off Shore Turbines. Denmark 2018																	
			Off Shore Turbines														
Turbines number and capacity					**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**2018**
Denmark East Off shore	MW	444	Production	GWh	156	102	124	126	88	82	71	87	130	150	118	163	1.398
	Number	192	Effect	MW	210	152	166	175	119	114	95	117	181	202	163	219	160
	MW/turbine	2,31	Efficiency	**kW/MW**	**472**	**343**	**374**	**395**	**267**	**257**	**214**	**264**	**407**	**455**	**368**	**493**	**359**
Demark West off shore	MW	847	Production	GWh	307	277	292	277	172	222	147	239	344	343	258	318	3.197
	Number	316	Effect	MW	412	412	392	385	232	309	198	321	478	461	359	428	365
	MW/turbine	2,7	Efficiency	**kW/MW**	**487**	**486**	**463**	**454**	**274**	**365**	**233**	**380**	**564**	**545**	**424**	**505**	**431**
Denmark total Off shore	MW	1291	Production	GWh	463	379	415	403	261	305	218	326	474	494	376	481	4.595
	Number	508	Effect	MW	622	564	558	560	351	423	293	439	658	663	522	647	525
	MW/turbine	2,5	Efficiency	**kW/MW**	**482**	**437**	**432**	**434**	**271**	**328**	**227**	**340**	**510**	**514**	**405**	**501**	**406**
			On Shore Turbines														
Denmark East On shore	MW	2000	Production	GWh	167	116	155	154	91	95	71	109	167	186	133	183	1.627
	Number	2300	Effect	MW	224	172	208	214	123	132	95	147	231	250	185	246	186
	MW/turbine	0,87	Efficiency	**kW/MW**	**295**	**226**	**273**	**282**	**161**	**174**	**125**	**193**	**304**	**330**	**244**	**324**	**244**
Denmark West On shore	MW	3670	Production	GWh	737	663	737	634	373	537	427	502	806	823	619	777	7.635
	Number	4672	Effect	MW	990	987	991	880	501	745	574	675	1.120	1.106	860	1.044	872
	MW/turbine	0,79	Efficiency	**kW/MW**	**270**	**269**	**270**	**240**	**137**	**203**	**156**	**184**	**305**	**301**	**234**	**285**	**237**
Denmark total On shore	MW	5670	Production	GWh	904	779	892	788	464	632	498	611	973	1.009	752	960	9.262
	Number	6972	Effect	MW	1.215	1.159	1.199	1.094	624	878	669	822	1.351	1.356	1.045	1.290	1.057
	MW/turbine	0,81	Efficiency	**kW/MW**	**274**	**262**	**271**	**247**	**141**	**198**	**151**	**185**	**238**	**305**	**236**	**291**	**239**
			Denmark Total														
Denmark total	MW	6961	Production	GWh	1.367	1.158	1.307	1.191	725	937	716	938	1.447	1.503	1.128	1.441	13.856
	Number	7480	Effect	MW	1.837	1.723	1.757	1.654	974	1.301	962	1.260	2.010	2.020	1.567	1.937	1.582
	MW/turbine	0,93	Efficiency	**kW/MW**	**321**	**301**	**307**	**289**	**170**	**227**	**168**	**220**	**351**	**353**	**274**	**339**	**276**
Production				**PJ**	**4,9**	**4,2**	**4,7**	**4,3**	**2,6**	**3,4**	**2,6**	**3,4**	**5,2**	**5,4**	**4,1**	**5,2**	**49,9**

Off shore wind parks

Summary

The age, number of turbines, capacities, production for each of the 6 off shore parks in East Denmark and the 8 parks in West Denmark except the 406 MW large Hornsrev 3 which began production by the end of 2018 are shown in table 20 and 21. The author suspects that the efficiency is declining with time but has not been able prove it.

Tabel 20

Danmark East Offshore, 2018																	
					Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	2018
København	MW	40	Production	GWh	5,9	3,9	6,7	7,4	4,0	3,6	2,1	4,5	6,8	8,4	7,2	8,0	68,7
27-12-2000	Number	20	Effect	MW	7,9	5,8	9,0	10,3	5,4	5,0	2,9	6,1	9,5	11,3	10,1	10,8	7,8
	MW per turbine	2	Efficiency	**kW/MW**	**199**	**144**	**226**	**258**	**135**	**125**	**71**	**152**	**237**	**282**	**251**	**270**	**196**
Hvidovre	MW	11	Production	GWh	3,2	2,7	3,0	3,5	1,8	1,8	1,1	2,5	3,3	3,7	3,1	3,8	33,5
23-11-2009	Number	3	Effect	MW	4,4	4,0	4,0	4,9	2,4	2,6	1,4	3,4	4,5	4,9	4,3	5,1	3,8
	MW per turbine	3,6	Efficiency	**kW/MW**	**404**	**374**	**373**	**450**	**219**	**237**	**134**	**313**	**419**	**455**	**395**	**474**	**354**
Slagelse	MW	21	Production	GWh	4,5	3,8	4,0	4,6	2,5	3,5	2,7	3,8	5,8	6,9	5,4	6,9	54,2
28-10-2009	Number	7	Effect	MW	6,0	5,7	5,4	6,3	3,3	4,9	3,7	5,1	8,0	9,2	7,4	9,2	6,2
	MW per turbine	3	Efficiency	**kW/MW**	**286**	**272**	**257**	**301**	**158**	**231**	**174**	**241**	**381**	**440**	**354**	**439**	**294**
Lolland	MW	207	Production	GWh	82,9	53,1	63,0	64,5	46,6	44,2	38,3	47,3	68,2	78,6	61,5	87,3	735,5
21-04-2010	Number	90	Effect	MW	111,4	79,0	84,6	89,6	62,6	61,4	51,5	63,6	94,8	105,6	85,4	117,4	84,0
	MW per turbine	2,3	Efficiency	**kW/MW**	**538**	**382**	**409**	**433**	**302**	**297**	**249**	**307**	**458**	**510**	**412**	**567**	**406**
Guldborgsund	MW	166	Production	GWh	59,7	38,8	46,9	46,2	33,6	29,2	26,4	29,2	46,0	52,8	40,6	56,9	506,4
17-06-2003	Number	72	Effect	MW	80,2	57,7	63,1	64,2	45,2	40,5	35,5	39,2	63,9	71,0	56,3	76,5	57,8
	MW per turbine	2,3	Efficiency	**kW/MW**	**484**	**349**	**381**	**388**	**273**	**245**	**215**	**237**	**386**	**429**	**340**	**462**	**349**
Denmark East Off shore	MW	444	Production	**GWh**	156	102	124	126	88	82	71	87	130	150	118	163	1.398
	Number	192	Effect	**MW**	210	152	166	175	119	114	95	117	181	202	163	219	160
	MW per turbine	2,31	Efficiency	**kW/MW**	**472**	**343**	**374**	**395**	**267**	**257**	**214**	**264**	**407**	**455**	**368**	**493**	**359**

Tabel 21

Denmark West off shore, 2018																	
					Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	2018
Hornsrev 1	MW	160	Production	**MWh**	55888	48756	49239	47156	30211	39612	25829	37621	53010	33108	0	0	420429
04-09-2002	Number	80	Effect	MW	75	73	66	65	41	55	35	51	74	44	0	0	48
	MW per turbine	2	Efficiency	**kW/MW**	469	453	414	409	254	344	217	316	460	278	0	0	300
Hornsrev 2	MW	209	Production	MWh	81475	72056	80522	68636	46332	60845	40102	57545	85452	94852	86895	97429	872142
14-05-2009	Number	91	Effect	MW	110	107	108	95	62	85	54	77	119	127	121	131	100
	MW per turbine	2,3	Efficiency	**kW/MW**	523	512	517	455	298	404	258	370	567	609	577	626	476
Lemvig	MW	17,2	Production	MWh	5784	4706	5497	4855	3104	4118	3648	4439	6902	6544	5313	6712	61622
09-01-2003	Number	8	Effect	MW	8	7	7	7	4	6	5	6	10	9	7	9	7
	MW per turbine	2,15	Efficiency	**kW/MW**	452	407	430	392	243	333	285	347	557	511	429	525	409
Lemvig II	MW	28	Production	MWh	0	1709	7551	6429	4495	6369	5345	6109	8430	9291	7811	9343	72882
17-02-2018	Number	4	Effect	MW	0	3	10	9	6	9	7	8	12	12	11	13	8
	MW per turbine	7	Efficiency	**kW/MW**	0	91	362	319	216	316	257	293	418	446	387	448	297
Norddjurs	MW	400	Production	MWh	154055	141226	139558	141035	83484	104459	67566	126848	180577	189199	150135	193478	1671621
21-09-2012	Number	111	Effect	MW	207	210	188	196	112	145	91	170	251	254	209	260	191
	MW per turbine	3,6	Efficiency	**kW/MW**	518	526	469	490	281	363	227	427	628	636	522	651	478
Odder	MW	5	Production	MWh	1438	1140	1136	924	462	657	414	713	1233	1350	1196	1518	12182
30-05-1995	Number	10	Effect	MW	2	2	2	1	1	1	1	1	2	2	2	2	1
	MW per turbine	0,5	Efficiency	**kW/MW**	387	339	305	257	124	182	111	192	343	363	332	408	278
Samsø	MW	20,7	Production	MWh	7235	5727	6181	6090	3147	4956	3019	4481	6271	6470	5657	7485	66719
08-02-2003	Number	9	Effect	MW	10	9	8	8	4	7	4	6	9	9	8	10	8
Per mølle	MW per turbine	2,3	Efficiency	**kW/MW**	470	412	401	409	204	333	196	291	421	420	380	486	368
Frederiks havn	MW	6,9	Production	MWh	997	1459	1905	1866	1110	1274	1110	1312	1983	2372	1375	2214	18978
	Number	3	Effect	MW	1	2	3	3	1	2	1	2	3	3	2	3	2
28-05-2003	MW per turbine	2,3	Efficiency	**kW/MW**	194	315	371	376	216	256	216	256	399	462	277	431	314
Demark West off shore	MW	847	Production	**GWh**	307	277	292	277	172	222	147	239	344	343	258	318	3.197
	Number	316	Effect	**MW**	412	412	392	385	232	309	198	321	478	461	359	428	365
	MW per turbine	2,7	Efficiency	**kW/MW**	487	486	463	454	274	365	233	380	564	545	424	505	431

Figure 40

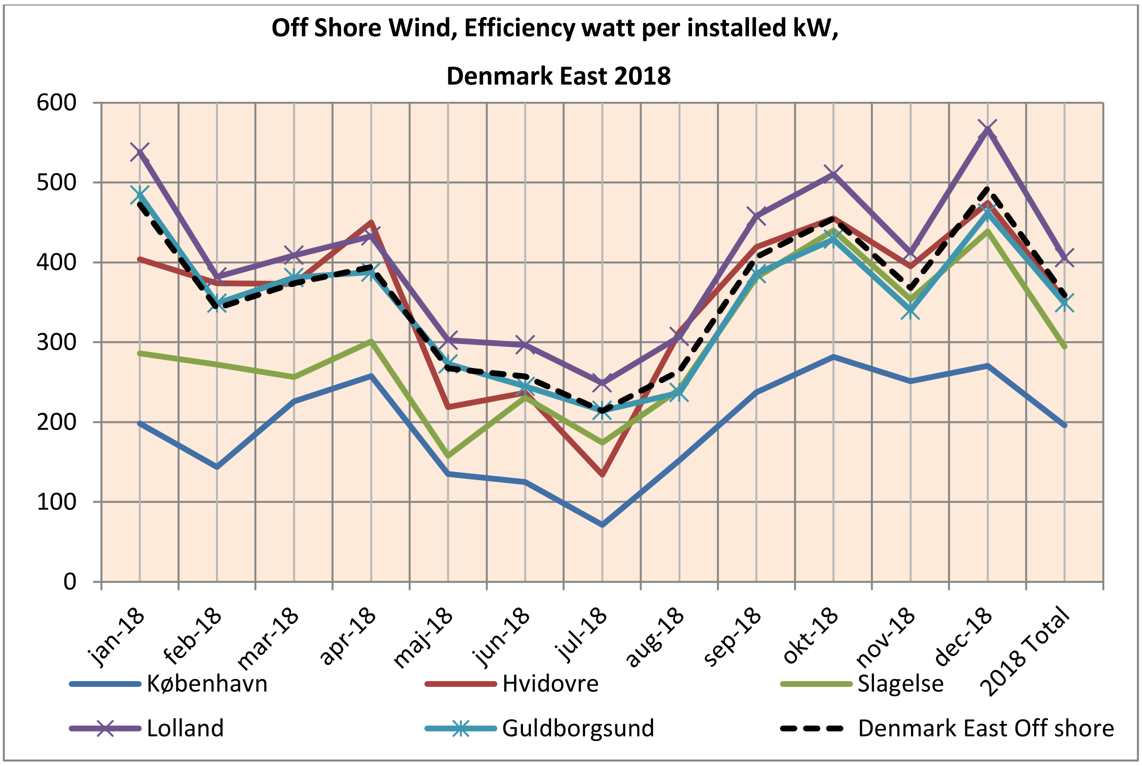
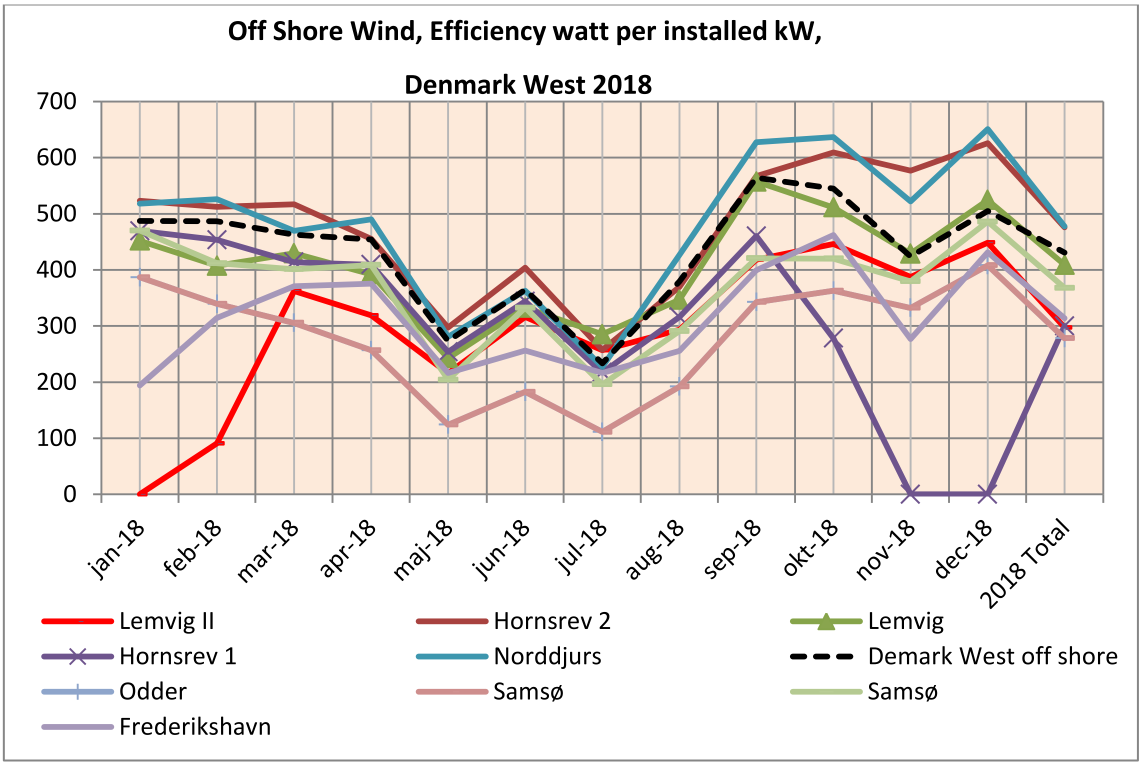


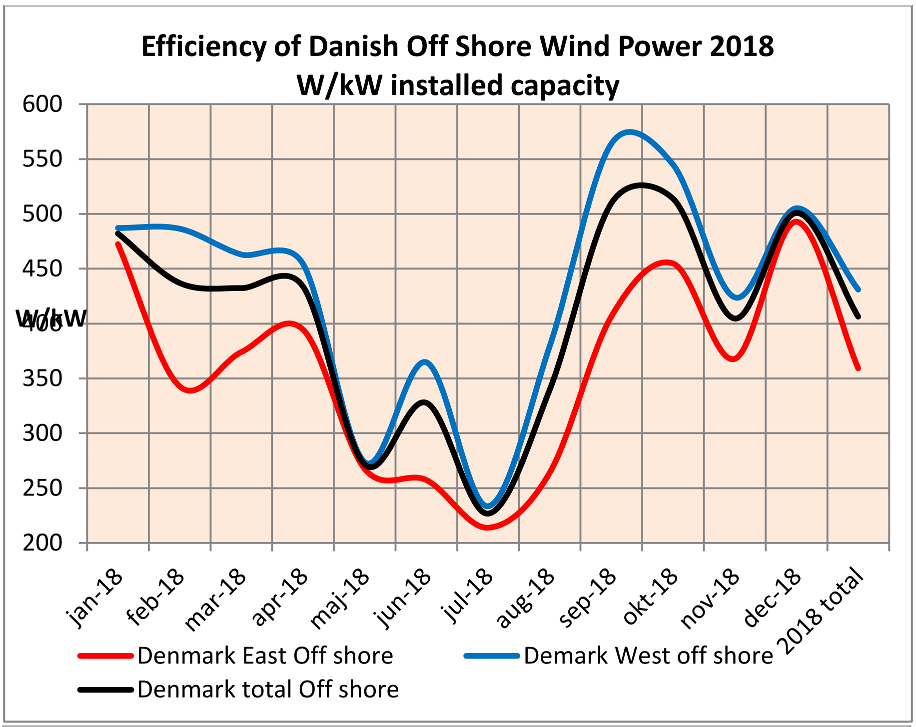
Figure 41



The variations from month to month are shown on figure 40 to 43.

Figure 43

Figure 42



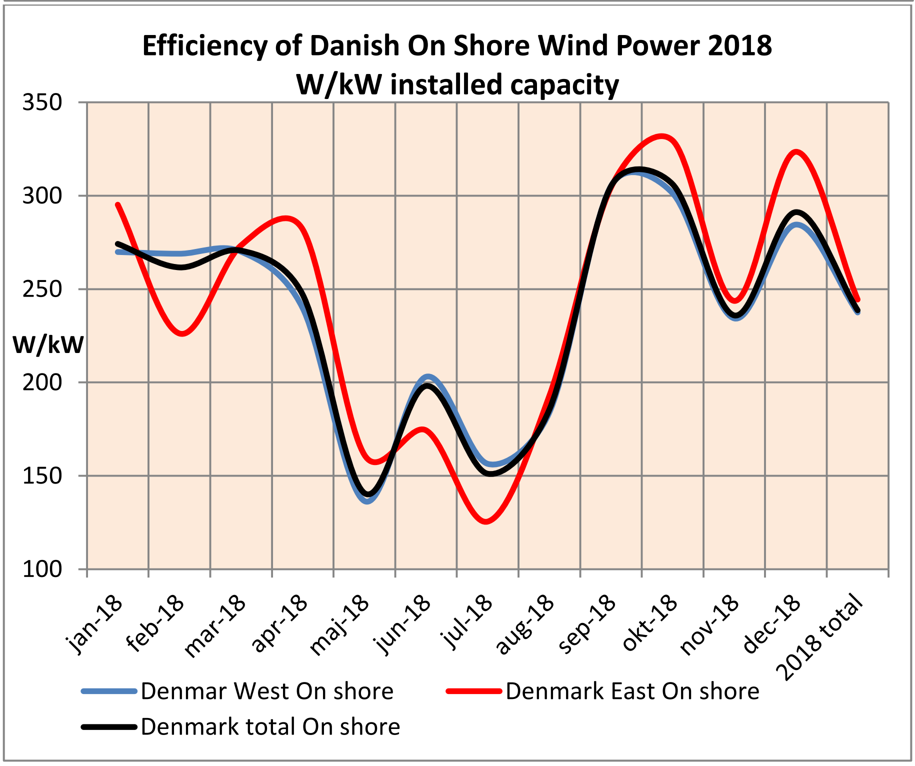


Figure 39 and 40 talk for themselves. Neither off shore nor on shore wind power can give a reliable supply of electricity.

Variation Wind Power 2018[viii]

Summary The graphs 44-47 below illustrate the wind power variation not from month to month but from hour to hour. Figure 44 and 45 illustrate the variation in total wind in the months January and July 2018.

Figure 44

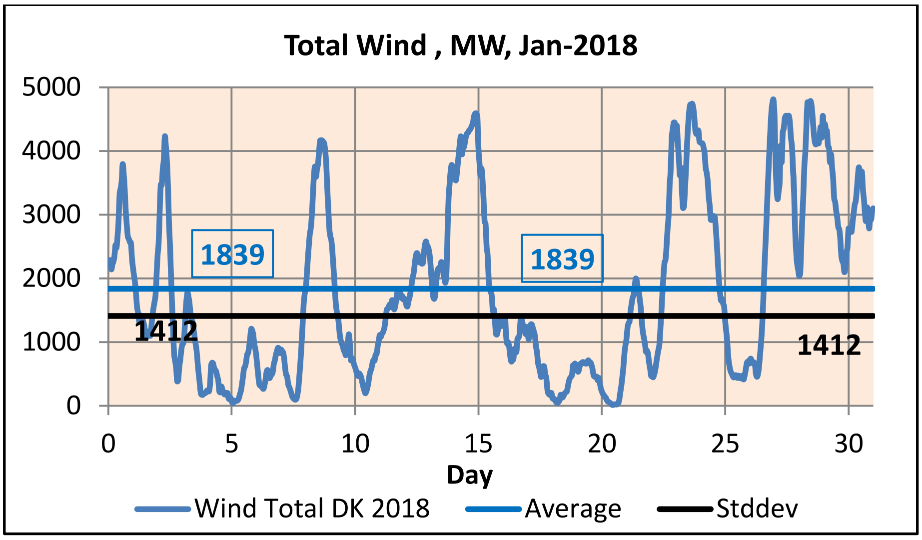


Figure 45

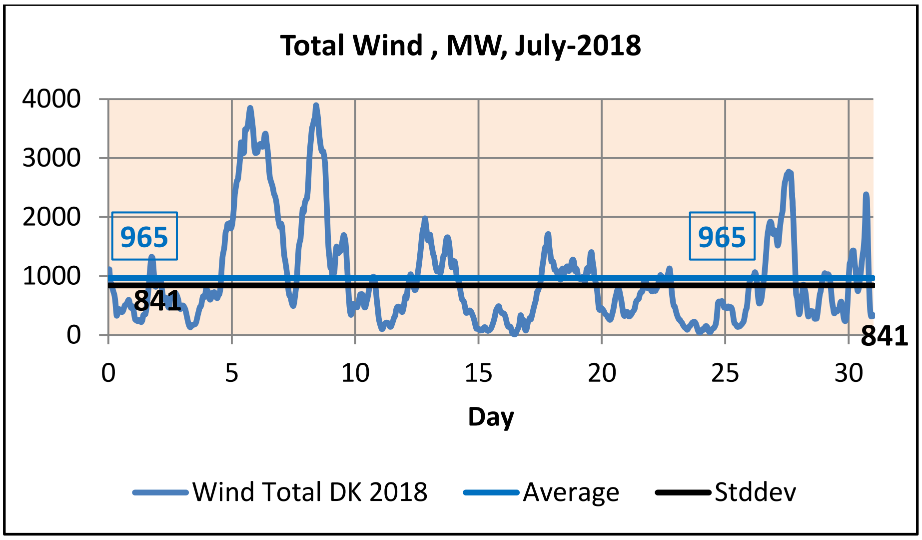


Figure 44 and 45 above illustrate the – uncontrollable- variation of wind power and illustrate the fact that wind power without sufficient back up/storage is an absurdity. Furthermore the graphs show that the wind power in January on average 1839 MW was nearly the double of the 965 MW for July.

This should interest persons who wish to have their electric cars driven by Wind Power.

Figure 46

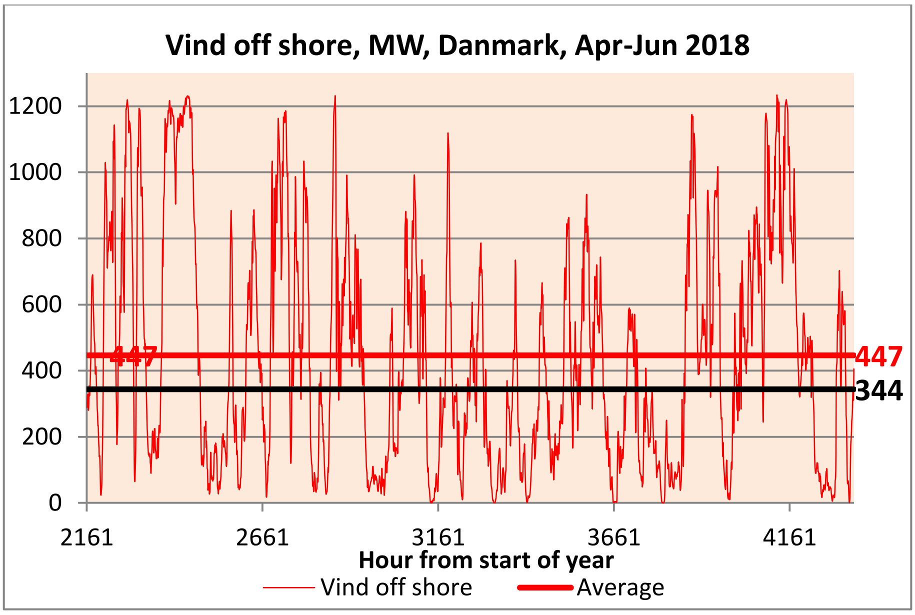


Figure 47

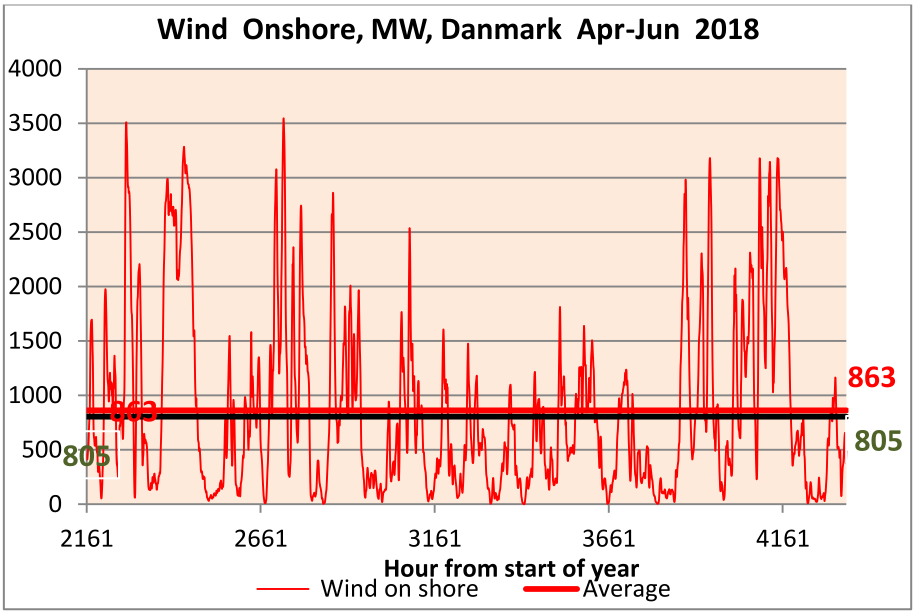


Figure 46 and 47 show, that on shore and off shore wind follow exactly the same pattern, although with a slightly lower standard deviation for off shore wind. 77% of average against 93% for onshore wind power in the period April-June 2018.

A lot of new off shore capacity is planned. You must hope that an arrangement with Norway has been made to secure the needed back up from the Norwegian hydropower.

Monthly Averages Wind Power 2012-18

Summary

It must be admitted, that there is an - although unclear - pattern in the variations from month to month (Table 22 and figure 48). Anyway it seems that you can't rely on a car powered by wind power for your summer holiday tour to Italy.

The figures 49-51 illustrate how large a part of the time wind power is available. For instance fig 49 illustrate that in 40% of the time the wind power is between 0% and 50% of the average for on shore wind parks. Off shore wind parks are a little more stable. Here the wind power is less than 50% of the average in 30% of the time only. Fig 52 illustrates the availability of solar power. In 50% of the time it is zero. Again: Have you said "green energy" you have also said "Back up."

We will look at the combination on wind and solar power in Germany later.

Tabel 22

Wind Power, Monthly Average, MW, Denmark 2012-2018													
	Jan	Feb	Mar	Apr	Maj	Jun	Jul	Aug	Sep	Okt	Nov	Dec	Average
2012	1.542	1.358	1.442	1.006	988	1.056	799	696	1.295	1.176	1.201	1.429	1.165
2013	1.279	908	1.552	1.227	915	1.205	731	987	1.018	1.627	1.451	2.237	1.265
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	1.557	2.179	1.689	1.916	1.363	1.747	1.201	1.256	1.155	1.833	1.608	2.276	1.640
2018	1.838	1.725	1.761	1.657	977	1.304	965	1.264	2.014	2.025	1.572	1.942	1.585

Figure 48

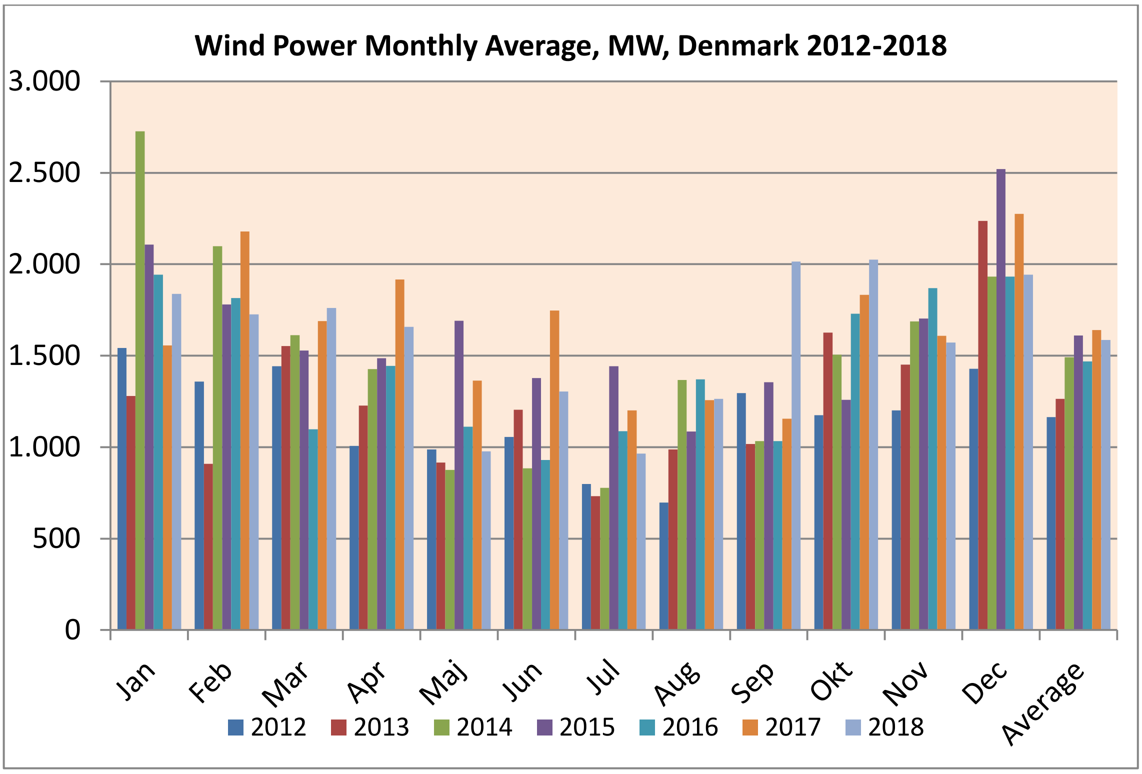


Figure 49

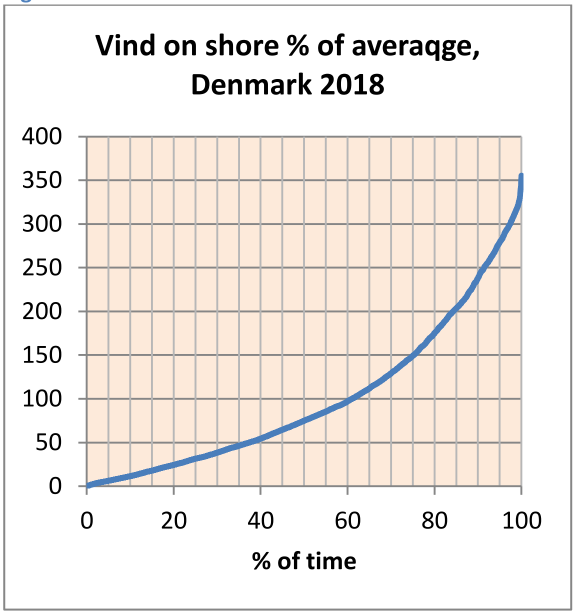


Figure 50

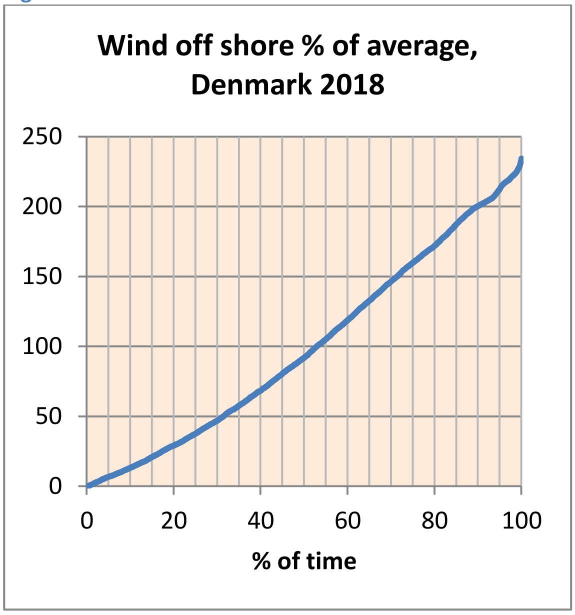


Figure 46 and 47 above show that less than 50 % of the average production is produced in 40% of the time by onshore turbines and in less than 30% of the time by off shore turbines.

Figure 51

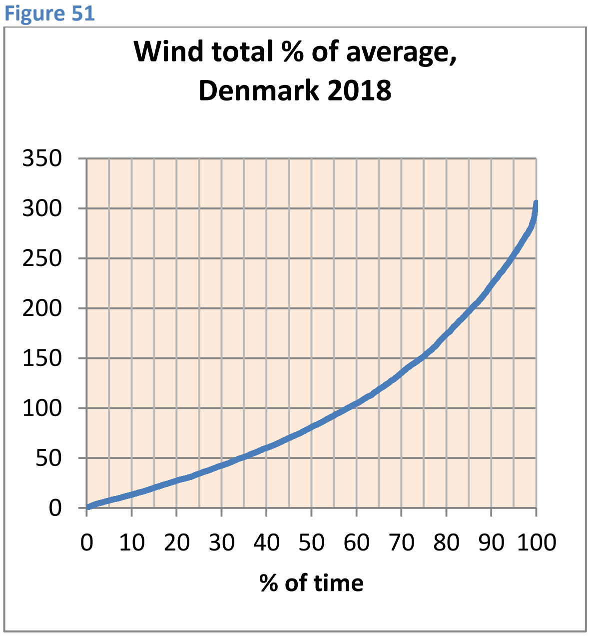
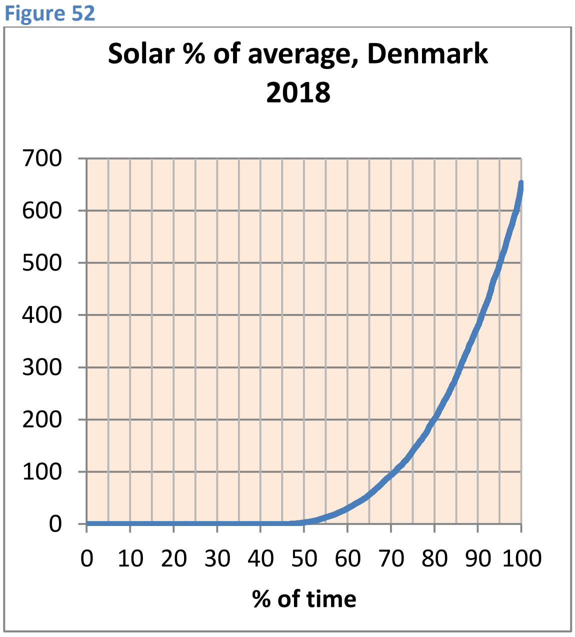


Figure 52



It can be seen from figure 37 that the total wind power is less than 50% of the average in 35% of the time and sun power yields nothing in 60% of the time.

Wind Power variation from Week to Week in 2018

Summary

As illustrated by the figures 53-55 below the wind power varies considerably from week to week. And the off shore wind power is not significantly more stable than the on shore power.

Figure 53

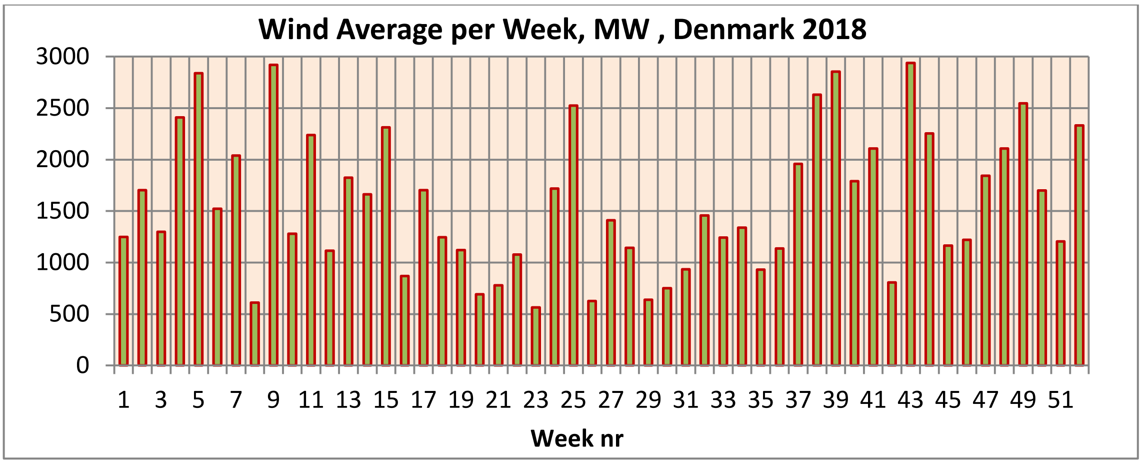


Figure 54

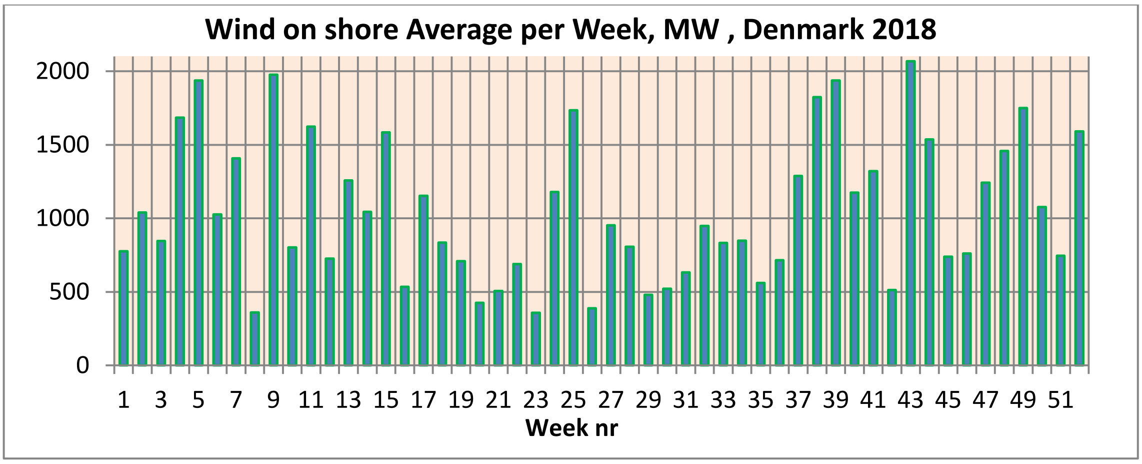
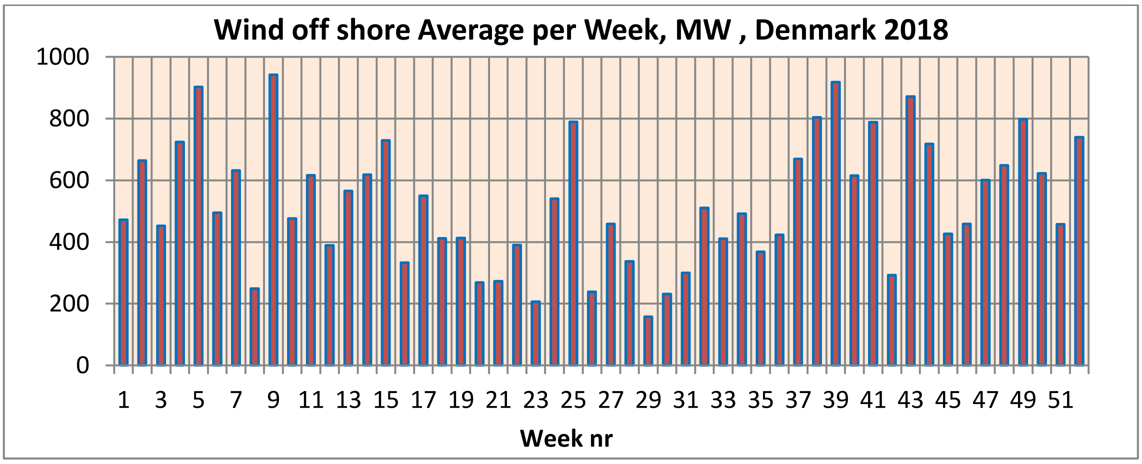


Figure 55



Wind and Solar Power Monthly Variation

Summary

It is up to the reader to study the many numbers, however, it should be remarked that the monthly average for the solar power varies between 11MW in December and 224 MW in May. And the wind power between 965 MW in July and 2025 MW in October.

Tabel 23

Vind and sun power, average, max, min and standard deviation per Month, MW, Denmark 2018										
	Wind on shore	Vind off shore	Wind Total	Solar	Wind +Solar	Wind on shore	Vind off shore	Wind Total	Solar	Wind +Solar
	January					February				
Average	1215	624	1839	21	1860	1159	566	1725	50	1775
Max	3632	1201	4806	331	4814	3473	1193	4594	479	4596
Min	2	5	15	0	38	15	3	21	0	21
Stddev	1059	388	1412	52	1412	991	384	1347	92	1348
	March					April				
Average	1199	563	1762	67	1829	1095	563	1658	145	1803
Max	3506	1206	4674	631	4830	3545	1232	4730	666	5140
Min	4	4	12	0	42	4	18	29	0	84
Stddev	1031	379	1381	119	1393	961	392	1326	192	1343
	May					June				
Average	624	353	977	224	1201	878	427	1304	212	1517
Max	2536	1118	3370	712	3887	3180	1234	4348	708	4657
Min	1	0	6	0	24	4	0	5	0	27
Stddev	476	258	706	248	746	834	337	1148	232	1169
	July					August				
Average	670	295	965	217	1182	822	442	1264	147	1411
Max	2792	1162	3895	715	4303	3491	1189	4660	655	5093
Min	7	1	9	0	42	4	0	6	0	17
Stddev	601	273	841	238	892	691	309	965	182	993
	September					October				
Average	1352	663	2015	112	2127	1357	669	2025	77	2102
Max	3491	1239	4730	623	4837	3759	1217	4850	522	5043
Min	2	0	4	0	11	8	1	9	0	56
Stddev	918	362	1253	158	1251	941	335	1237	128	1239
	November					December				
Average	1046	527	1573	25	1598	1291	657	1948	11	1959
Max	3389	1090	4479	408	4479	3616	1092	4695	227	4764
Min	1	1	1	0	1	63	18	137	0	137
Stddev	817	336	1133	57	1131	887	303	1164	30	1167

Figure 56

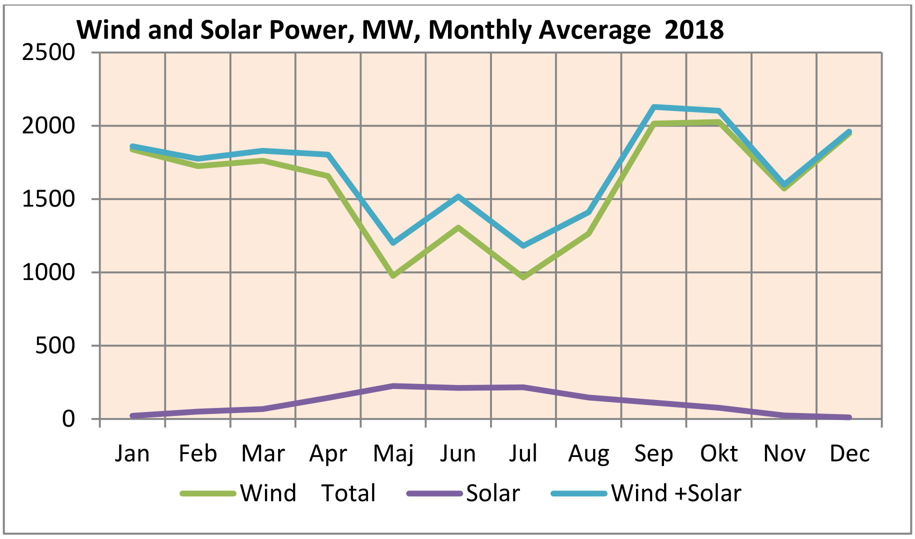
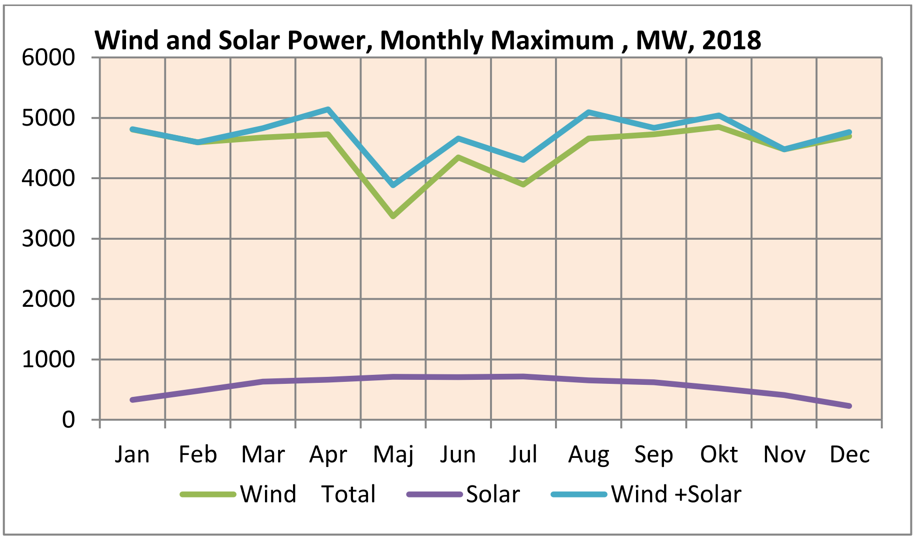


Figure 57



It should be observed, that the averages do not tell very much. In a modern society electricity must be at disposal when it is needed.

Neither wind nor solar energy can comply with this condition.

This is illustrated more clearly in the following section.

Wind Power and Load

Summary

When speaking of the proportion of Wind Power in the Danish system it is mostly forgotten to mention, that the wind power sometime is higher than the load, and it may also be forgotten to mention that by high winds some and not so small amounts of electricity must be exported to get balance in the system. The relations between wind power, load and im- and export are shown in table 17 hereunder.

It should be observed that we import up to 88 % of the load and export up to 83% of the load. These high figures are caused by the large amount of wind power in the Danish system, and are surely a special case. Other countries are not so lucky that they can draw on the abundant water power from their neighbours.

The figures 45-48 showing the relation betrween wind power and load, consumption, should convince everybody that you can't say wind power without saying back up, be it hydro power, thermal power stations or some other form which until now exists only in somebody's imagination.

Tabel 24

Wind Power, Import and Export relative to load W/kW					
	2018	Jan Mar	Apri- Jun	Jul- Sep	Oct- Dec
Wind/Load W/kW 2018					
Average	408	405	363	400	462
Max	1486	1283	1419	1486	1336
Min	0	2	1	1	0
Stddev	306	310	293	316	297
Observations	8760	**2160**	2184	2208	2208
Import/Load W/kW					
Average	229	81	329	353	143
Max	880	524	880	789	584
Min	0	0	0	0	0
Stddev	228	112	244	239	148
Observations	8760	**2160**	2184	2208	2208
Export/Load W/kW					
Average	63	112	42	29	67
Max	831	775	831	677	710
Min	0	0	0	0	0
Stddev	132	164	115	90	129
Observations	8760	**2160**	2184	2208	2208

The relation between Wind power and Load is illustrated by the figures 42-45 hereunder

Figure 58

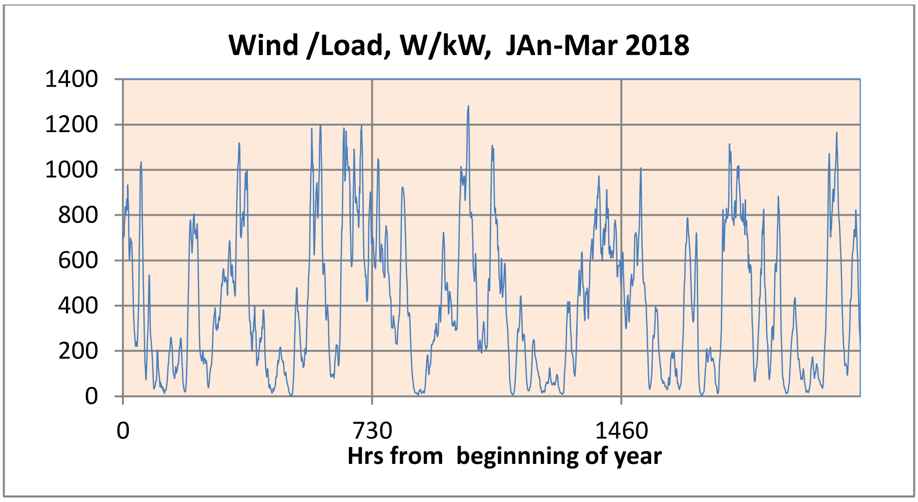


Figure 59

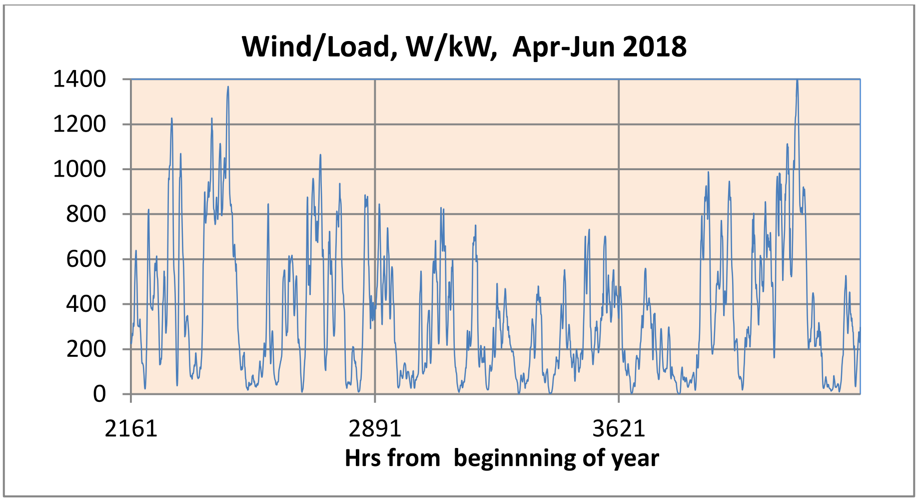


Figure 60

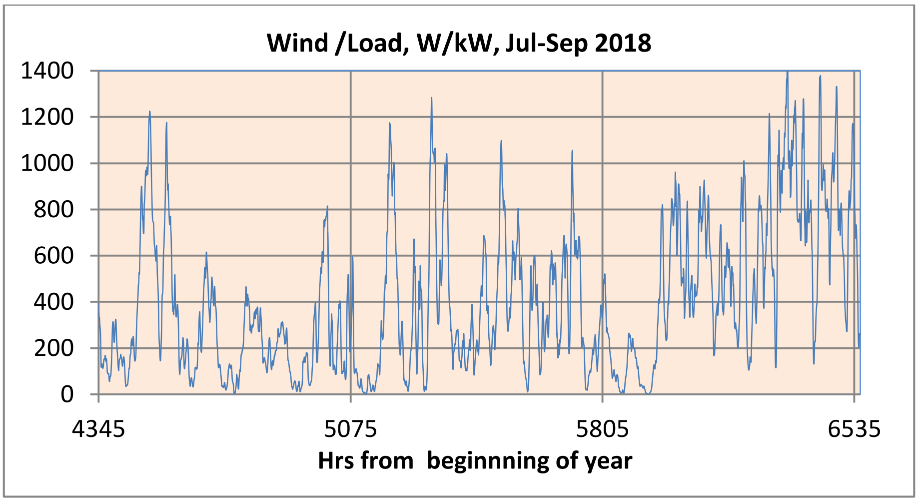
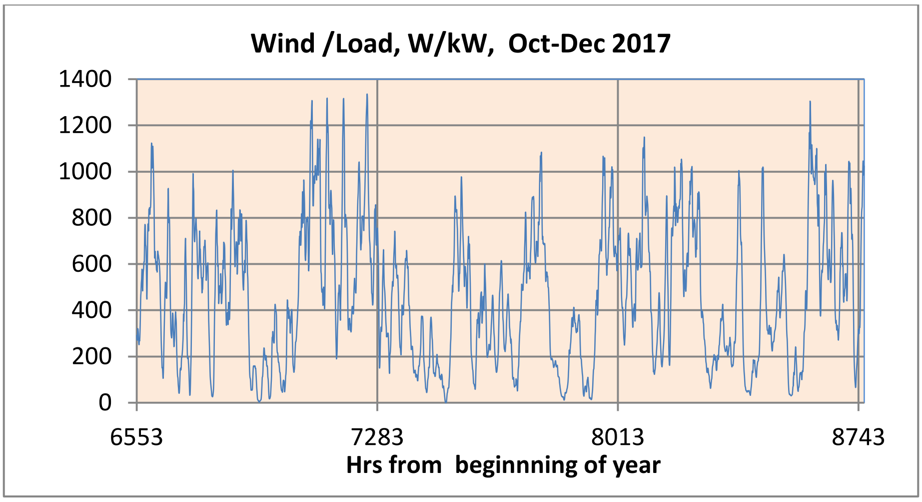


Figure 61



Useful Wind Power

Summary

The wind power was on average 1586 MW in 2018 and the load 3900 MW, so a rough calculation indicate that 40,8% of our electricity is supplied by wind power. However the wind power is sometimes higher than the load, and sometimes we export electricity simultaneously with the production of wind power. If we correct for this we find that only 1337 MW of wind power was used in Denmark, which reduces the wind power used in Denmark to 1337 MW, or 34% of the average load.

Figure 48-59 above illustrate that the wind power sometimes is larger than the load. This is expressed in figures in table 23 below. **"Useful Wind"** is defined as the wind power less the net export. (If the export is larger than the wind power, the useful wind power is defined as zero not as a negative value).

Tabel 25

	2018	Jan	Feb	Mar	Apr	Maj	Jun	Jul	Aug	Sep	Okt	Nov	Dec
	Average Wind MW												
Average Wind	1586	1839	1725	1762	1658	977	1304	965	1264	2015	2025	1573	1948
Max	4850	4806	4594	4674	4730	3370	4348	3895	4660	4730	4850	4479	4696
Min	1	15	21	11	29	6	5	9	6	4	9	1	137
Stddev	1231	1412	1347	1381	1326	706	1147	841	965	1253	1237	1133	1164
	Useful Wind MW												
Average Useful	1337	1458	1248	1145	1256	969	1251	929	1191	1816	**1793**	1429	1565
Max	4088	3703	3536	3512	3545	3042	3859	3427	3502	4088	**4050**	3839	3633
Min	0	15	21	0	29	6	5	9	6	4	**9**	1	137
Stddev	929	955	849	848	864	691	1044	751	819	1049	**980**	933	801
	Wind/Load W/kW												
Average	408	420	389	404	447	277	363	282	359	557	520	374	484
Max	1486	1196	1283	1166	1367	844	1419	1226	1284	1486	1336	1084	1303
Min	0	3	6	2	9	2	1	2	2	1	2	0	30
	Exchange/Load W/kW												
Average	153	47	-48	-95	33	398	435	426	377	171	93	167	-8
Max	880	524	309	294	638	720	880	787	789	768	520	584	377
Min	-831	-643	-775	-717	-831	-252	-554	-355	-459	-677	-710	-529	-698

Figure 62

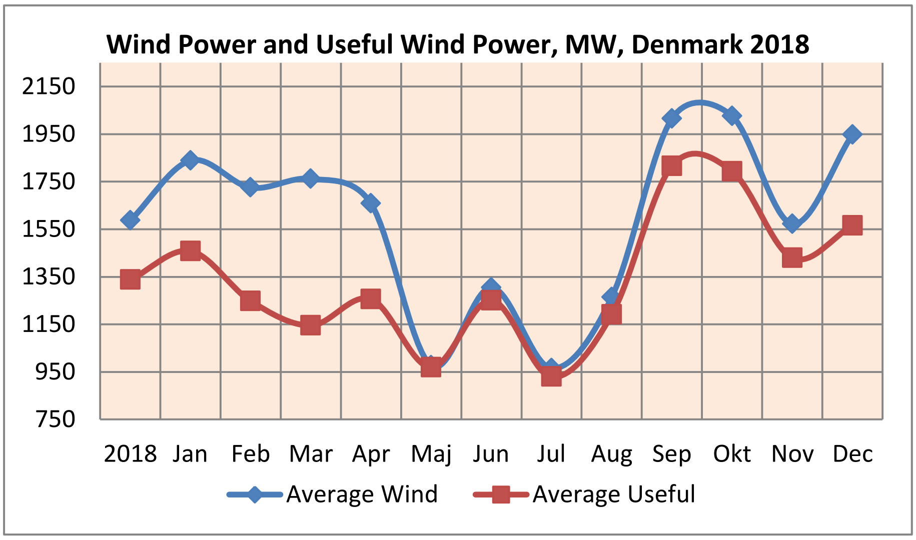


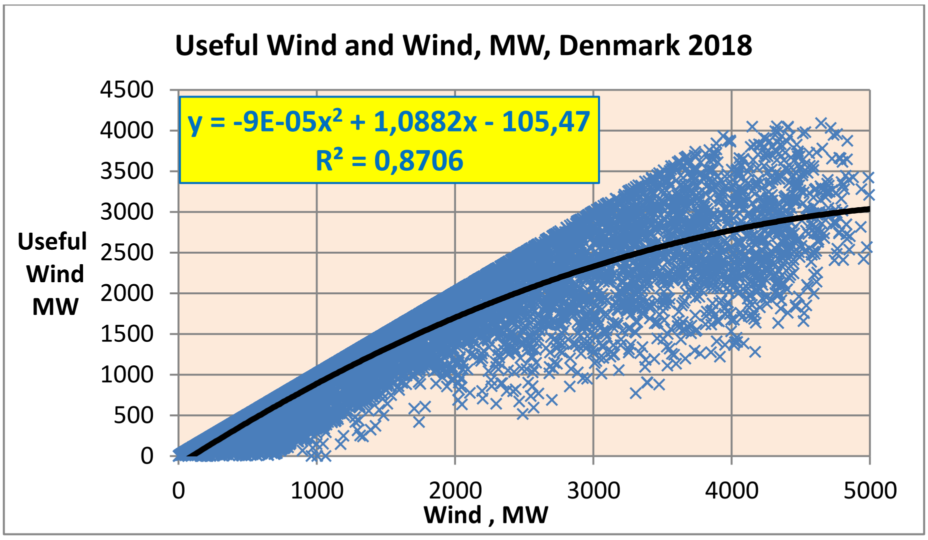
Fig 62 shows that Denmark in the months January, February, March, and April and again in the months September and October produces more wind power, than can be used by the Danish system. The differences are 381 MW, 477 MW, 817 MW and 402 MW in January, February, March and April and again 199 and 232 MW in September and October. The figures may differ from year to year of course.

Table 15 gives the figure 3900 MW average electricity consumption in Denmark in 2018. Table 23 above gives the figure 1586 MW for the average wind power i.e. 40,7 % of the load. A more honest calculation would use the useful wind power 1337 MW, i.e. 34,3 %.

You may wonder what will happen when the plans to build another 10 or more GW off shore capacity are realised.

Figure 60 hereunder illustrates the decline of usefulness by increasing wind power. Up to a wind power of about 2000 MW the most can be used in Denmark, but by a wind power of 3000 MW on average of about 2300 MW can be used in Denmark, and by a wind power of 4000 MW only about 2800 MW can be used.

Figure 63



However, there may other reasons that the wind power can't be used in Denmark than it is higher than the load. A large part of the district heating is coupled to power stations, so when it is cold the power stations have to produce heat and at the same time electricity.

You may then argue that it is this electricity that is exported and not the wind power. Anyway the wind power is far too expensive and unreliable to be an alternative to the thermal power stations.

It should be observed too that the Danish electricity import can be as high as 88 % of the load and the export 83% of the load. (Table 23 bottom left, here these figures are given as watt/kW i.e. as pro mille.)

Our high proportion of wind power in the system necessitates this high exchange. There is not necessarily anything wrong with that. But not many countries will have this possibility, and it is very questionable if we can go on with this high proportion of foreign exchange, if the plans to build a lot of new wind power capacity are fulfilled.

Wind Power and Exchange.

Summary

There is a clear relation between wind power and export. Based on the regression equation in figure 63 you can calculate the figures in table 26 hereunder showing a fast decrease in the proportion of useful wind, when the wind power surpasses 2500 MW, which in 2018 was the case in a little more than 20% of the time.

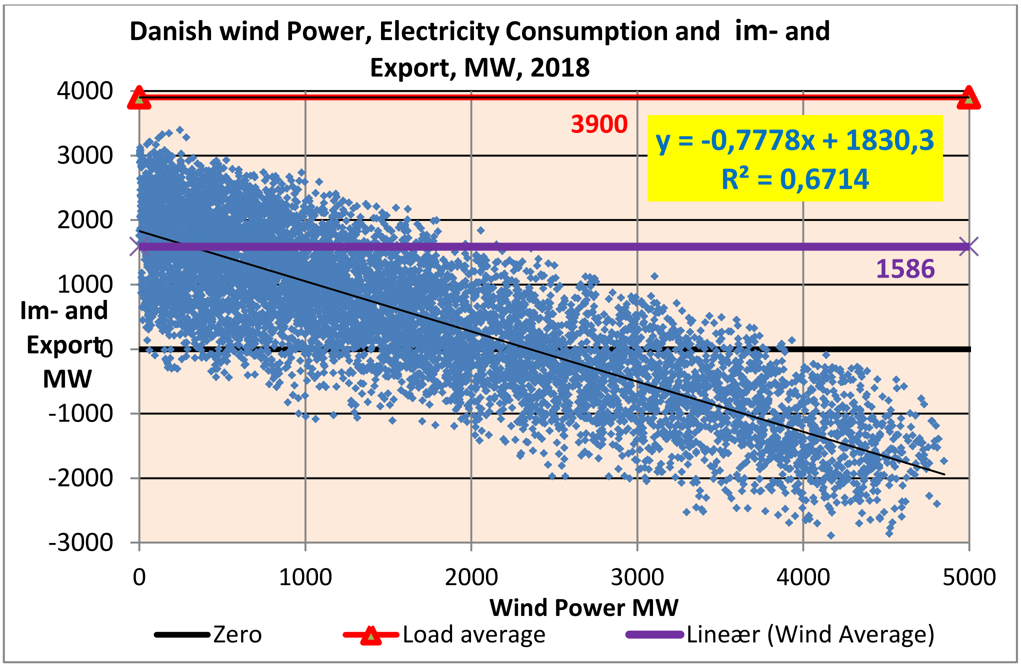
Tabel 26

Vind	Exchange	Useful vind	
x	y	x+y	%
500	1441	500	100
1000	1052	1000	100
1500	663	1500	100
2000	274	2000	100
2500	-115	2385	95
3000	-504	2496	83
3500	-893	2607	74
4000	-1282	2718	68
4500	-1671	2829	63
5000	-2060	2940	59
5500	-2449	3051	55

It is well known already that we have a large in- and export of electricity. It may be less well known that this im- and export are determined by the amount of wind power in the system.

Figure 64 below illustrates the relation between wind power and im/export of electricity

Figure 64



Import is positive and export is negative. A significant export is observed when the wind power exceeds 3000 MW. The regression equation in the diagram indicates that on average 504 MW is exported when the wind power reaches this level, and 1230 MW are exported by a wind power of 4000 MW. The correlation coefficient of 0,82 (the square root of 0,6714) is high enough to justify the calculations of the export part of the wind power.

Very significant changes of the Danish energy system must be performed before it makes any sense to expand the wind power as proposed by the majority of political scientists in our parliament. Not to speak about the Youth Parliament in the Streets.

The costs don't seem to interest anybody. Not to speak of what is physically possible.

Tabel 27

Danish Wind Power and Im- and Export of Electricity, MW				
	Wind DK	**Exchange**	**Import**	**Export**
January to December 2018				
Average	1586	596	846	249
Max	4850	3391	3391	2891
Min	1	-2891	0	0
Stddev	1231	1168	827	509
January to March				
Average	1777	-137	355	492
Max	4806	2586	2586	2771
Min	12	-2771	0	0
Stddev	1381	1033	510	676
April to June				
Average	1309	1034	1186	153
Max	4730	3391	3391	2891
Min	5	-2891	0	0
Stddev	1123	1136	861	433
Jul to September				
Average	1408	1139	1241	102
Max	4729	3211	3211	1942
Min	3,6	-1942	0	0
Stddev	1121	1050	875	287
October to December				
Average	1852	339	593	254
Max	4850	2527	2527	2206
Min	1,2	-2206	0	0
Stddev	1195	958	625	475

Table 27 above illustrates the importance of im- and export of electricity. The maximum import level was 3391 MW and the maximum export was 2891. This should be compared with an average Wind power of 1586 MW and an average load of 3900 MW.

It is the author's hope that figure 64 and table 27 should impress people talking about expanding our off-shore wind power capacity by 12-15 GW. Or at least that the following figures 65-68 could be a wake-up call.

Figure 65

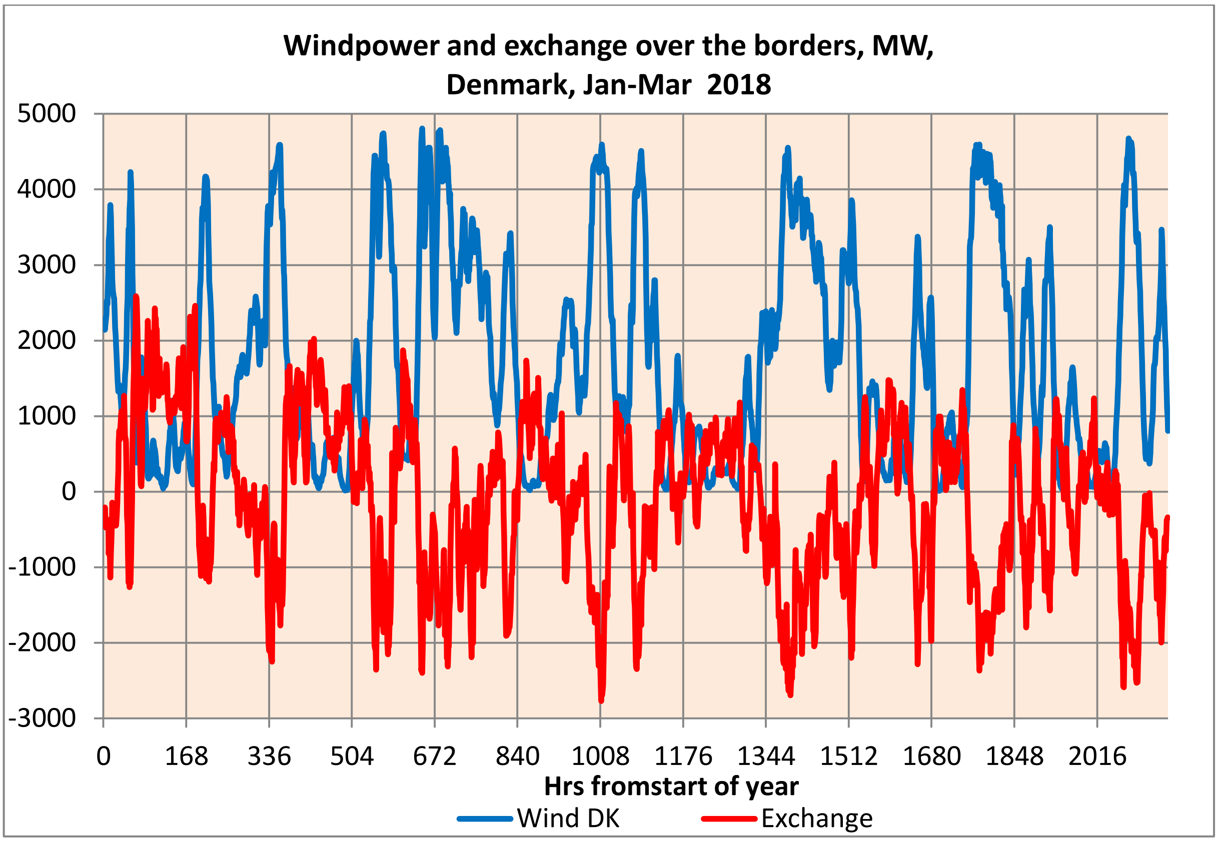


Figure 66

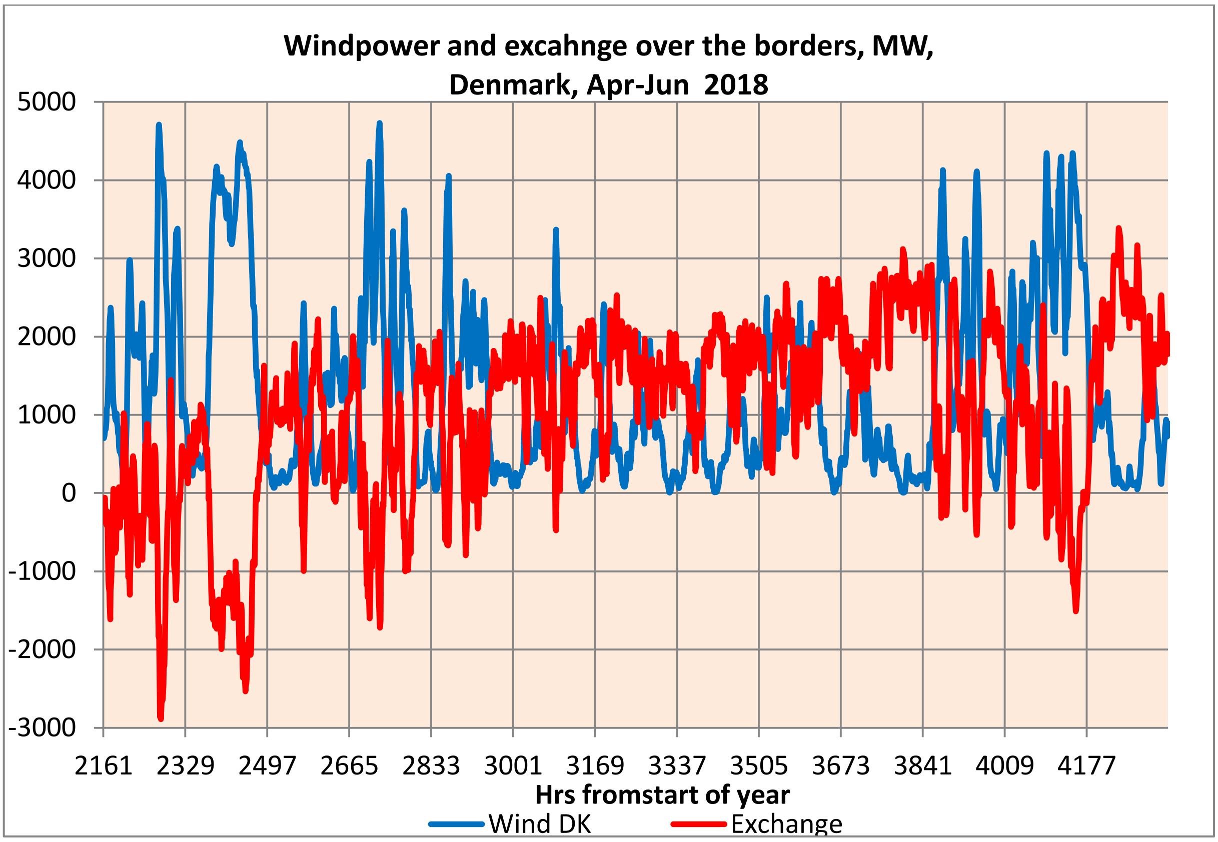


Figure 67

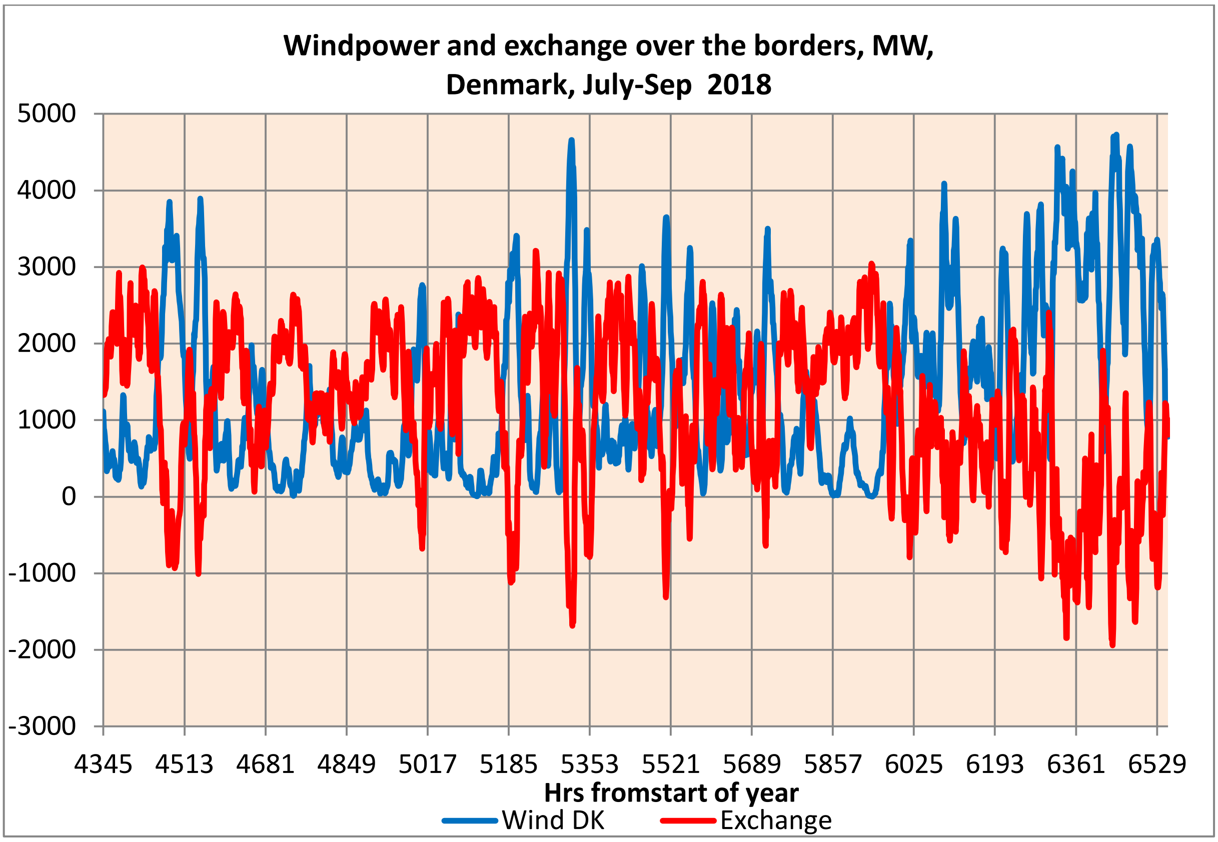
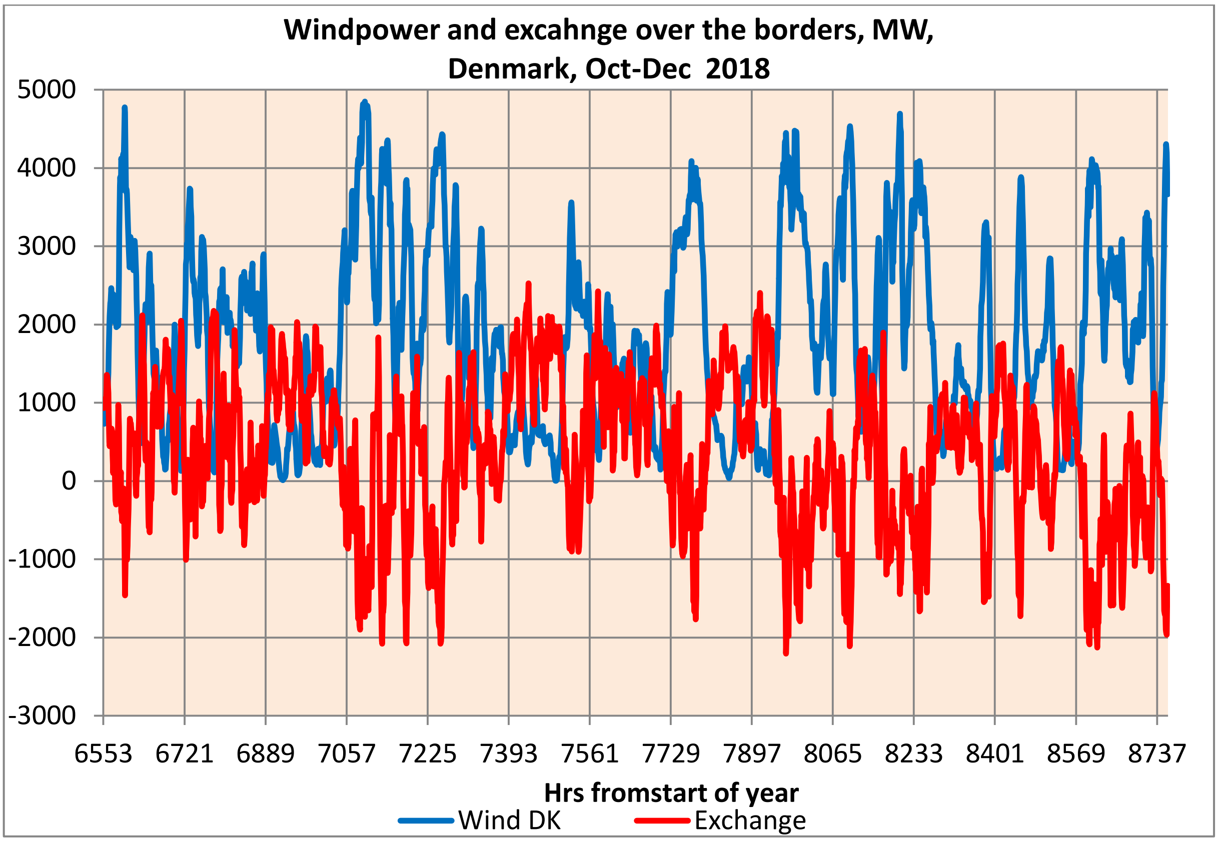


Figure 68



Power Exchange with Norway, Sweden and Germany

Summary

There is a clear correlation between the wind power and the exchange with Norway and Sweden and only a very weak correlation between the wind power and the exchange with Germany. That is no wonder. Germany has plenty of wind power and there is a high degree of simultaneousness between the wind in in Denmark and in Germany.

Until 2010 when a DC cable with a capacity 600 MW was laid between Fünen and Sealand there was no direct electric connection between East and West Denmark.

An AC cable between Sealand and Sweden was established already in 1914 whereas Jutland was connected by DC cables to Sweden in 1965 and to Norway in 1977. Both East and West Denmark are connected to the continental system, So Denmark transfers electricity from Germany to Scandinavia too, which makes it a little more difficult to calculate the direct exchange with Norway and Sweden on the one and Germany on the other hand. But by the help of a little Boolean Algebra it can be done.

Tabel 28

Import and Export of electricity 2018				
		Norway + Sweden	Germany	Total
Average	MW	383	213	596
Max	MW	3220	2121	3391
Min	MW	-2771	-1895	-2891
Stddev	MW	992	540	1168
Average import GWh		3358	1867	5225
Average import PJ		12	7	19
Average Wind		MW	1586	
Average Load		MW	3900	
Danish Energy Consump-tion 2017 (Table 7)		MW	22373	
		PJ	706	

As can be seen from table 28 above we import about 3% of our total energy consumption in form of electricity. That may be clever. But it is hardly clever that we export up to 3391 MW electricity where the average load is 3900 MW.

According to table 27 above the maximal wind power was 4850 MW in Oct-Dec 2018. So far we can export a high effect, but the politicians and the Wind Power Company Oersted talk about increasing the off shore wind power by about a factor 7, adding about 6 GW to the domestic electricity production – 1,5 times the average present consumption and reaching a maximum of about 15 GW off shore wind.

We have heard very very little about how to use this amount of electricity. It will be shown below, that the German and Swedish and Norwegian wind power to a high degree are produced and not produced at the same time as the Danish.
The correlation between wind power and exchange with Norway +Sweden and Germany are shown in the figures 63 and 64 below.

Figure 69

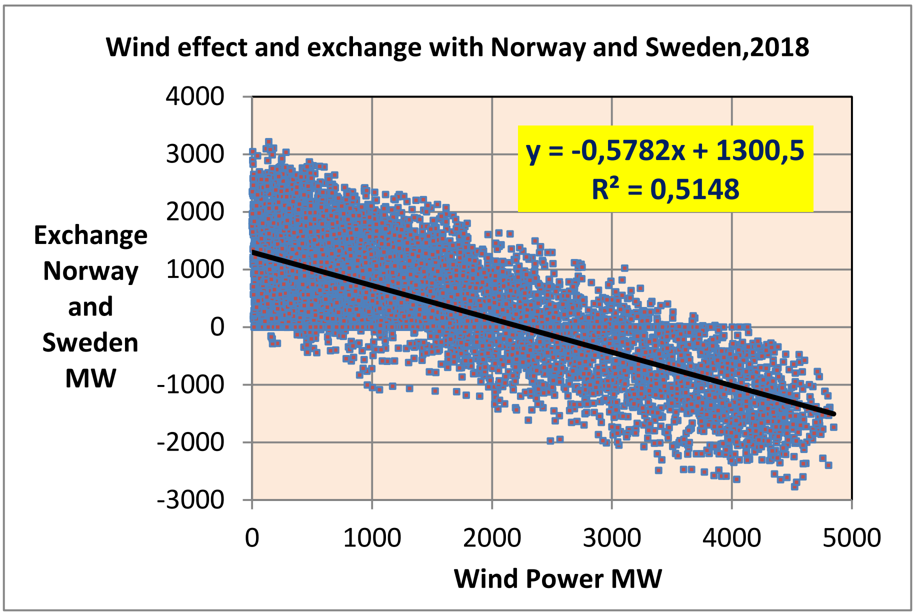
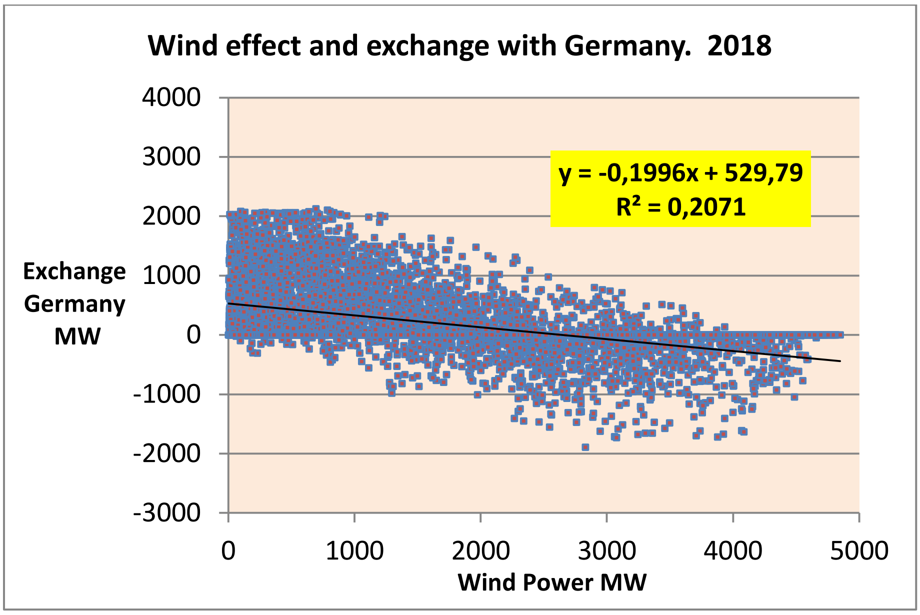


Figure 70



It is easy to see that there is only a very weak correlation between the Danish wind power and the exchange with Germany. This is easy to understand when observing the wind power profiles for Germany and Denmark.

Wind AND Solar Power in Denmark, Germany, Norway and Sweden[ix]

Summary

Table 29 below shows that you can't make a graph to compare the "green energy" in systems of different size. You may use a logarithmic scale as in figure 71 below, but the author prefers to normalize the data. Thus each of the hourly data are divided with the average yearly output for each country and thereafter multiplied by 1000. You then obtain the dimensionless unit (W power/average kW power), which enables you to make meaningful comparisons between systems of different size.

Further you may add the normalized hourly values for each of the countries and divide by the number of countries to get a normalized sum.

The result of this operation is shown in table 30 and in the figures 72-73 below. should make it clear that wind power in different countries can only be of limited help for their neighbours. The wind power simply differs too little from North Cape in Norway to Bavaria in Germany. A distance of about 3000 km.

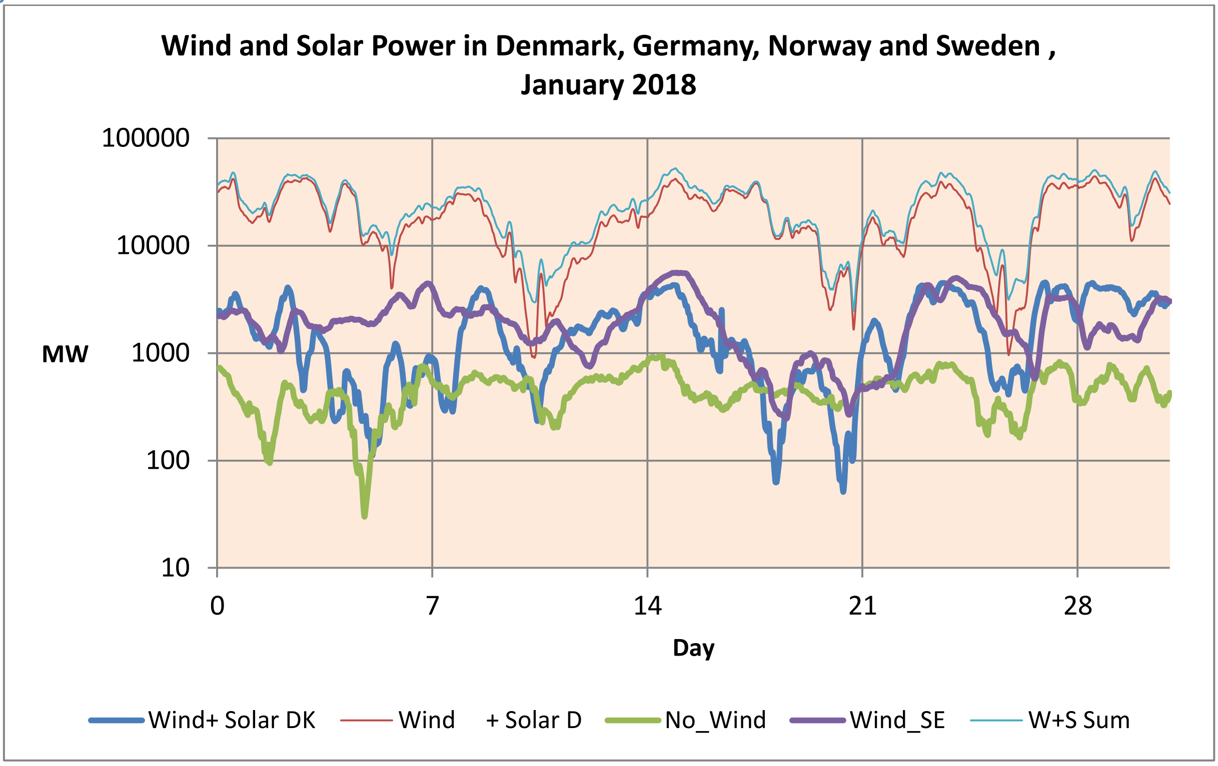
Figure 74 below illustrates the simultaneousness between the wind power in Denmark, Norway and Sweden. It must be justified to claim that in a large part of the time, the systems can't supply each other.

Figure 75 illustrates that the same is the case for the wind power in Denmark and Germany. So when Denmark demands that Germany should expand her transmission systems to be able to buy more of our superfluous wind power we ridicule ourselves.

Tabel 29

Wind+Solar Power, Denmark, Germany, Norway and Sweden MW, January 2018					
	Denmark	Germany	Norway	Sweden	Sum
Average	1798	20392	464	2110	24780
Max	4538	44052	937	5612	52497
Min	51	903	30	247	2477
Stddev	1320	11742	175	1231	13216
Stddev % of average	***73***	***58***	***38***	***58***	***53***

Figure 71



Normalized data

Tabel 30

Normalized Wind Power MW/GW, Norway+Sweden+Denmark+Germany, 2018					
	Jan-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
Average	1000	1093	818	833	1255
Max	2774	2774	2068	2509	2665
Min	82	214	97	82	279
Stddev	536	536	418	527	524
Stddev % of average	54	49	51	63	42

Figure 72

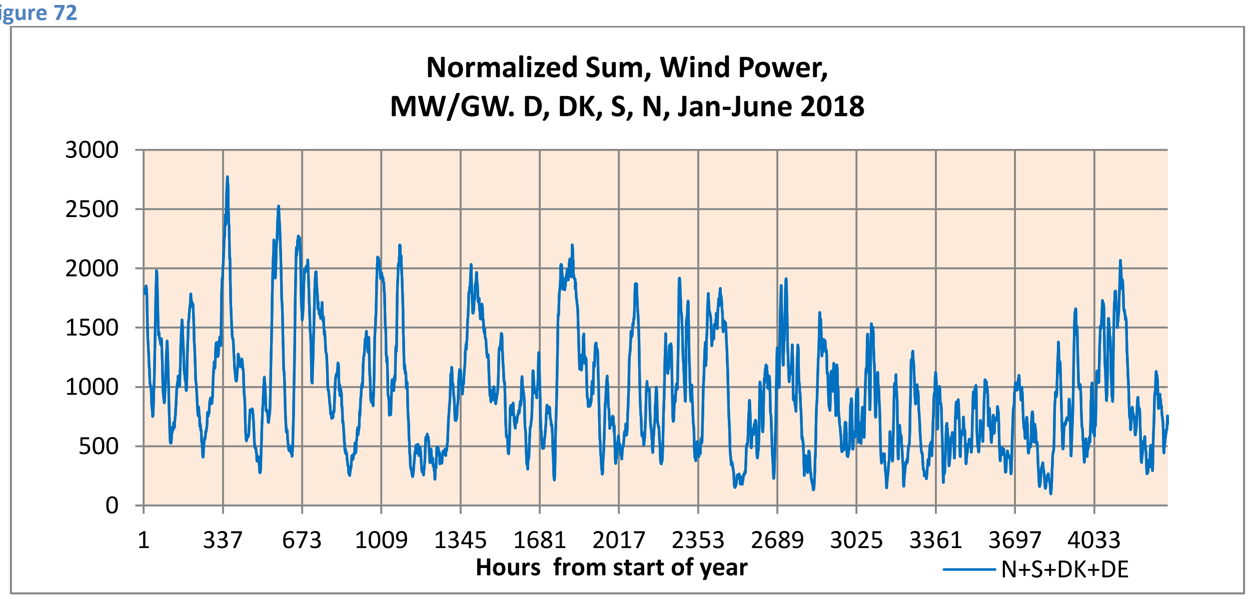
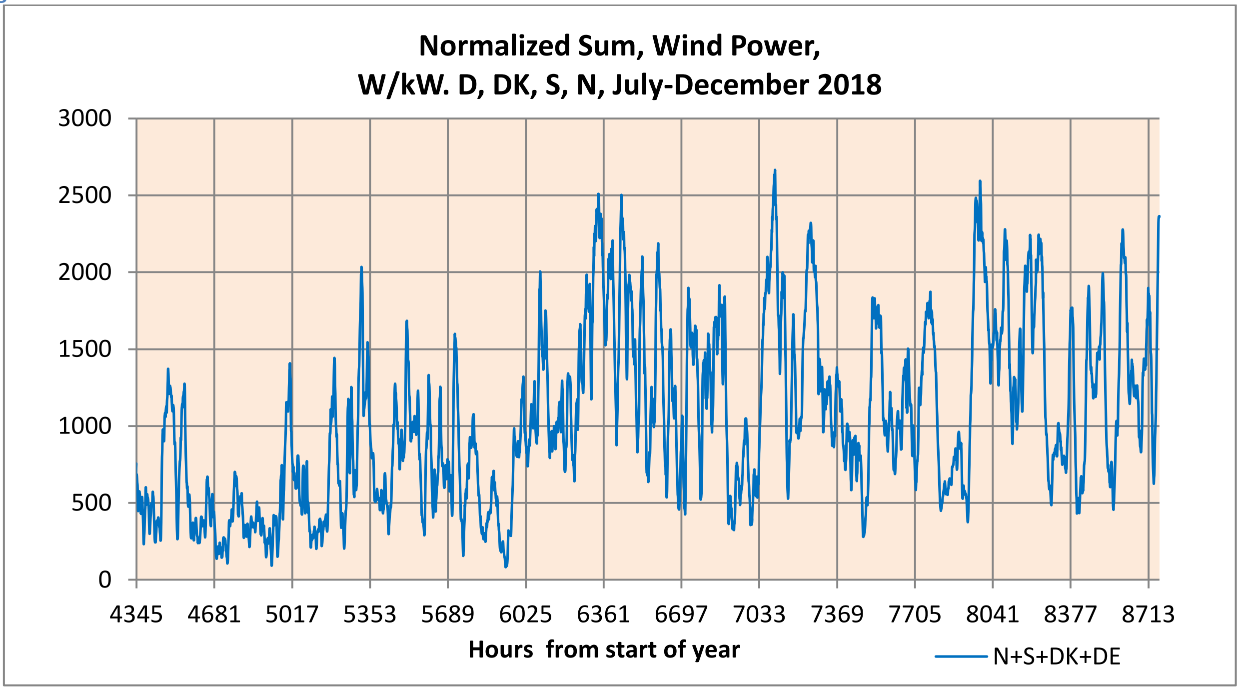


Figure 73



From table 27 it can be seen, that the normalized average differs between 818 MW/GW in the period April to June and 1255 MW/GW in the period Oct-Dec 2018. We will in the following look at the demand for storing electricity if an even supply should be secured.

Figure 74 below illustrates the simultaneousness of wind power in Denmark, Norway and Sweden, and it seems evident that Norwegian and Swedish wind power must be of much less interest for Denmark, than the Scandinavian hydro-power. Alas the Scandinavian hydro power is of great interest for Germany, The Netherlands and Germany too.

Figure 74

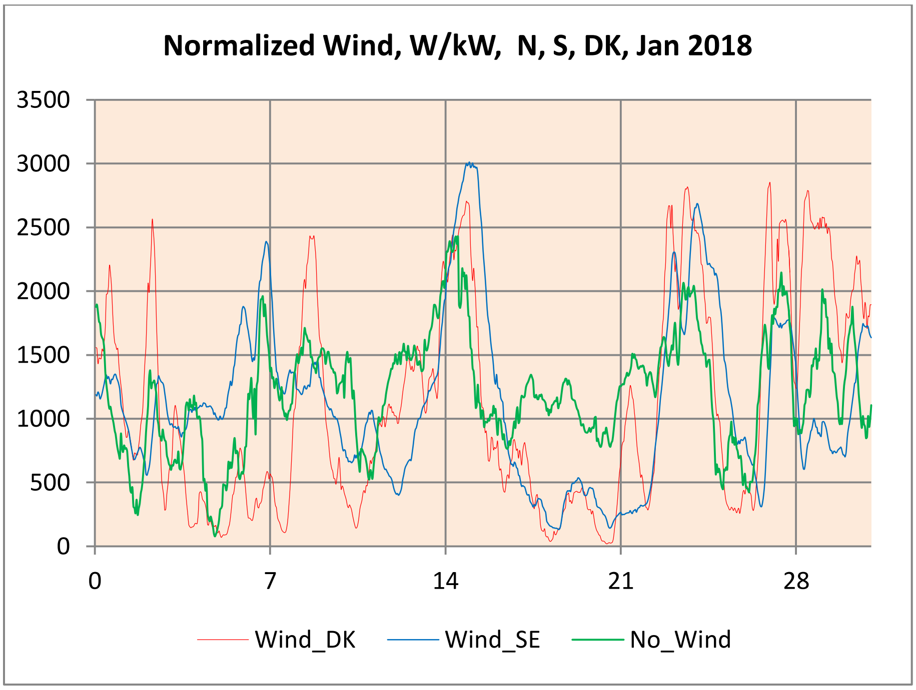
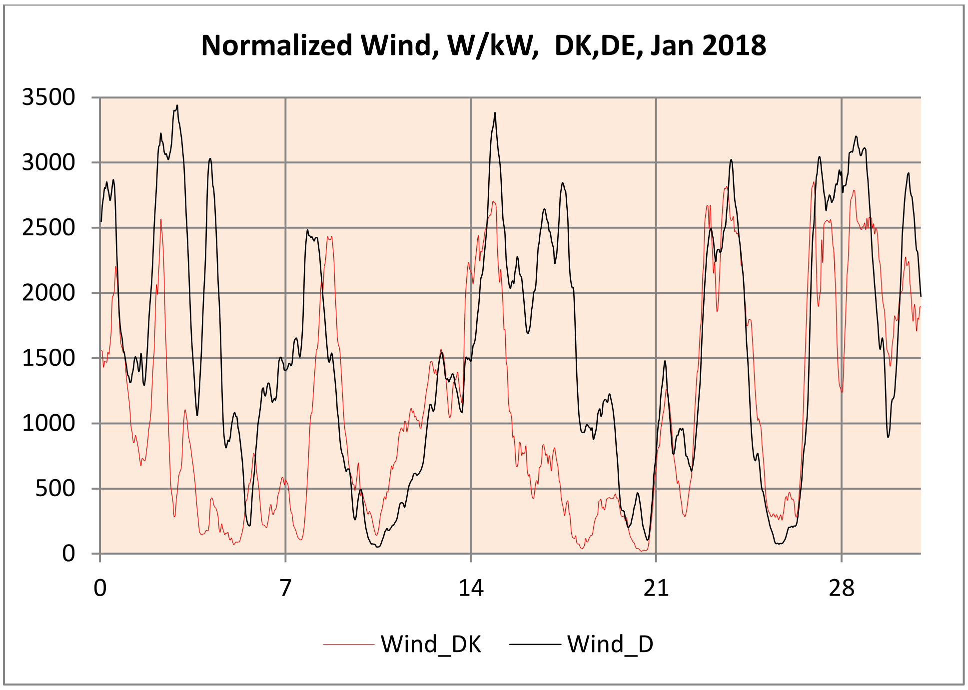


Fig 75 below illustrates the synchronism between Danish and German wind Power in January 2018. The synchronism is not perfect but at least large enough to ridicule the Danish demand for a larger transfer capacity to Germany. Especially the Danish demands that Germany should be more interested in cables to Denmark than in the North Stream 2 gas pipeline to Russia.

Figure 75



Danish wind turbines produced on average 1,6 GW in 2018. North Stream 2 will have a capacity of 50 billion m³ gas/year corresponding to 63 GW.

According to BP.s Statistic 2018 the German energy consumption in 2017 was totally 335 Mio t oil equivalent corresponding to 445 GW. So North Stream 2 could deliver about 15% of the German energy. There may be a few hours per year where the Danish wind turbines could deliver about 2 GW to Germany. The electricity trade with Germany in 2018 can be expressed as:
Average import 213 MW
Maximum import 2121 MW
Maximum export 1895 MW
Standard deviation 540 MW.

So Danish politicians demanding better connections to Germany in replacement for Russian gas simply ridicule themselves.

Expanding and Storing off Shore Wind VI

Summary

The political system talks about adding 12000 MW to the present abt. 1700 MW of off shore capacity. Based on data from 2018 we have estimated the consequences.

Table 31 below show the data from 2018 + the estimated future data. Figure 76 show the load and wind power in MW for every hour in the period Jan-Mar 2018, and figure 77 shows the same + the estimated future wind power. As can be seen the estimated future wind power is much higher than the load the most of the time.

We can estimate the cost for building of 12 GW off shore wind capacity, 270 billion DKK, about 50.000 DKK/inhabitant, but we have heard nothing about the costs for the investments in systems which could use this uncontrollably and violently varying wind power.

It is possible to calculate how large a storage you would need to get a constant power supply from the wind turbines.

The result is shown in table 32 and 33 below. Under the chosen conditions we find that the output would be 6361 MW, which should be compared to the average load in 2018 of 3900 MW. The storage capacity should be 6790 GWh corresponding to 1358 times the capacity of the largest European pumped storage, Vianden in Luxembourg. And then we should still create systems able to use about 3 GW of electricity.

The off shore capacity was 1291 MW by the end of 2018, however 406 MW were added at the end of the year, but the production from this added capacity was very close to zero in 2018.

Tabel 31

Estimate for future Danish Wind Power

	Total Load 2018	Total Wind 2018	Future off shore Wind	Future total Wind
Average	3900	1586	5732	6789
Max	6076	4850	13434	16925
Min	2294	1	0	6
Stddev	782	1231	3908	4724
Stddev % of average	**20**	**78**	**68**	**70**

Figure 76

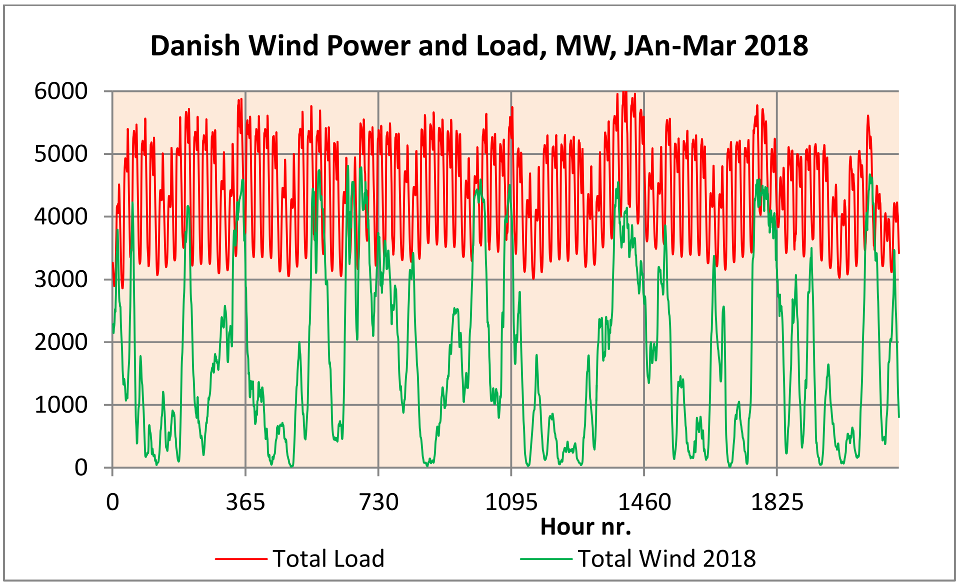


Figure 76 above illustrates the load and the wind power in Denmark in the period Jan-Mar 2018 and figure 73 hereunder the situation if the off shore wind power capacity is expanded to 14000 MW. It should be observed, that the calculations presume proportionality between capacity and production. However new and probably more efficient wind turbines would probably give a higher production than estimated.

Figure 77

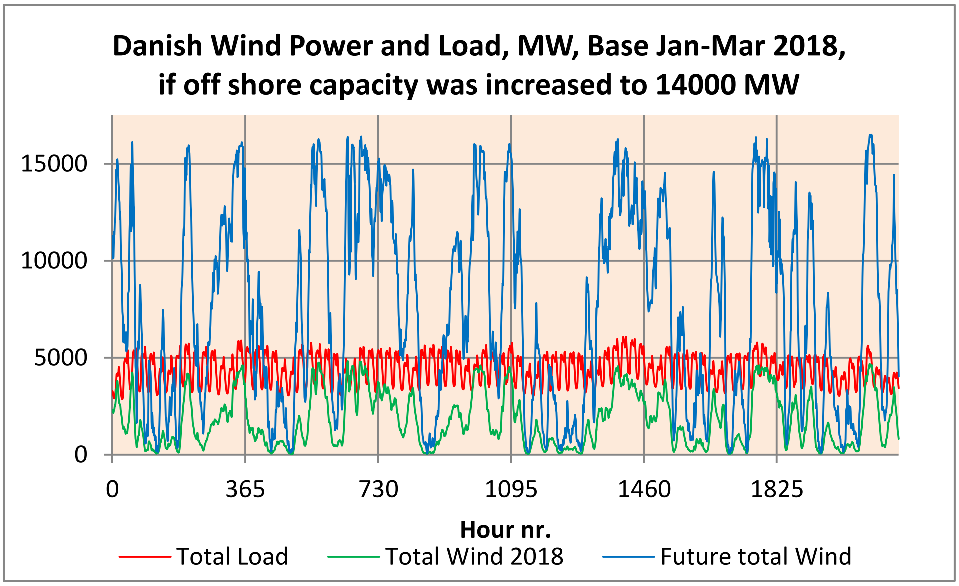


Figure 74 above illustrates the situation after adding 12000 MW of off shore capacity.

In 2018 the load was on average 3900 MW. With the added wind capacity the wind turbines would supply 6789 MW, varying between 6 MW and 16925 MW. So it is evident that something must be done to store this wind energy.

Storing of Wind Power

Assuming a constant output from the system we can calculate the demand for storage capacity. A constant output is of course not what will be demanded, but since nobody knows what a future electricity system will demand we have used this assumption to get an idea of the storage demands. The result is shown in table 28 hereunder.

Tabel 32

Future total Wind		To Reservoir	To reservoir after losses	From Reservoir	Regene-rated Power	Resulting Power	Reservoir content GWh
	MW	MW	MW	MW	MW	MW	GWh
Average	6789	2254	2029	2029	1826	6361	3817
Max	16925	10564	9507	7062	6355	6361	6790
Min	6	0	0	0	0	6361	0
Stddev	4724	3040	2736	2444	2200	0	1835

Tabel 33

Loss by storing	Wh/kWh	100
Loss by reproduction	Wh/kWh	100
Loss totally	Wh/kWh	190
Storage Efficiency	Wh/kWh	810
Loss	MW	428
Loss	%	6,3
Loss	GWh/year	3752
Loss by a price of 700 DKK/MWh	Mio DKK/year	2626
Storage capacity	Future reservoir	Vianden in Luxembourg
GWh	6790	5
hrs of average production	1000	
Max input MW	10564	1040
Max Output MW	6355	1290
Condition 1: To reservoir - From reservoir =		0
Condition 2: Minimum storage content =		0
Calculated factor		0,9369
Storage Start of Period	GWh	4523
Storage 1 Tesla battery	kWh	100
Necessary number	Mio	68

Table 29 gives some details about the calculations. We calculate with a loss by storing and regeneration of electric power of 100 Wh/kWh or 10 % by each of the operations. This corresponds to the losses in Europe's largest pumped storage system, Vianden in Luxembourg.

Vianden has a storing capacity of 5 GWh. According to the calculations Denmark would need a storage capacity 6790 GWh corresponding to about 25 % of the total Swedish hydrostorage capacity. Or 68 million Tesla batteries.

An input capacity of up to 10-11 GW would be needed. The capacity of the Danish connections to Germany + Sweden + Norway is 5,67 GW.

Figure 78

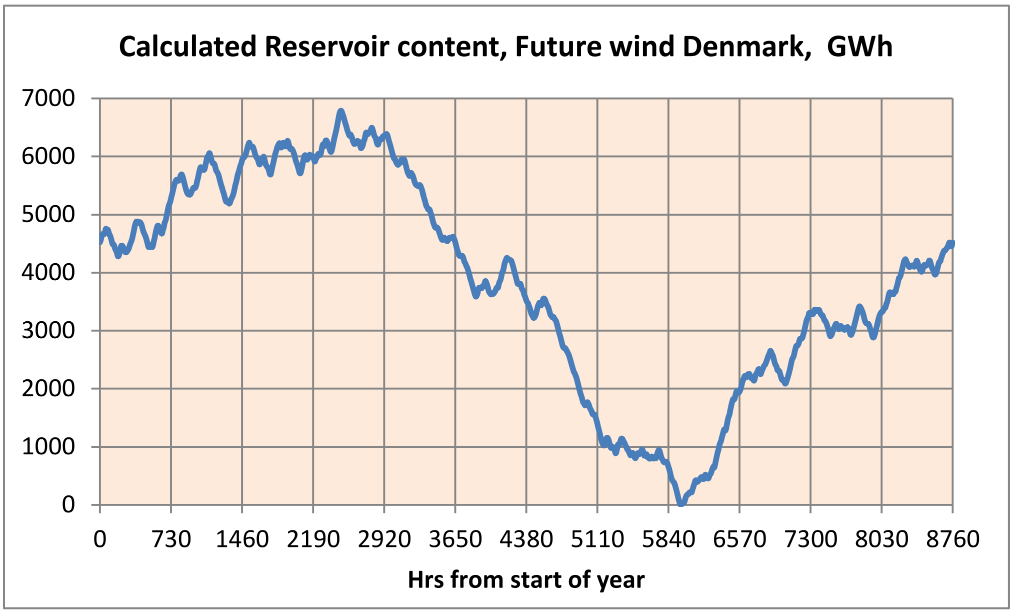


Figure 75 above illustrate the variations of the stored energy during the year, showing a minimum in the beginning of September and a maximum in April.

The author finds it very very strange that nobody seems to ask for what and how the planned electricity should be used, not to speak of calculations about what the experiment will cost.

The calculation method for obtaining a constant output.

It is assumed that the when the wind power surpasses the yearly average times an unknown factor smaller than one, the difference between the actual wind power and the calculated limit is stored. The losses by storing and retrieving are arbitrary constants.

When the actual wind power is less than the calculated limit power is retrieved form the storage.

When the year is gone the stored wind power must equal the retrieved wind power plus the losses. The unknown factor is determined by iteration so that this condition is fulfilled.

The storage may not be less than zero. This condition is fulfilled by a manual calculation of the storage by the beginning of the year.

North Sea Cable. Viking Link [IX,X]

Summary

Justification for the Viking Link.

The author has seen reports assuming that there in the future will be a price difference for electricity between Denmark and the UK and that these assumed differences in a distant future could make the Viking Link profitable.

The author has chosen another assumptions reasoning:

When the wind power in a country is higher than a constant times the average wind power export might be interesting, and import might be interesting if the wind power is less than the constant times the average wind power. So if the wind power in both countries is higher than the constant times the average and if the wind power in both countries is lower than the constant times the average no exchange will take place.

The Viking Link will have a transfer capacity of 1400 MW. If we assume that export might be interesting if the wind power is higher than 1,25 times the average, and that import might be interesting if the wind power is lower than 1,25 times the average based on the data from 2018 we find that on average Denmark might import 133 MW and export on average 122 MW to the UK. Totally **255 MW would be transferred in a cable with a capacity of 1400 MW.**

A calculation based on the **estimates for the future wind power** (table 35 below) results in a total transfer of on average 186+166 MW = **372 MW.**

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	250	MW
Exchange per year	2190	GWh
Capital cost per MWh	**256**	**DKK/Mwh**
Capital cost per MWh exchange		
At full capacity	48	DKK/MWh

Conclusion

The system price for electricity in the Nordic countries was on average 324 DKK/MWh in 2018. After sending electricity through the cable the price would thus be at least 324+256 = 580 DKK/MWh.

The possible exchange, average per month and per year has been calculated by a constant of 1,25 (as defined above) and a constant 1,5 for the years 2016, 2017 and 2018 and for the case that Denmark expands it offshore capacity to 14 GW wind Power.

Danish and British Wind Power

The graphs 79-82 hereunder illustrate the Danish and British Wind Power in 2018. It should be easy to see that a high degree of simultaneousness exists between the two systems.

Figure 79

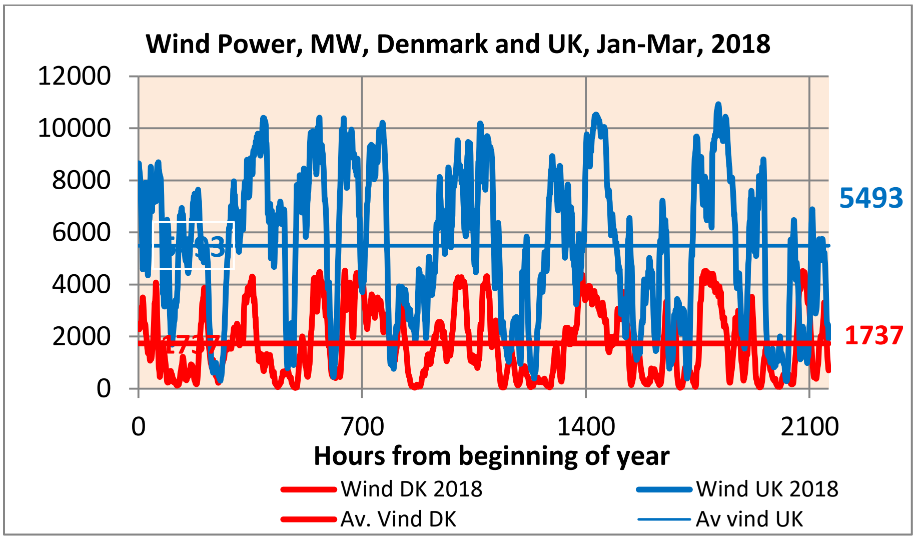
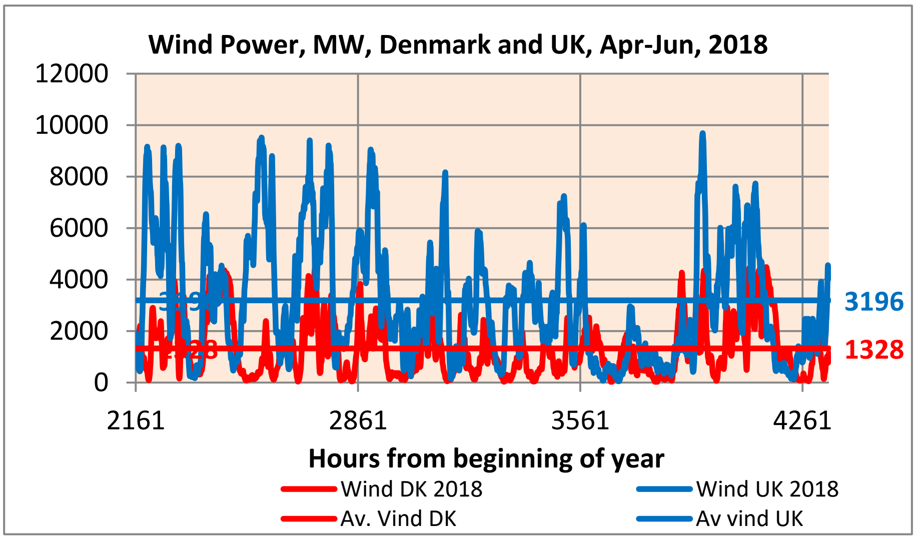
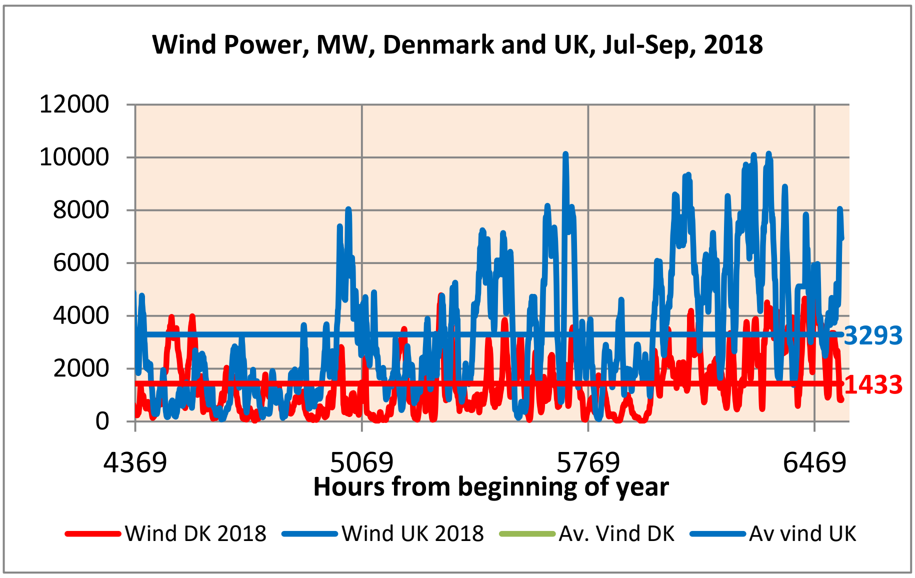


Figure 80



From the end of May and until mid-June there is a nearly 300 hours long Period with very little wind in both Denmark and UK

Figure 81



In July there is very little wind in both DK and UK.

Figure 82

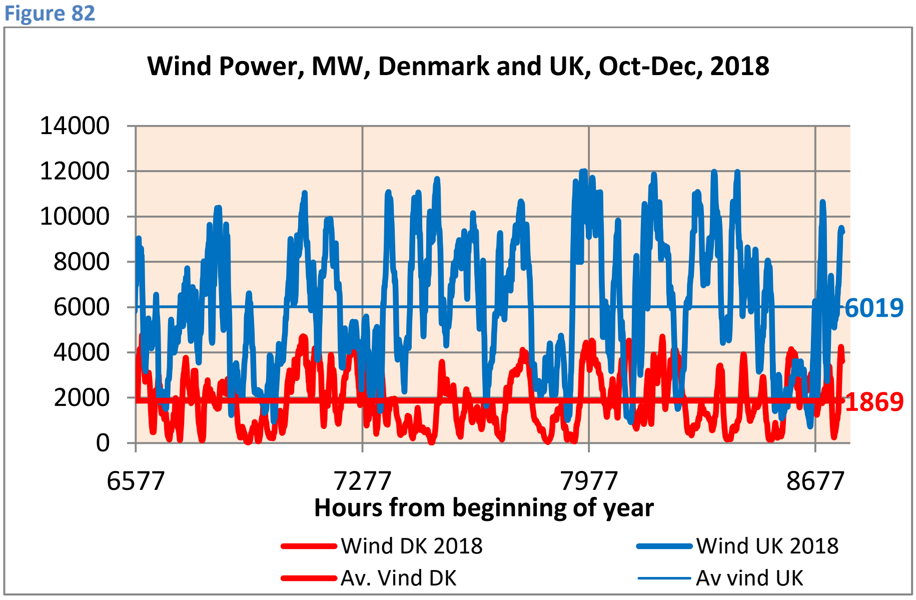
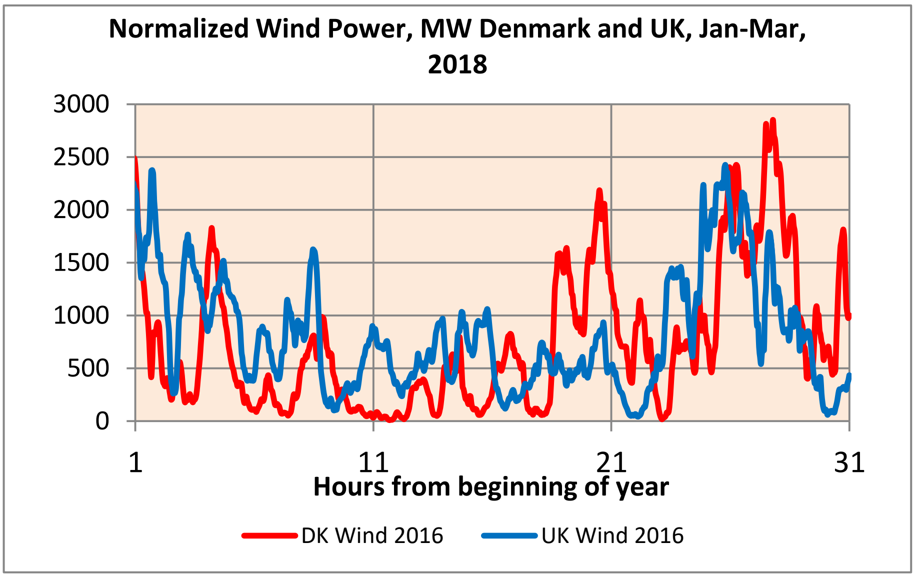


Figure 83



The British wind power is about 3 times larger than the Danish so it is easier to compare if you normalize the figures which is done by dividing each figure from each country by the yearly average and then multiply by 1000.

Tabel 34

Possible exchange of Wind Power between UK and Denmark based on Wind Power in 2018											
Const DK	Const UK	Wind 2018		Export potential		Import potential		Possible Exchange		Transfer limited	
1,25	***1,25***	**DK**	**UK**	**DK**	**UK**	**DK**	**UK**	**DK To UK**	**UK To DK**	**UK to DK**	**UK to DK**
Average	**MW**	1592	4498	360	789	758	1914	136	140	122	133
Max	**MW**	4783	12002	2793	6379	1979	5575	2559	1979	1400	1400
Min	**MW**	11	48	0	0	0	0	0	0	0	0
Stddev	**MW**	1213	2911	656	1382	703	1882	398	374	337	346
Std**dev % of av**er.		76	65	182	175	93	98	293	266	277	260
Hours				**2898**	**3057**	**5862**	**5703**	**1424**	**1583**	**1424**	**1583**

Table 30 above illustrates the calculations. The first to be observed are the constants DK 1,25 and UK 1,25.

If the Danish wind power is less than 1,25*1592 (the average Danish Wind Power in 2018) =1,25*1592= 1990 MW it is assumed that import might be interesting, and export is interesting if the wind power is higher than that value.

The corresponding value for the British wind power is 1,25*4498= 5662 MW.

So when the Danish wind power is lower than 1990 MW and the British higher than 5662 MW there should be a basis for Danish import of British Wind Power.

Import to Denmark might thus be interesting in 5862 hours and it might be interesting to import on average 758 MW to Denmark. However British export must be interesting for UK too, i.e. at the same time as Denmark might import, the British wind power must be higher than 5662 MW.

Both conditions are fulfilled in 1583 hours and the possible export from UK to Denmark is calculated to on average 140 MW.

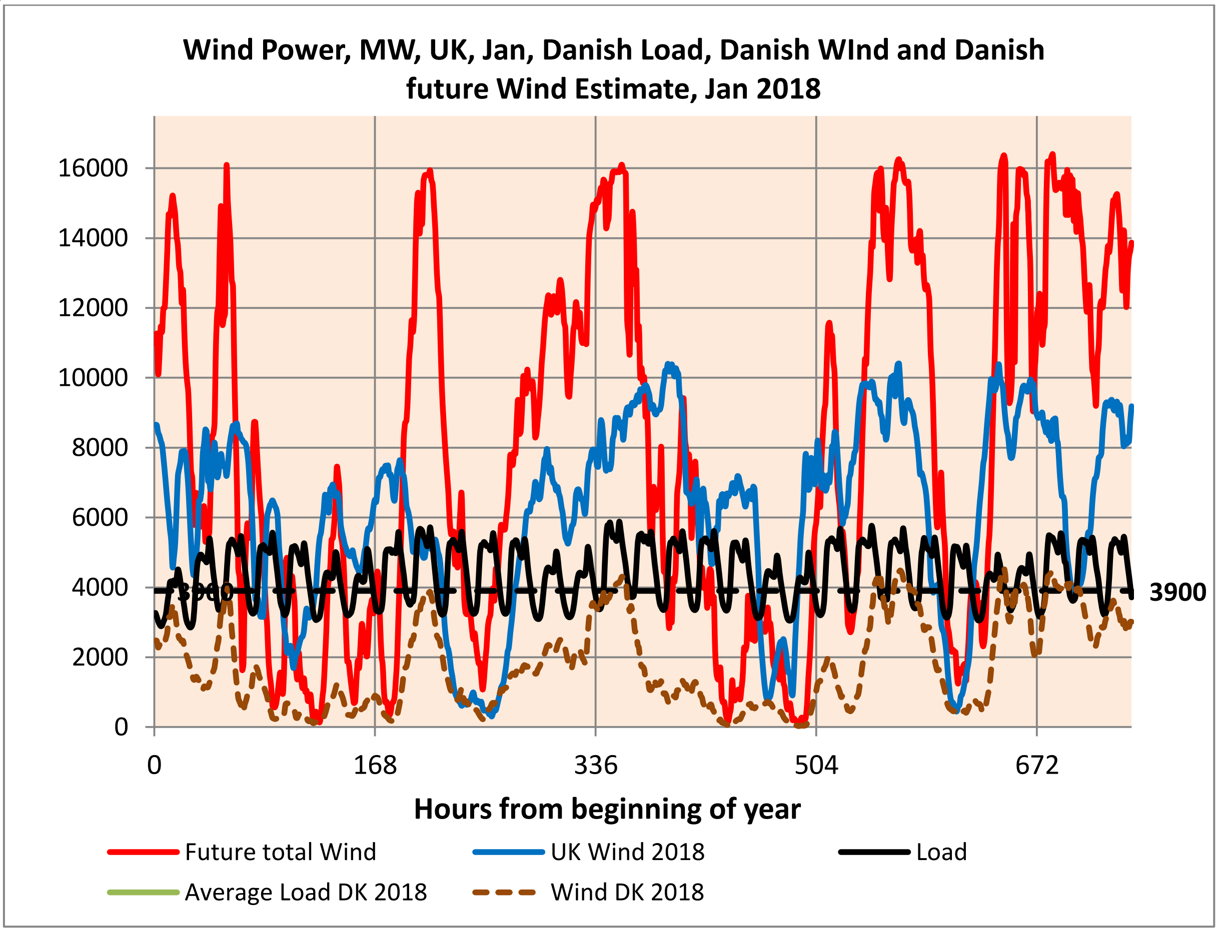
And export from Denmark should be of interest in 1424 hours and with an average export of 136 MW.

However, as can be seen the exchanges reach a maximum of 2559 and 1979 MW, where the Viking Link capacity is only 1400 MW.

Accounting for this limitation we find a slightly lower exchange from UK to Denmark 133 MW and the opposite way 122 MW.

Denmark plans to expand her off shore wind power capacity from the present 1697 MW to about 14000 MW. Based on the figures from 2018 this would result in an average wind power production of 6789 MW where the present load is only 3900 MW. And the Danish wind power would be considerably higher than the British, as shown in figure 80 Hereunder. So there will surely be a desire to export wind power.

figure 84



The Danish wind power could if existing plans are realized reach a maximum of 17000 MW with an average of 6800 MW, and the neighbouring countries will hardly wish to by Danish electricity when it blows.
The average Danish load in 2018 was 3900 MW, and the capacity of the Viking Link will be 1400 MW.
It will be interesting to see how the political system will bring the planned wind power in concordance with the load.

Tabel 35

Possible Exchange UK Wind 2018, and Denmark future Estimate											
Const DK	**Const UK**	Estimated future Wind	**Wind 2018**	**Export potential**		**Import potential**		**Transfer unlimited**		**Transfer limited**	
1,25	**1,25**	**DK**	**UK**	**DK**	**UK**	**DK from UK**	**UK from DK**	**DK to UK**	**UK to DK**	**DK To UK**	**UK to DK**
Average	**MW**	6789	4498	1351	789	3049	1914	309	268	186	166
Max	**MW**	16925	12002	8438	6379	8481	5575	5443	5929	1400	1400
Min	**MW**	6	48	0	0	0	0	0	0	0	0
Stddev	**MW**	4724	2911	2218	1382	3026	1882	858	792	443	423
Stddev % of av.		70	65	164	175	99	98	277	295	238	2541
Hours				**3211**	**3057**	**5549**	**5703**	**1585**	**1431**	**1585**	**1431**

It may be surprising to see that Denmark's potential for electricity import increases after a tremendous expansion of the wind power capacity. However it is assumed that the electricity consumption will increase too, and even with an off shore wind capacity of 14 GW the wind power may approach zero. And in spite of the huge expansion of the wind power the calculated potential for the wind power exchange rises from (122+133) to only (186+166) MW on average.

Tabel 36

Exchange, MW average, per month 2016, 2017, 2018 and for future Danish Wind

Constant	DK to UK	UK to DK	DK to UK	UK to DK	DK to UK	UK to DK	DK to UK	UK to DK	DK to UK	UK to DK	DK to UK	UK to DK	DK to UK	UK to DK	DK to UK	UK to DK
	2016				2017				2018				Estimated Future Wind DK			
1,25	Unlimited Transfer		Max transfer 1,4 GW		Unlimited Transfer		Max transfer 1,4 GW		Unlimited Transfer		Max transfer 1,4 GW		Unlimited Transfer		Max transfer 1,4 GW	
Jan	48	187	48	184	54	96	54	93	48	266	45	260	59	386	56	280
Feb	101	100	101	99	222	154	207	139	56	135	56	127	126	222	107	154
Mar	65	73	65	73	151	121	142	117	167	150	139	134	376	246	204	153
Apr	159	83	137	83	323	63	292	61	245	198	205	183	507	365	300	214
May	75	104	75	103	157	42	136	40	30	58	30	56	155	83	107	72
Jun	59	8	59	8	218	73	204	73	190	23	166	23	374	46	209	38
Jul	68	19	64	19	109	54	105	54	104	20	96	18	326	26	140	19
Aug	117	72	115	72	83	48	83	48	127	71	117	71	329	116	197	96
Sep	13	147	13	145	40	111	40	111	244	92	234	92	501	208	330	166
Oct	167	80	154	80	93	176	92	172	136	59	132	58	264	82	213	71
Nov	157	86	139	86	95	357	95	323	24	337	24	309	87	815	58	394
Dec	52	72	51	72	65	171	64	163	265	284	220	278	615	645	317	348
Average	90	86	85	85	133	122	125	116	136	141	122	134	310	269	187	167
Sum DK +UK		176		170		255		241		277		256		580		353
Wind MW average	DK	UK			DK	UK			DK	UK			DK	UK		
	1454	2412			1687	3689			1592	4498			6789	4498		

Table 33 above shows the resulting transfers given as average MW per month in the years 2016-2018 + for the estimated increase of the Danish off shore Wind Power by a constant 1,25 for the cutting point relative to the average wind power. It is observed, that there has been a remarkable increase in the British wind power production from 2016-2018. Nearly a doubling, whereas the Danish wind power has gone up and down. The increase in transferred wind power is small compared to the increase in the British wind Power, not to speak of the estimated Danish future wind power. An increase from 1454 MW in 2016 to 6789 MW in the future might according to the calculation model give an increase in the Danish export to the UK from an average of 90 MW in 2016 to a future average of 187 MW.

Tabel 37

Exchange, MW average, per month 2016, 2017, 2018 and for future Danish Wind																
Constant	DK to UK	UK to DK	DK to UK	UK to DK	DK to UK	UK to DK	DK to UK	UK to DK	DK to UK	UK to DK	DK to UK	UK to DK	DK to UK	UK to DK	DK to UK	UK to DK
	2016				2017				2018				Future Wind DK			
1,50	Unlimited Transfer		Max transf 1,4 GW		Unlimited Transfer		Max transf 1,4 GW		Unlimited Transfer		Max transf 1,4 GW		Unlimited Transfer		Max transf 1,4 GW	
Jan	66	148	66	145	46	61	45	55	70	160	67	157	135	229	106	162
Feb	89	87	89	85	194	151	181	139	66	110	63	104	147	158	115	126
Mar	45	53	45	52	114	86	112	81	121	120	109	107	402	148	201	119
Apr	156	67	137	67	301	52	277	52	232	177	208	152	608	225	307	170
May	31	42	31	42	105	18	96	18	11	19	11	19	46	28	36	27
Jun	31	0	31	0	193	33	189	33	151	19	138	19	319	28	172	25
Jul	49	2	48	2	52	4	51	4	70	9	69	9	182	9	84	9
Aug	111	20	110	20	37	6	37	6	96	37	86	37	220	55	151	50
Sep	10	111	10	108	23	68	23	63	220	85	214	85	593	134	359	115
Oct	140	82	136	82	71	185	71	174	151	56	142	56	328	86	238	76
Nov	142	72	132	72	83	316	83	269	19	381	19	323	74	640	58	376
Dec	54	67	51	67	42	190	40	175	219	315	202	293	533	619	286	359
Average	77	62	74	62	104	97	100	89	119	124	110	113	299	196	176	134
Sum DK +UK		139		135		201		188		242		223		495		310
Wind average	DK	UK			DK	UK			DK	UK			DK	UK		
MW	1454	2412			1687	3689			1592	4498			6789	4498		

According to the calculations for table 34 the cutting point for im- and export of wind power is 1,5 times the average against 1,25 times the average wind power for table 33. Taha does'nt make a great difference. By the estimated future Danish Wind power of 6789 MW the constant 1,25 would give a Danish an export of on average 187 MW against 176 MW by a constant 1,5.

By varying the constant for Denmark and for England we can create a table showing to total exchange between the 2 countries.

We have chosen the case with British wind Power 2018 and an estimated future Danish Wind Power of on average 6789 MW.

Tabel 38

Calculated load, MW, of he Viking Link by different constants								
		Constant Denmark						
	358	*0,6*	*0,8*	*1*	*1,2*	*1,4*	*1,6*	*1,8*
Con- stant UK	*0,6*	312	345	385	429	482	537	599
	0,8	342	351	365	390	423	462	511
	1	381	365	358	363	377	400	430
	1,2	438	397	370	356	353	354	362
	1,4	498	438	393	361	337	312	299
	1,6	555	480	418	366	320	274	240
	1,8	618	529	450	381	315	252	199

It has surprised the author that even wide variations in the chosen constants doesn't result in a good utilization of the Viking Link.

Figure 85

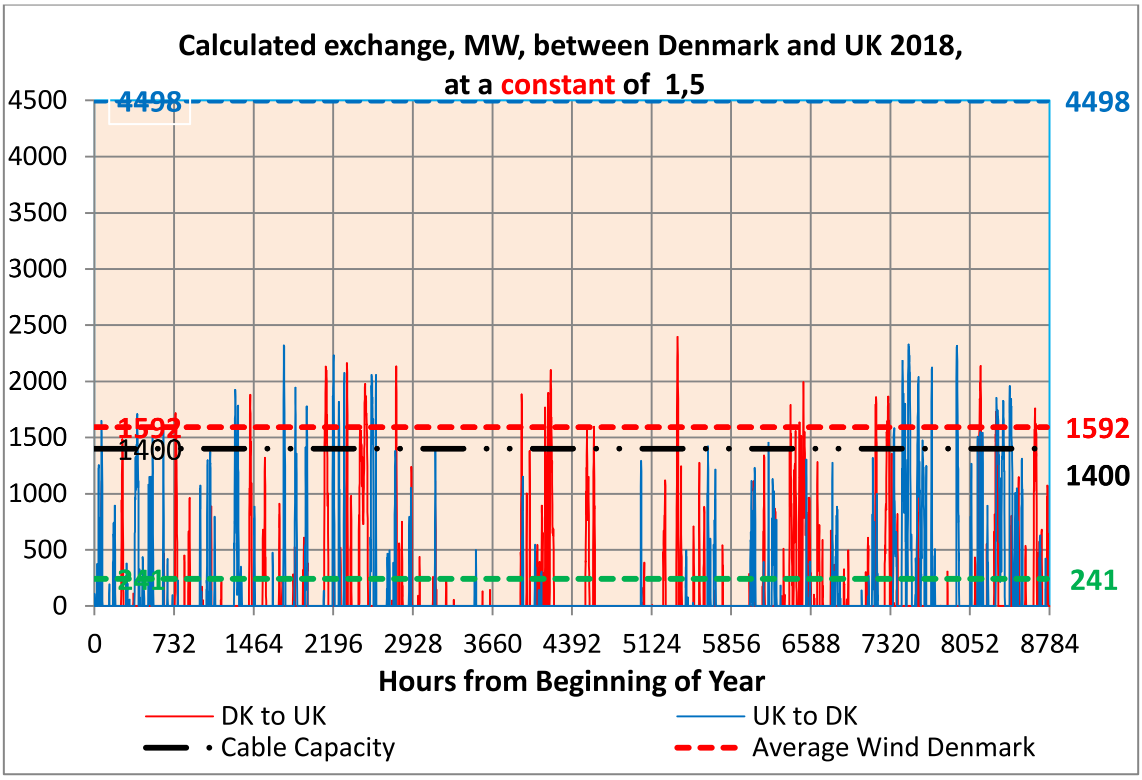


Figure 82 above illustrate that there isn't much to loose by limiting the capacity of the Viking Link to 1400 MW.

Discussion

It may well be discussed if presumptions for the calculations – that import/export becomes interesting if the wind power is larger or smaller than a figure defined by the average wind power.

However the author is convinced that there must be a relationship between the exchange and the actual wind power. It would be absurd if Denmark built wind power to supply the British market and vice versa. So there must be a relationship between the actual wind power effect and the exchange. And it has been shown, that the criteria may vary considerable without making a great difference in the magnitude of the exchange.

The relationship could be different price levels. However in a free market there will always be a relationship between price and supply.

If on the other hand we are not in free market, no calculations of profitability can be made at all.

Die Energiewende [IX]

Summary

Germany has during the last 10 years expanded her wind and solar power dramatically, so that wind and solar power in 2018 accounted for 29,5 % of the electric load. However that is only partly true. As illustrated by figure 86 there is a strong correlation between export of electricity and production of wind and solar power. So you can claim that a third of the wind and solar power produced in Germany is exported. Often at very low prices, and mainly to Poland and Holland, which should not surprise anybody since Holland and Poland have a wind power share in their electricity supply of only 9,4% and 7,2% respectively. So the German customers pay, and the neighbours can laugh. And the Russians dream of a profitable gas export to Germany.

Tabel 39

Wind+Solar and Exchange, MW, Germany 2018

					Exchange		
	Load D	Wind_D	Solar_D	W+S	Germany	Poland/ Germany	Netherlands /Germany
Average	58062	12394	4716	17110	-5677	3528	1814
Max	78327	44628	28955	50217	7437	7907	8613
Min	35434	273	0	667	-17647	-848	-2767
Stddev	9893	9049	7153	10091	4068	2528	1875
Stddev % of average		73	152	59	72	72	103

On average Germany produced 17110 MW Wind+Solar power in 2018 corresponding to 29,5 % of the average electric load of 58062 MW. A third of this, 5677 MW, was exported. Mainly to Poland and The Netherlands.

Figure 86

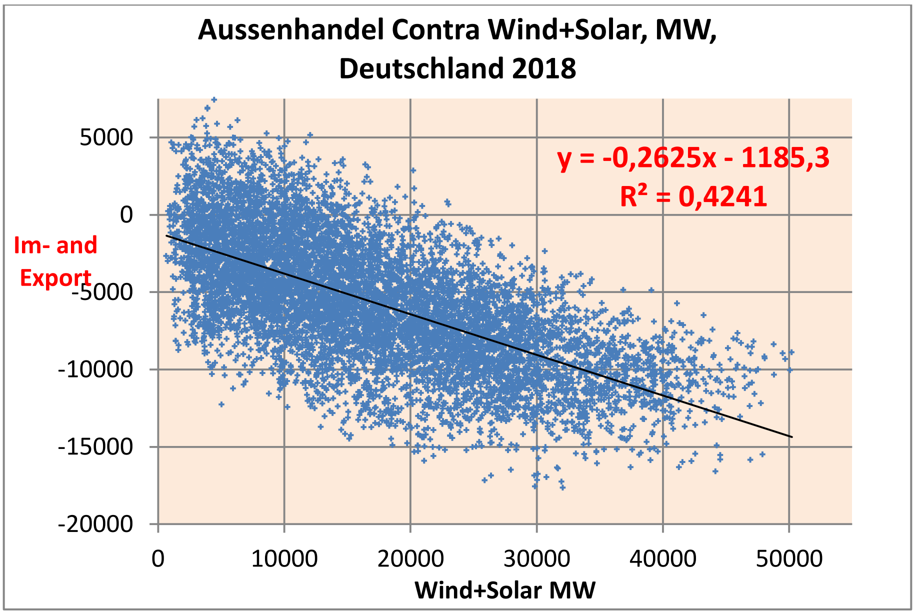


Fig 86 illustrates that Germany can't use more than about 2/3 of the generated wind and solar power.
Danish wishes that Germany should build stronger transmission lines so that we could export the wind power which can't be sold in Denmark, when it blows, thus are meaningless.

The maximal German wind + solar power in 2018 was 50217 MW. The regression equation in figure 86 allows us to calculate a table showing the expected import/export as a function of the wind + solar power.

Tabel 40

Wind + solar	Exchange	
MW	MW	% of W+S
0	-1158	
5000	-2471	49
10000	-3783	38
15000	-5096	34
20000	-6408	32
25000	-7721	31
30000	-9033	30
35000	-10346	30
40000	-11658	29
45000	-12971	29
50000	-14283	29
55000	-15596	28
Average		
17110	-5677	33

It is no wonder that Poland and The Netherlands are the main importers of cheap – often very cheap- German green energy since the wind power share of the electricity consumption was only 9,4 % in The Netherlands and 7,2% in Poland and since The Netherlands have very little nuclear power (Average 2018 was 253 MW) and Poland none.

It always blows and the sun shines somewhere [IX,X]

Summery Alas, that is not true. The author has compared the wind power in Belgium, Germany, Spain, France, UK and the Netherlands based on hourly registrations of the wind power in each of the six mentioned countries. As shown in table 41 hereunder the combined wind and solar power varied between 89360 MW and 5671 MW with an average of 36635 MW. We will later look at the demands to a storage system enabling an even supply of wind and solar energy.

Tabel 41

Wind and Solar Power, MW, in Belgium, Germany, France, Spain, UK and The Netherlands 2018

	Belgium	Germany	Spain	France	UK	Nether-lands	Sum
Average	1122	17108	6894	4169	5742	1598	36635
Max	4119	50217	19175	13418	16171	5449	89360
Min	7	667	442	525	75	27	5671
Stddev	791	10090	3435	2429	3177	1029	16526
Stddev % of average	70	59	50	58	55	64	45

Since the wind power capacity differs greatly from country to country it gives no meaning to compare directly, however you can normalize each of the hourly figures by dividing them with the average yearly output for each country, multiply by 1000 and thus obtain the dimensionless unit (W power/average kW power), and thus enable you to make meaningful comparisons. Further you may add the normalized hourly values for each of the six countries and divide by 6.

Tabel 42

Normalized Wind Power W/kW, 2018

	Belgium	Germany	Spain	France	UK	NL	Sum
Average	1000	1000	1000	1000	1000	1000	1000
Max	3662	3601	2876	3739	2668	3029	2818
Min	8	22	44	138	11	0	95
Stddev	863	730	592	730	647	789	563

Table 42 shows the normalized wind power for the 6 mentioned countries, The standard deviation becomes somewhat lower when the wind power is added for all six countries but is still considerable. 563 W/kW or 56% of the average. And the yield varied between 9,5 and 281 % of the average. So the demands for back-up will be huge no matter how powerful grids are built.

The graphs hereunder illustrate the findings for 2018.
It is evident that it does not always blow somewhere.

Figure 87

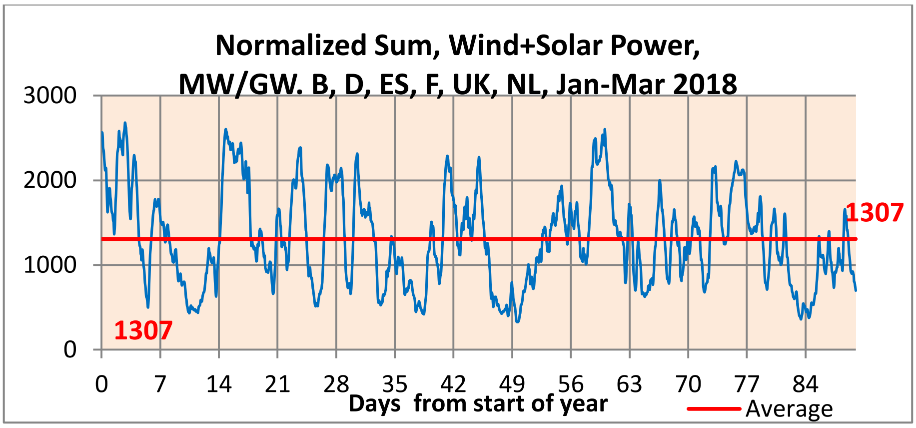


Figure 88

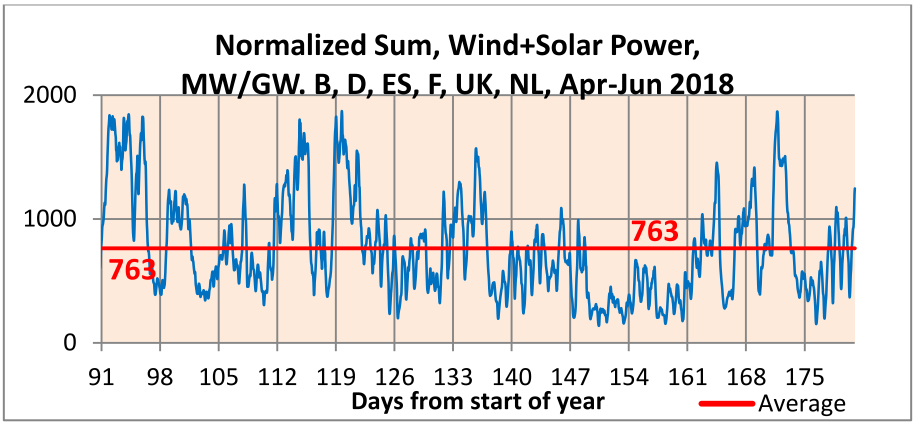


Figure 89

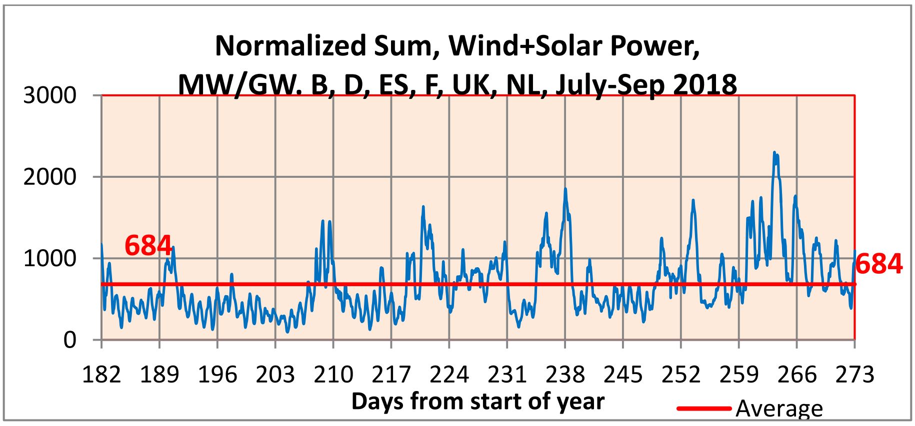
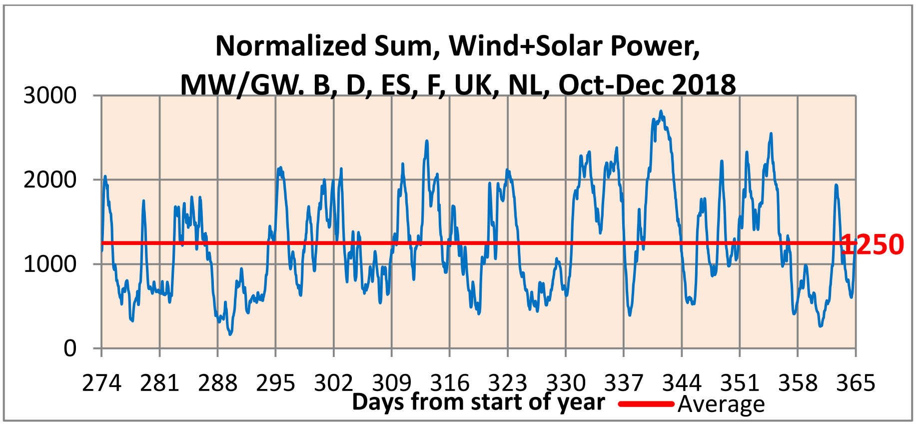


Figure 90



Wind + Solar Power % of load in Belgium, Germany, France, Spain, UK and the Netherlands

Summary

Table 43 below gives the data for the proportion of wind and solar power of the load in the six countries. This proportion varies between 45% and 3% with an average of 19%. If it is chosen to increase the proportion to for instance 50% i.e. a factor 2,5 you would still have periods where wind and solar give only 7-8% of the load and periods where the yield will be 112 % of the load.
The figures 91 to 94 below illustrate the variation of the supply relative to the load.

Tabel 43

Wind + Solar Power % of load in B,DE,F,ES,NL,UK 2018					
	Year	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
Average	19	19	19	17	19
Max	45	43	45	43	44
Min	3	4	4	4	3
Stddev	8	8	8	8	8
Stddev %	42	40	43	47	39

Figure 91

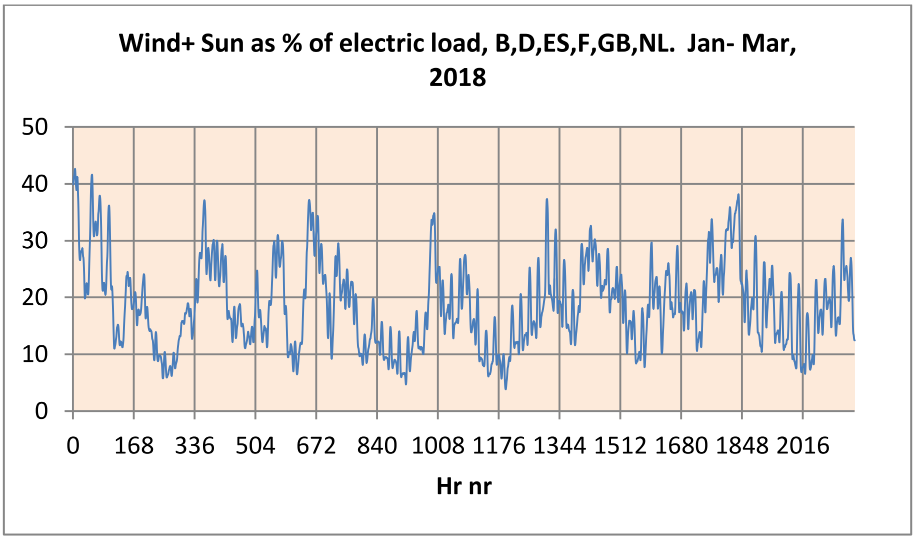


Figure 92

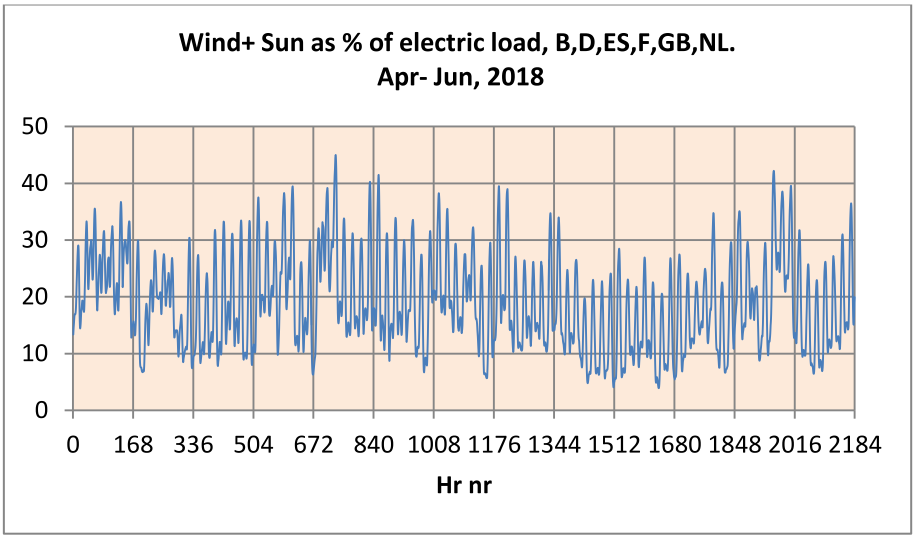


Figure 93

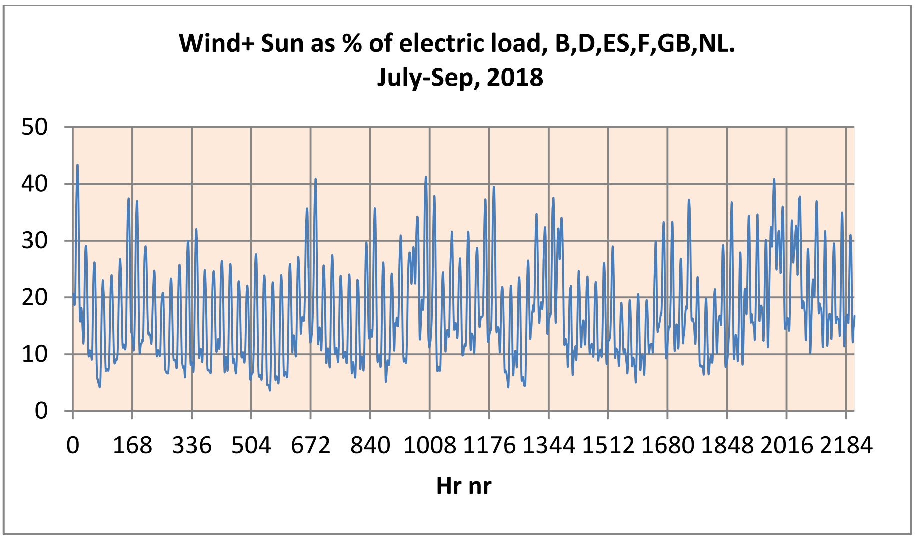
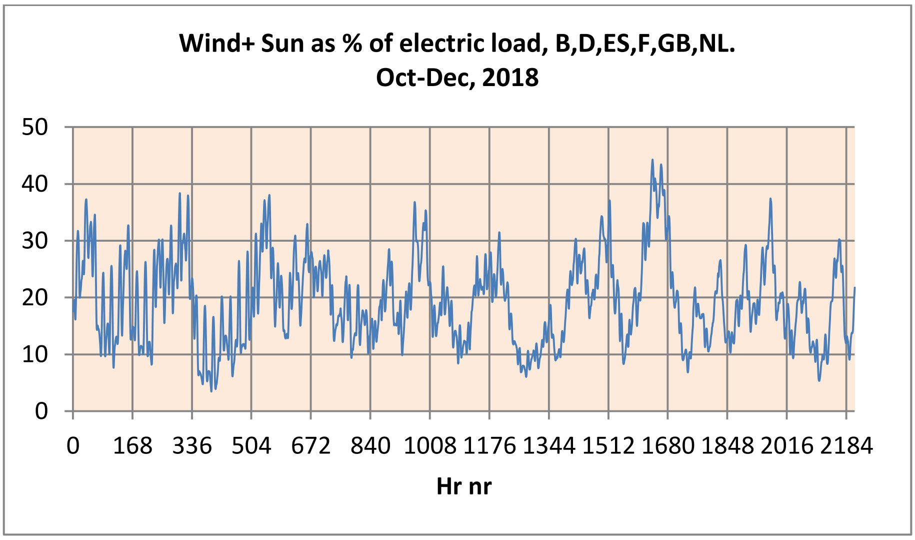


Figure 94



Some Data from Belgium, Germany, Spain, France, United Kingdom and The Netherlands [iX, x, x]

Summary

Table 44 hereunder gives data about energy consumption, the share of nuclear power and (wind+solar), effect consumption and carbondioxide emission per capita and per kWyear. (1 kWyear = 8760 kWh, since there is 8760 hours per normal year))

It is remarkable that Germany in spite of **Die Energiewende** and in spite of the highest proportion of wind and solar energy in the energy consumption has both the highest carbon dioxide emission per produced unit of energy (kWyear) and per capita. France has the highest share of nuclear power in her energy supply, 14,5 % and by far the lowest carbon dioxide emission both per capita and per consumed kWyear.

Angela Merkels "Energiewende seems to be a complete failure!

Carbon Dioxide and population [xi]

Tabel 44

Wind+Solar Effect 2018 Compared with the Total Energy Consumption										
			B	DE	ES	F	UK	NL	Sum	DK
Wind + Solar	Average	MW	1.122	17.110	6.894	4.169	5.743	1.598	36.635	*1.860*
	Max		4.119	50.217	19.175	13.418	16.171	5.449	89.360	*4.814*
	Min		7	667	442	525	75	27	5.671	*38*
	Stddev		791	10.091	3.435	2.429	3.177	1.029	16.526	*1.412*
	Stddev	% of aver.	70	59	50	58	55	64	45	*76*
Nuclear	Average	MW	3.107	8.199	6.082	44.729	6.923	253	69.294	*0*
	Max		4.982	9.500	7.117	58.432	8.322	551	86.806	*0*
	Min		234	4.591	4.045	28.920	4.912	0	50.650	*0*
	Stddev		1.273	1.029	847	6.375	657	268	7.913	*0*
	Stddev	% of aver.	41	13	14	14	9	106	11	*0*
Average electric load		MW	9.924	58.062	29.063	53.803	31.440	13.267	195.558	*3.900*
Total Effect Consumptio		GW	80,8	434,5	180,0	308,6	248,1	111,7	1364	*22*
Electric Load/Total Effect		%	12,3	13,4	16,1	17,4	12,7	11,9	14,3	*17,7*
Carbn dioxide Emissions		mio t	100	799	281	356	385	164	2085	*35*
Wind+Solar/Total Energy		%	1,39	3,94	3,83	1,35	2,31	1,43	2,69	*8,45*
Nuclear/Total Energy		%	3,85	1,89	3,38	14,50	2,79	0,23	5,08	*0,00*
Inhabitants		Thousands	11.299	80.689	46.122	64.395	64.716	16.925	284.146	*5.733*
Electric load/Capita		W	878	720	630	836	486	784	688	*680*
Total Effect/Inhabitant		kW	7,15	5,39	3,90	4,79	3,83	6,60	4,80	*3,84*
Carbon dioxid/capita		t	8,85	9,90	6,09	5,53	5,95	9,69	7,34	*6,11*
Carbon dioxide /kWyear		t/kW year	1,24	1,84	1,56	1,15	1,55	1,47	1,53	*1,59*

Comments to table 44.

Average electric load The electricity consumptions for each of the 7 countries are shown as **average MW**.

Total Effect Consumption. The BP yearly statistics gives the energy consumption for each of the countries in Mtoe per year. **The author has transferred the data to GW.**

So it is easy to calculate electricity, wind+solar power and nuclear power as per cent of the total energy consumption.

Belgium's effect consumption per capita is by far the highest 7,15 kW and UK has the lowest 3,83 kW. This must reflect the types of industry found in the different countries.

It is seen too that France with 14,5 % nuclear power in the total energy supply has by far the lowest carbon dioxide emission per capita, 5,53 t/capita/year against Germany's 1,89 % and 9,9 t/capita/year.

That is of course no wonder considering that Germany must export about a third of her wind and solar power, and has to use brown coal to generate electricity, when the sun doesn't shine and the wind doesn't blow.

The Danish figure is lower 1,59 t carbon dioxide per kWyear. At first we import a lot of our electricity, and where Germany generates electricity with brown coal Denmark uses imported wood, which is considered not to give any carbon dioxide emission. It is not the authors intention to discuss the "sustainability" of this arrangement, but anyway it can be mentioned, that it is hardly possible for Germany to do the same. The supply of wood is limited, and it would be quite a task to transport wood pellets from the sea ports in Holland and Belgium to Duisburg, Frankfurt and Ludwigshafen.

figure 95

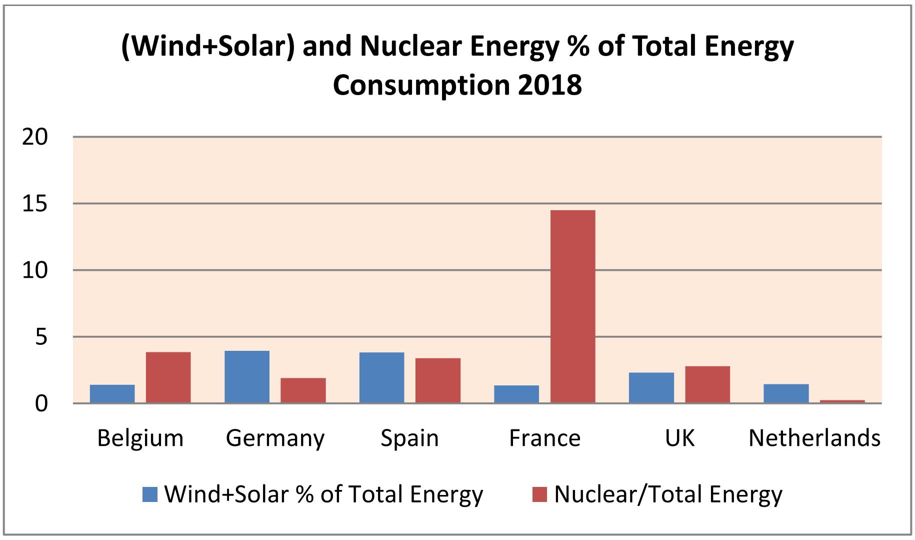


figure 96

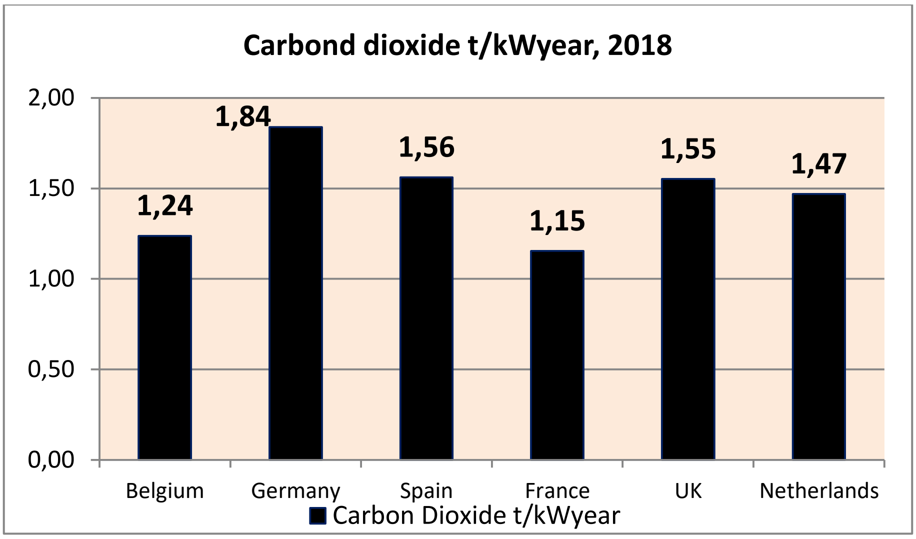


Figure 87 and 88 illustrate that Germany and Spain have the highest proportion of of wind and solar energy in their energy supply. And the highest emission of carbon dioxide per produced kWyear ***(One kWyear equals 8760 kWh)***

Storing of Green Energy

Summary

It is evident that the most severe limitation for usage of wind and solar power is their instability and that this limits their usefulness until a storage method has been found. A precondition for The Danish engagement in Wind energy has been the access to the Scandinavian hydro power and the storage capacity of Swedish and Norwegian magazines, about 120 TWh. For comparison the Danish electricity consumption is about 35 TWh/year.

With the expansion of wind- and solar power throughout Europa follows the question: "Is the storage capacity large enough?" And not only for the storage capacity but also for the capacity to receive an effect of many GW and to deliver them again when needed.

The maximal output delivered by Swedish and Norwegian hydropower stations in 2018 was 39546 MW. A very considerable part of these 39 GW was used in Norway and Sweden. The maximal export from Norway + Sweden in 2018 was 10277 MW and the maximal import was 7053 MW. So the author supposes that about 15 GW transfer to and from Scandinavia will be an absolute maximum.

So let us look at the storage demand for Germany+ Spain + France + Belgium + United Kingdom in 2018, calculated under the presumption that Wind and Solar power should deliver an even effect, realizing of course that the reality will differ from that. Anyway the author thinks that this calculation at least will be a god indication of the magnitude of the task to make wind and solar energy useful on a large scale.

According to the calculations the 6 countries in question would need a storage capacity of 18 TWh, or about 15% of the Scandinavian hydro power magazine. This is may be not so frightening before you remember that this is more than 3600 times the capacity of Europe's largest pumping storage Vianden in Luxembourg. And the maximum input to the reservoir would be 54 GW, 8 times the maximum power import for Norway + Sweden in 2018. And the maximum delivery would be 30 GW, the double of the maximal power export from Norway and Sweden.

You might modify the demands, but anyway they would be very much larger if for instance wind + solar should deliver 10% of the energy supply instead of the present 2,3%

Tabel 45

Calculation of the necessary storage capacity for an even supply of wind+ solar power							
Wind+Solar Germany, Spain, France, Belgium, United Kingdom, Netherlands 2018		To Reservoir	To reservoir after losses	From Reservoir	Regene-rated Power	Resulting Power	Reservoir content GWh
Column	I	II	III	IV	V	VI	VII
	MW	MW	MW	MW	MW	MW	GWh
Average	36635	7621	6859	6859	6173	35187	9065
Max	89360	54173	48756	32795	29516	35187	18241
Min	5671	0	0	0	0	35187	0
Stddev	16526	10794	9714	8784	7905	0	5540

Column I in table 39 gives the data for the wind and solar power in the described countries in 2018 based on an observation every hour. Column II indicates the electricity transferred to the storage and column III the input to the storage after losses. Column IV shows the amount taken from the storage, which equals the amount put into the storage, and column V the regenerated power after losses. Column VI shows the resulting power from wind, solar and storage, which is being kept constant , and column VII the movements in the reservoir.

Tabel 46

Loss by storing		***100***
Loss by reproduction	**Wh/kWh**	***100***
Total loss by Storing		190
Storage Efficiency		810
	MW	1448
Loss	%	4,0
	GWh/year	12684
Loss by a price of 700 DKK/MWh	Mio DKK/year	8879
Storage capacity	Future reservoir	Vianden in Luxem-bourg
GWh	**18241**	**5**
hrs of average production	**498**	
Max input MW	**54173**	1040
Max Output MW	**29516**	1290
Condition 1: To reservoir - From reservoir =		**0**
Condition 2: Minimum storage content =		**0**
Calculated constant		**0,9605**
Storage Start of Period	**GWh**	**6582**

Table 46 above shows at first the loss per kWh by storing, calculated to be totally 19% as in Vianden.

Thereafter follows the calculated loss according to the calculations, and the magnitude of the demanded storage, 18,241 TWh corresponding to 182 million Tesla Batteries a 100 kWh! And corresponding to 498 hours of average production. The storage should be 3600 times larger than the storage in Vianden.

The maximum input to the storage is calculated to 54 GW corresponding to about the average electricity production in Germany and the regeneration to 29 GW. You might say that it does not pay to store the peaks, but it will more difficult to reduce the necessary output.

If imaginative ideas like storing the wind power by heating stones and thereafter raising steam to power a gas turbine the losses and the necessary storage would be much higher.

Figure 97 shows the calculated reservoir content in GWh during the year.

figure 97

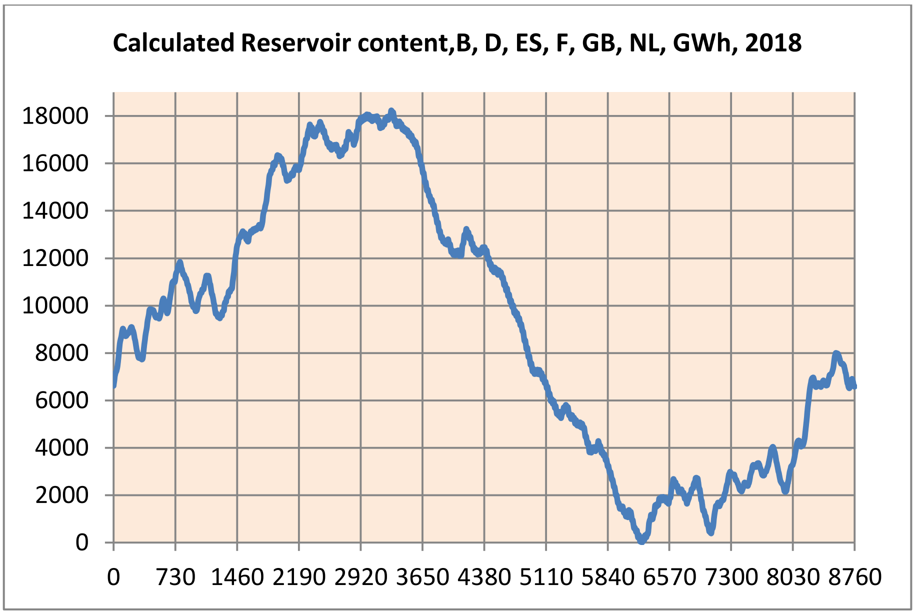


Figure 98 shows the input to the reservoir in January. It might be reasonable to cut the peaks and lose the corresponding amount of electricity.

Figure 98

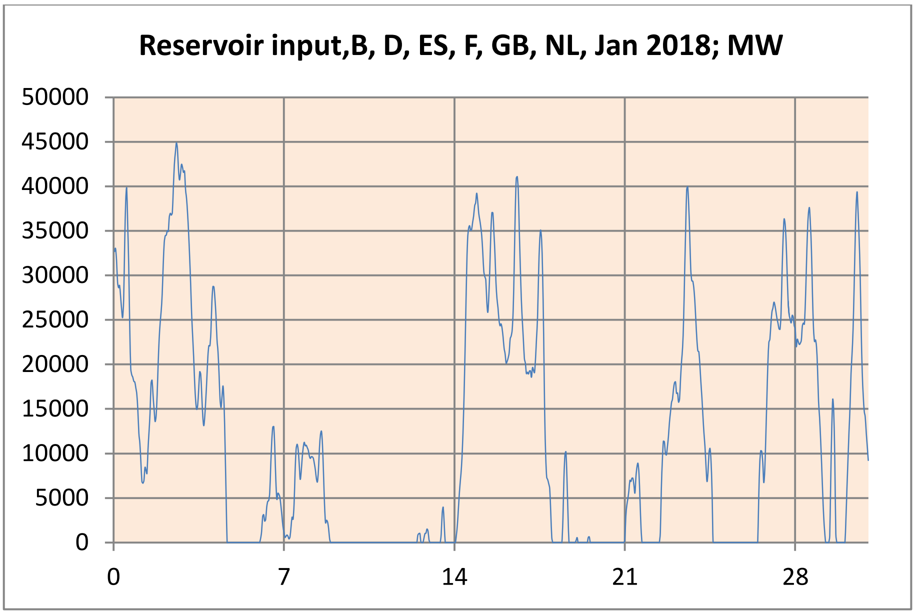
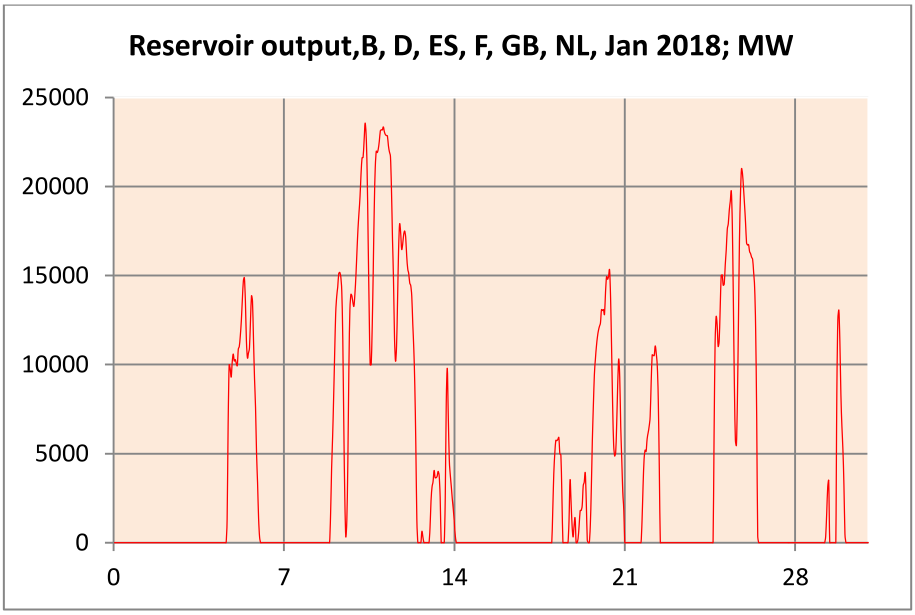


Figure 99 shows the calculated delivery from the reservoir in January. Here too It might be reasonable to cut the peaks and and get the electricy from other kinds of back-up. But then you don't get a "fossil free society".

Figure 99



Wind and Nuclear Power xii

Summarry. Most politicians, journalists and a large majority among common people seem to believe that nuclear power is prohibitively expensive.
We don't know the exact cost for maintenance of off shore wind power but this is surely not lower than 0,7 cent/kWh and probably much higher. We don't know either what it will cost to decommission the turbines after 20-30 years of service.
So we assume that the operation costs for off shore wind power impossibly can be lower than the operation costs for nuclear power.
Vattenfall informs that the cost for the latest Danish off shore wind power park, Horns Rev 3 commissioned by the end of 2018, was 9 billion DKK and that the production is expected to be on average 194 MW. This results in an investment of **46 million DKK/MW**.
Ingeniøren informed us on April 15, 2019 that the still not commissioned Finnish Reactor Oulkiluoto 3 will cost 41 billion DKK and on average deliver 1484 MW. I.e. **27 mio DKK/MW**. Other informants say the cost will be not less than **37 mio DKK/MW.**
The author has tried to find information for the four 1400 MW reactor being built by The United Arab Emirates and find a specific investment of **37 mio DKK/MW.**

The four more than 30 years old Finnish nuclear reactors yielded on average 2499 MW in 2018, and the standard deviation was 15% of the average.
The Finnish wind turbines yielded on average 615 MW with a standard deviation of 74% of the average.

So nuclear power even from a new and still unpaid reactor is inevitably much cheaper than off shore wind power, and it is reliable.

According to table 49 below the unpredictable variations in wind power are very large and not at all comparable with the stability of nuclear power.

We see a lot of fanciful – and absolutely unrealistic – ideas about how to solve the problems arising from the unpredictable variations for the wind power.

The author is an experienced chemical engineer and dares to conclude that all these ideas will cost a lot of money and they can't be realised.

The figures shown with red script are given in the above mentioned home pages. The rest of the figures are calculated by the author based on these figures. The Swedish figures are given by to digits only, so you might wish a higher accuracy but the resulting figures for the costs minus capital costs can´t be completely wrong.

Tabel 47

Exchange rates 13.05.2019	
SEK/DKK	0,6893
DKK/US$	6,66
DKK/€	7,4668

Cost comparison, Wind and Nuclear [XII, XIII, XIV, XV]

On April 15, 2019 the periodical "Ingeniøren" informed that the cost for Olkiluoto would cost 41 billion DKK. Others say that 55 billion DKK is closer to the truth and we were informed too that the production would be on average 1484 MW. Vattenfall informs us that the latest Danish off shore wind park has cost 9 billion DKK and will yield on average 194 MW

Tabel 48

Comparing generation costs for Oulkiluoto 3 and Barakah Nuclear Power Plant with Hornsrev 3

		Oulkiluoto		Horns Rev 3	UAE
Investment	Billion DKK	41	55	9	199,8
	Billion US$				30
Depreciation Period	Year	30	30	30	30
Interest rate	% pa.	3,0%	3,0%	3,0%	3,0%
Capital Cost/year	Mio DKK	2.092	2.806	459	10.194
Specific investment	DKK/W	27,63	37,06	46,38	37,14
Nominal Capacity	MW	1600	1600	406,7	5600
Efficiency		0,928	0,928	0,477	0,961
Average yield	MW	1.484	1.484	194	5.380
Hours/year	Number	8.760	8.760	8.760	8.760
Production	GWh/year	**13.000**	**13.000**	**1.700**	**47.129**
Capital Cost	DKK/MWh	**162**	**218**	**270**	**216**
Operation Forsmark 2018		89	89		89
Maintenance Horns Rev 3 minimum				50	
Sum		**251**	**306**	**320**	**305**
Operation Ringhals 2018	DKK/MWh	130	130		
Sum		**292**	**348**		

The only figures which can be considered to be really reliable are the operation costs for Forsmak and Ringhas, 89 and 130 DKK/MWh. The maintenance cost 50 DKK/MWh for Horns Rev is probably much too low, but we have not been able to find a better figure.

But the author is convinced in the conclusion: **"It is not true, that nuclear power costs more than off shore wind Power"**

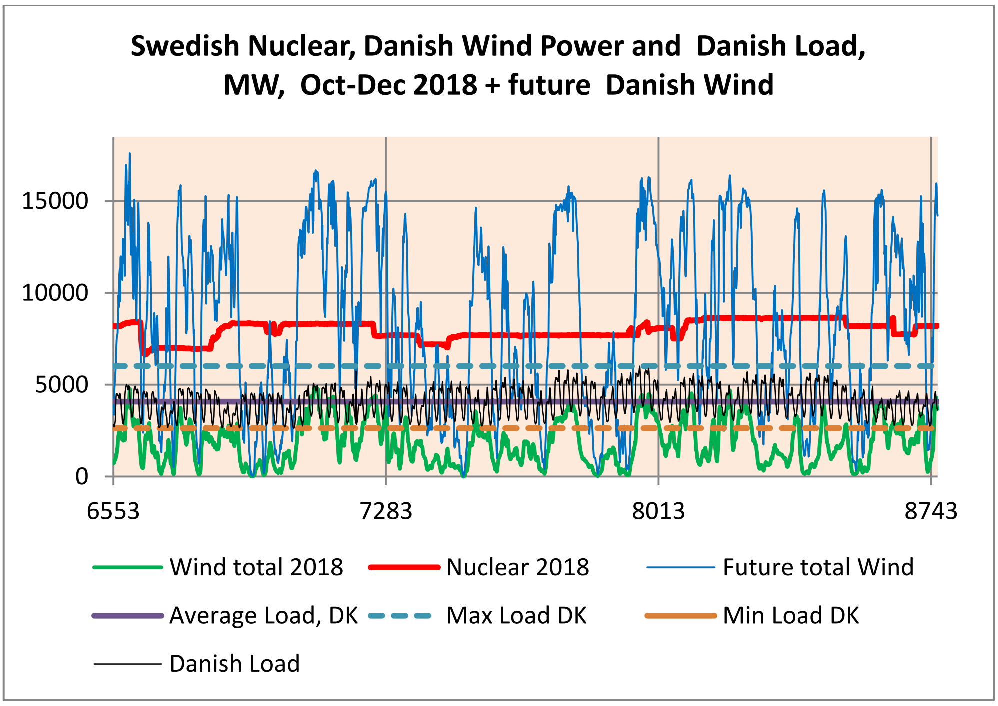
Danish Plans and Swedish nuclear power [IX]

Summary

Figure 100 below illustrates Swedish nuclear power, Danish wind power, and Danish future windpower if the plans to build 12 GW new off shore capacity are realized. It should be no problem for the watchful reader to see that it will be a tremendous task to get the black curve – the present Danish load – to fit together with the future wind power – the blue curve.

The author finds it completely impossible to understand that the wind power lobby has been able to sell the idea of building a huge off shore wind capacity without having presented any sensible idea of how to use this wind power.

Figure 100



In figure 100 above the red curve illustrates the Swedish production of nuclear power hour for hour in the period October-December 2018, and the green curve shows the Danish wind power in this period.

The blue curve shows the hypothetical Danish wind power if the actual plans to build another 12000 MW of shore wind power capacity are realized.

The dotted blue and brown lines show maximum and minimum Danish load in the period. It will not be an easy task to fit the future wind in between these two lines.

Tabel 49

	Sweden	Denmark				
	Nuclear	Wind off Shore	Wind total	Future off Shore	Future total Wind	Load
2018, MW						
Average	7510	529	1586	5732	7318	3900
Max	8677	1239	4850	13434	18164	6076
Min	3394	0	1	0	6	2294
Stddev	1116	360	1231	3908	5083	782
Stddev% of Av	15	68	78	68	69	20

Table 44 above shows the nuclear power in Sweden in 2018, and the Danish of shore, total wind and load in 2018 plus the estimated future wind power if the off shore wind capacity is increased by 12 GW. **It is evident, that if the investment should make sense a market for the wind power must be found. So far we have heard nothing about those future customers. It should be observed too that the nuclear power has a standard deviation of 16% of the average whereas the wind has a standard deviation of 70-80% of the average.**

Everybody who has ever been responsible for any kind of production will without difficulty understand that the uncontrollable variation is a huge problem.

Figure 101-104 below show the estimated future wind power in Denmark, the nuclear power in Sweden, the Danish electricity load and the wind power in 2018 in the months January, April, July and October

Figure 101

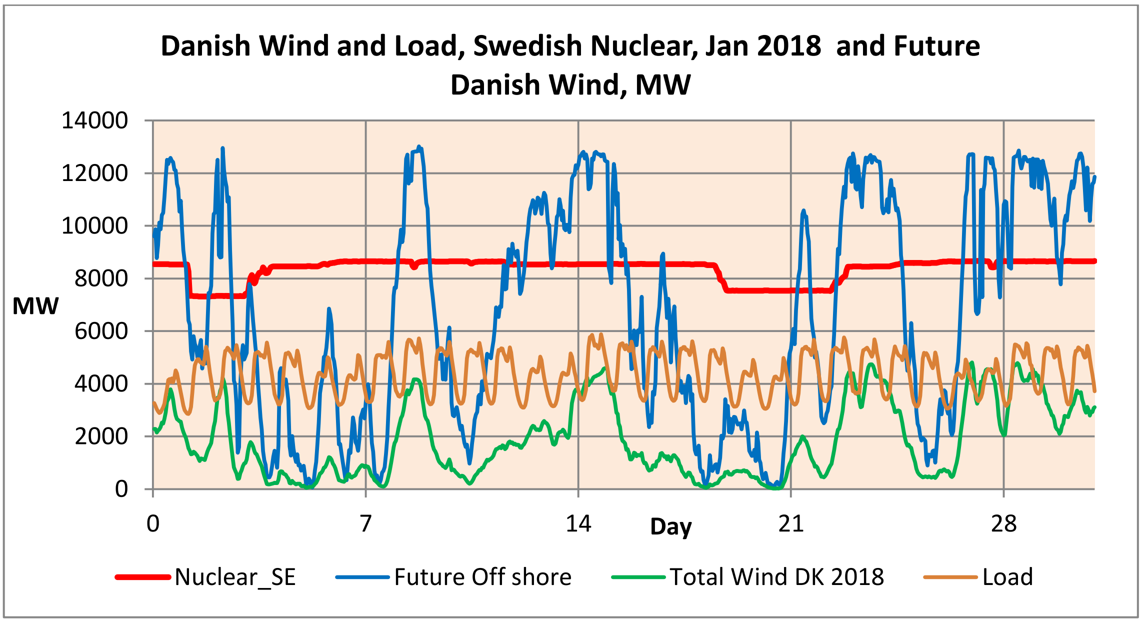


Figure 102

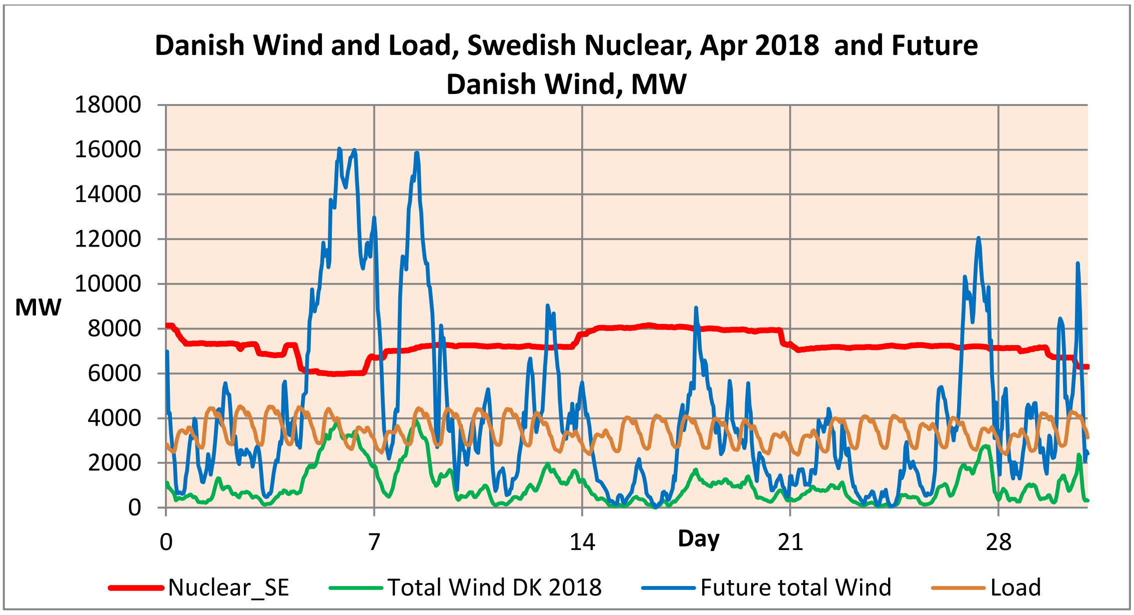


Figure 103

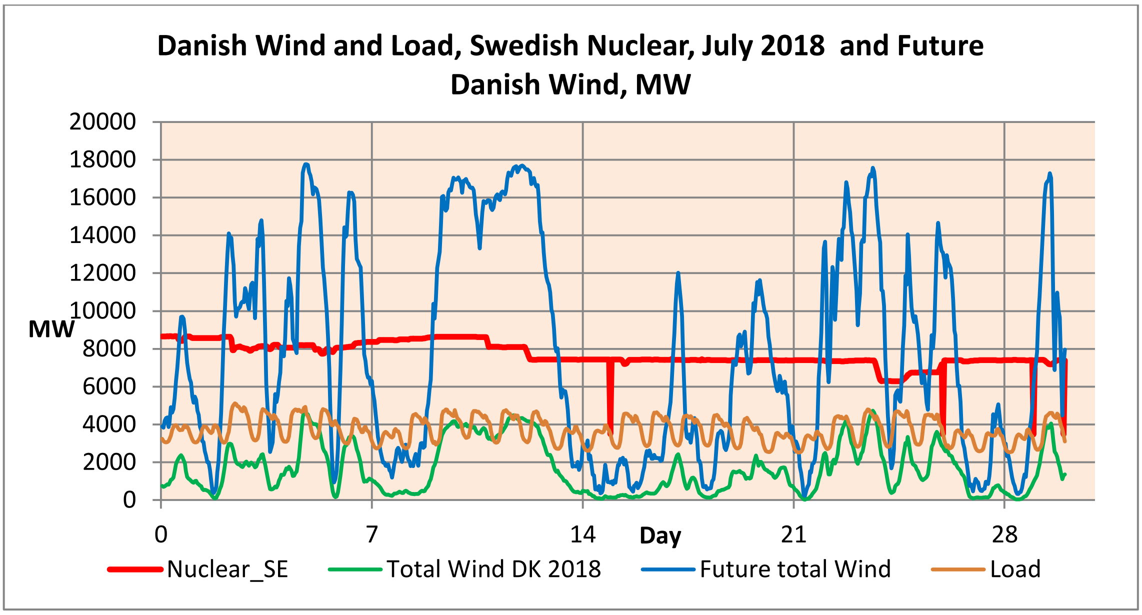
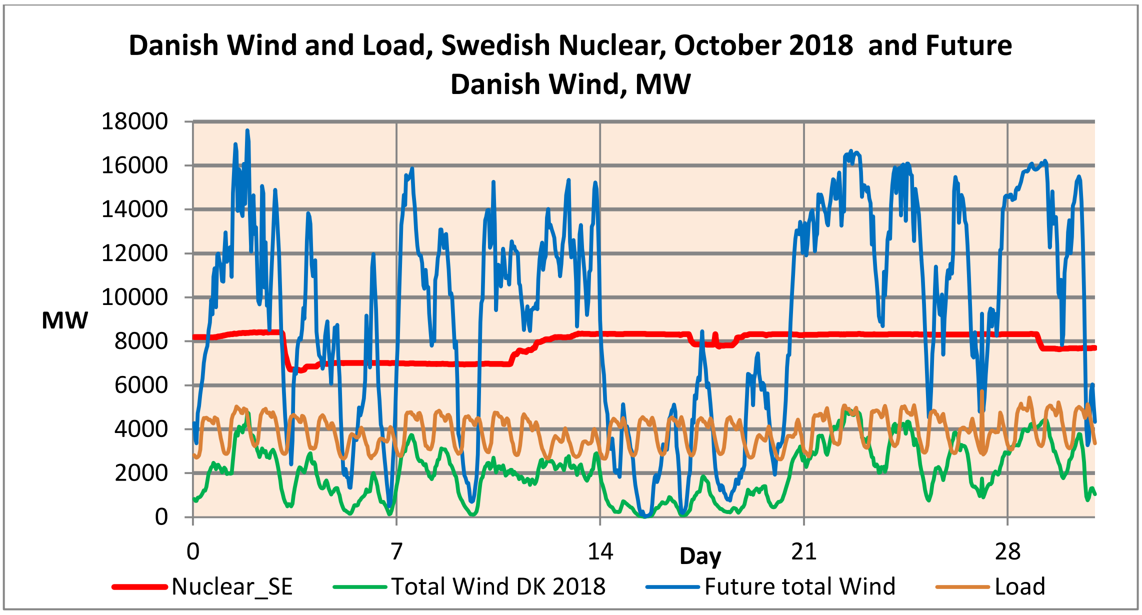


Figure 104



It will be a tremendous task to get the blue curves – future wind power – to fit together with the brown curves – the electric load.

Until now we have not heard anything serious about how that could be done.

We have shown above that the difference in costs for producing wind power only differs slightly from the cost for nuclear power.

But to fit the brown and the blue curves together will without any possible doubt be absolutely ruining – apart from the fact that no realistic process for storing huge amounts of electric energy are in sight.

So it is time to congratulate the wind power industry for it's efficient salesmanship.

Søren Kjærsgård
July 22, 2019

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