AN OUTLINE HISTORY OF DANISH WIND TURBINE PRODUCTION: Output and Longevity from 1977 to 2014.

Introduction

The Danish Energy Agency (http://www.ens.dk/en/info/facts-figures/energy-statistics-indicators-energy-efficiency/overview-energy-sector/register) has been legally bound responsible for keeping a register since 1977to maintain an extensive register of all commissioned and decommissioned Danish wind turbines (WT),, with a considerable amount of information about every one of them. The register is known as the "Master data register for wind turbines". Collects all its data on an Excel Spreadsheet, which is publicly available via the above link. It is updated monthly and by August 2014 included a total of around 7 900 WT's, of which over 5 300 non decommissioned (*i.e.* grid connected) turbines. Of these well 500 are off shore. There are in all ca. 2 600 decommissioned WT's in the register, all of them on shore. Of the decommissioned WT's 23 were ≥ 2 MW, while 925 are commissioned. About 7 000 in all were < 2 MW, of these 4350 were commissioned and 2 660 decommissioned. In this Report you will find figures about the (nominal) capacity growth in Denmark to date and especially data on their operation

Other data for every turbine includes *inter alia.* the turbine identifier (GSRN), date of grid connection and decommission, capacity in kW, rotor diameter (m), hub height (m), manufacturer, type, local authority, type of location (on/off shore), cadastral district and number, X and Y coordinates from UTM 32 Euref89 and National Survey and Cadastre, distribution company and type of grid connection. There are also production data (per quarter or month), with historical, annual data in kWh.
In the following report the numbers are retrieved from the register Anlaegprodtilnettet

The Initiation of the Danish Wind Energy Programme.

The Danes began their Wind Energy Programme in 1977 with 20 kilowatt to 400-kilowatt capacity Wind Turbines. The first WT for which data are available was Wind Turbine which had **GRSN 570715000000032516** as its Turbine identifier or (GSRN). It was commissioned on Dec 15, 1977 and decommissioned on Nov 30, 2002. It had a capacity of 22 kilowatts, was built by an unknown manufacturer and located in the Local Authority area of Varde. According to the data ,below, it had a stabile output profile until the final 2 years before being decommissioning.

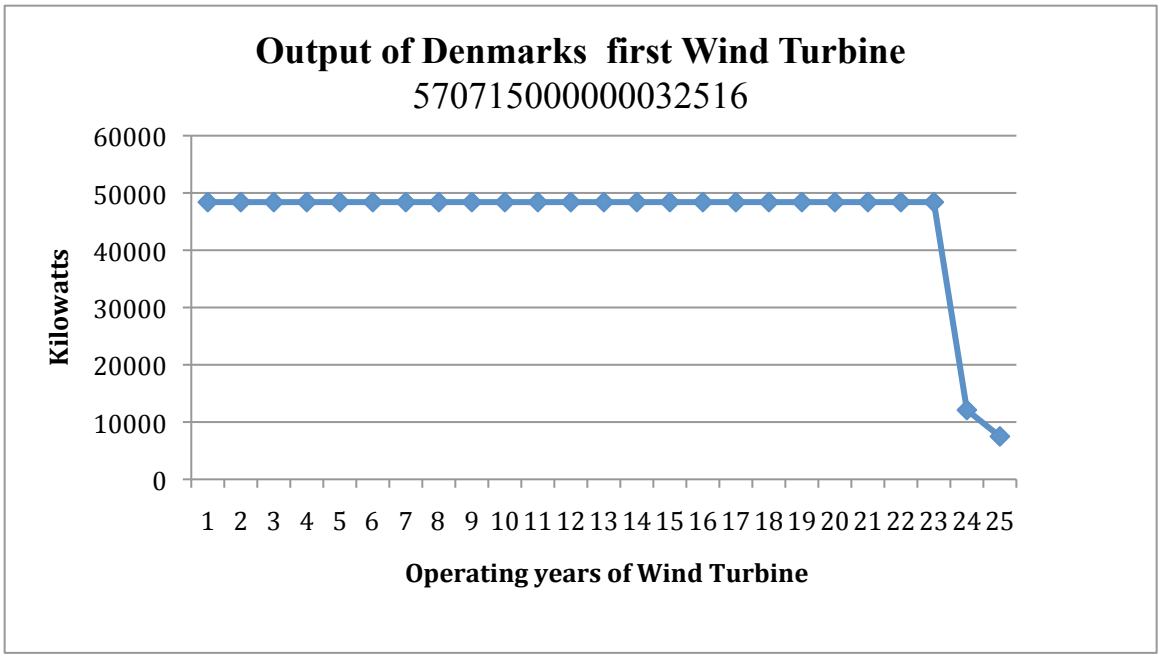


Fig 1, GRSN 570715000000032516; It was commissioned on Dec 15, 1977 and decommissioned on Nov 30, 2002. It had a capacity of 22 kilowatts and an unknown manufacturer

Initial Capacity Trends.

From 1977 until October 6th 1981 all WT's commissioned had a capacity of less than 100 kilowatts. Wind Turbine **GSRN 570715000000027543,** was produced by an "Ukende " an unknown manufacturer. It had an output capacity of 225 kilowatts per hour. There is no output listed for this Wind Turbine, even though it was decommissioned on April 15, 2000.

On January 1st, 1982 Vestas installed wind Turbine **GSRN 570715000000048494.** It had an output capacity of 400 kilowatts. It was decommissioned on May 7th, 2008.

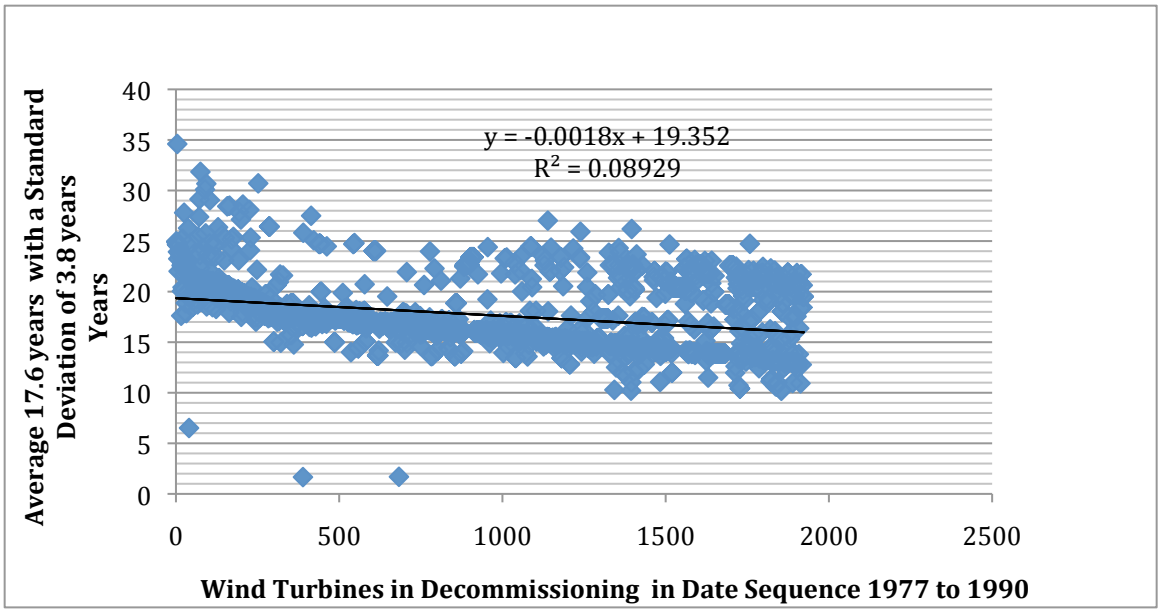


Fig 2, The operating life trend line for Wind Turbines Commissioned between 1977 and 1990. The data scatter is significant as is the down ward trend in operating life

The First 650-Kilowatt Wind Turbine

On January 1st 1989 a 650-kilowatt wind turbine **GSRN 570715000000010972** was commissioned to the grid again by an unknown manufacturer and no data are recorded. It was decommissioned on June 1st, 1999.
Until then and subsequently until, July 1st, 1990 all WT'S were lower than when the

manufacturer DVT introduced a range of 400 kilowatt WT's starting with wind turbine number **GSRN 570714700000001376** in Lolland with a total of 24 WT's in all of which were listed with the same output over their productive lives. They were decommissioned on July 25th, 2012

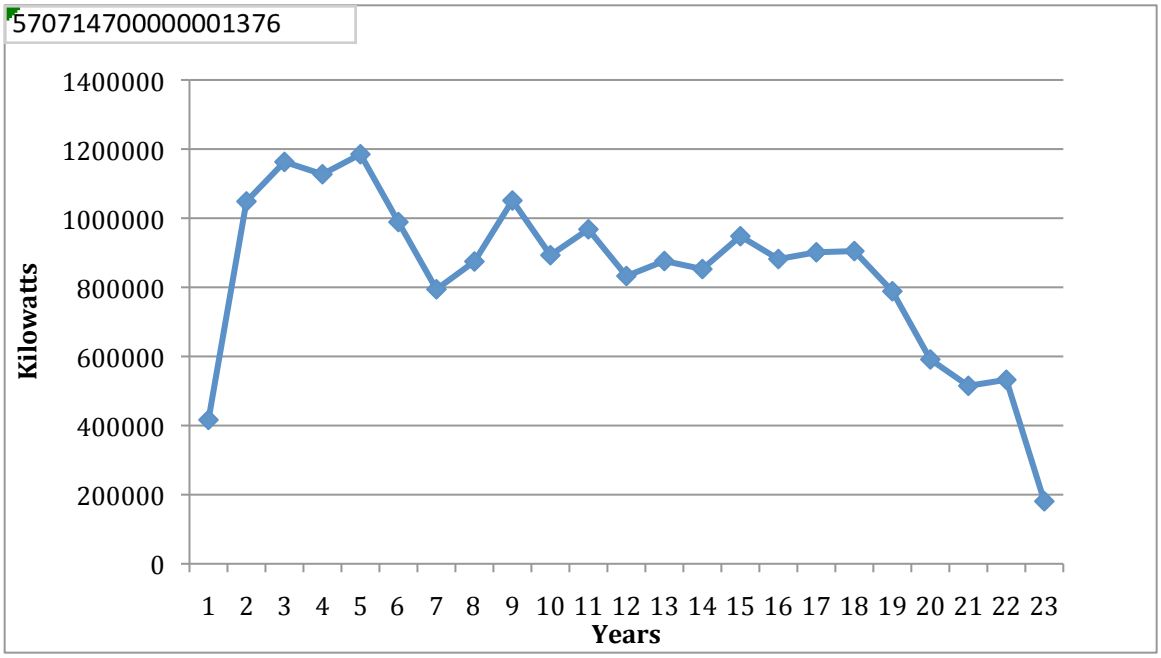


Fig 3, GRSN 570714700000001376 . A 400 Kilowatt WT, Commissioned July 1st 1990 decommissioned Jul 25, 2012. Manufacturer DVT, Machine type DVT 400, Location Lolland and island south West of Copenhagen.

The Subsequent Pattern of Commissioning

From then on however the capacity of WT's commissioned reduced to a capacity of 150 kilowatts with the occasional 400-kilowatt one interspersed. Typically these WT'S had an operating life of 21 / 22 years, although **GSRN 570715000000030420, a**150 kilowatt capacity Wind Turbine manufactured by **DWP** fared less well as it was commissioned in August 15th 1990 and decommissioned on October 16th 2002.
From then until December 18th 1993 there was a series of small capacity WT' rating from 22 kilowatts to 300 kilowatts which lasted between 8 and 22 years before decommissioning.

The introduction of 1 Megawatt Wind Turbines

The First 1000 kilowatt Wind Turbine ,commissioned on Dec 18th, 1993, **GSRN 570714700000000133** and being decommissioned on the October 9th 2009. Its manufacturer is listed **as EK-ElTech, and it was** located onshore in Hvidovre.

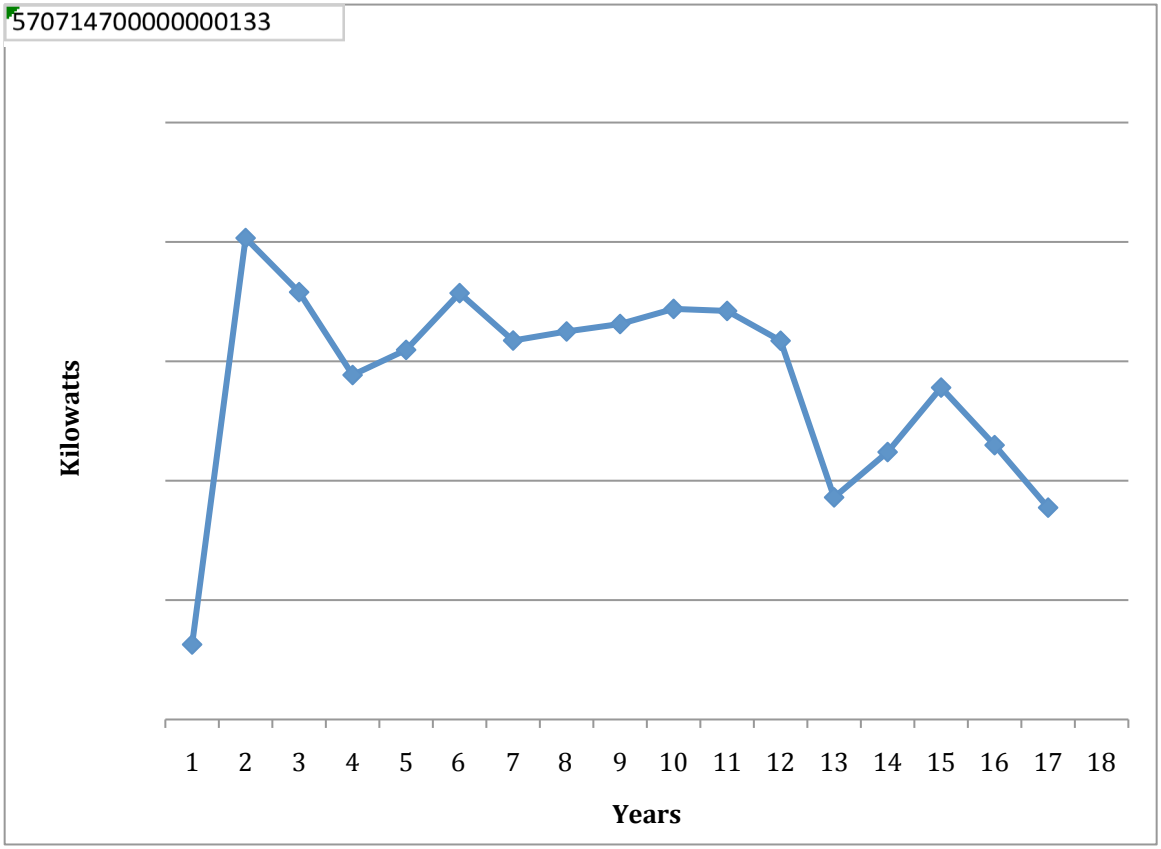


Fig 4,GSRN 570714700000000133, The First 1000 kilowatt wind Turbine commissioned on Dec 18, 1993, and decommissioned on the October 9th 2009. Its manufacturer is listed as EK-ElTech.

The renewed Pattern of Commissioning

The next 1000-kilowatt (1 megawatt) WT was **GSRN 570715000000035692** commissioned on October 1st 1994 and decommissioned on May 31st, 2008,. It was manufactured by **BONUS** and located in Esbjerg. For the first two years it was listed as having no output. And first generated in its third year . After the introduction of these 1000 kilowatt WT's we see a return to smaller 500 to 900 kilowatt wind turbines.

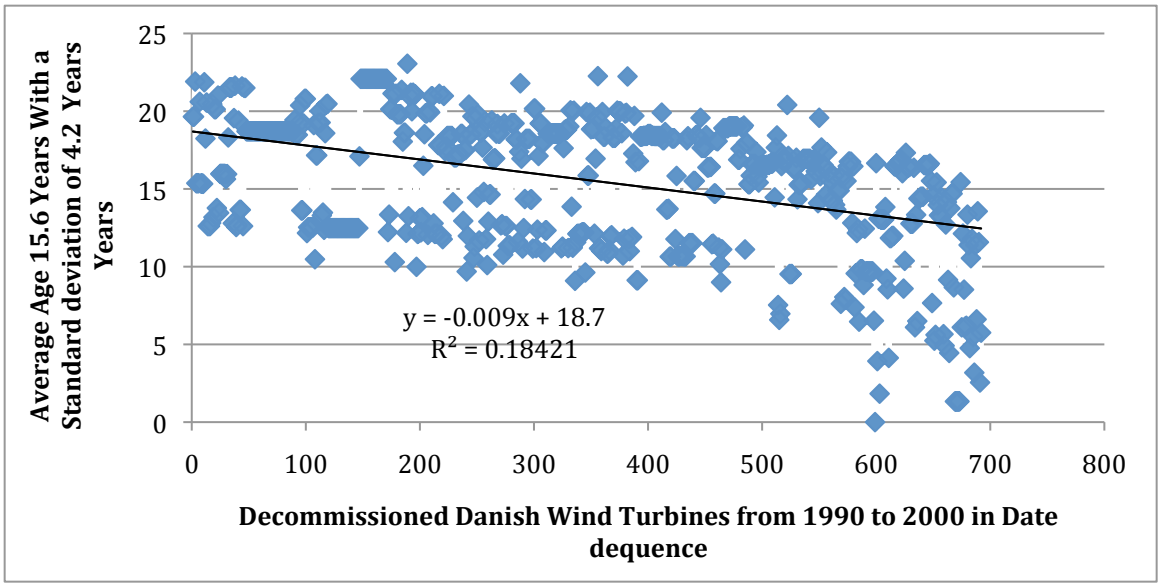


Fig 5, The operating life trend line for WT's Commissioned between 1990 and 2000. The data scatter is significant as is the downward trend in operating life.

The Introduction of 1750-Kilowatt Wind Turbines

GSRN 570715000000042287, Commissioned on December 15th, 2000 and Decommissioned on Sep 5th, 2013, manufactured by **Vestas** as Type V 66 1,75. Located in Ringkøbing-Skjern

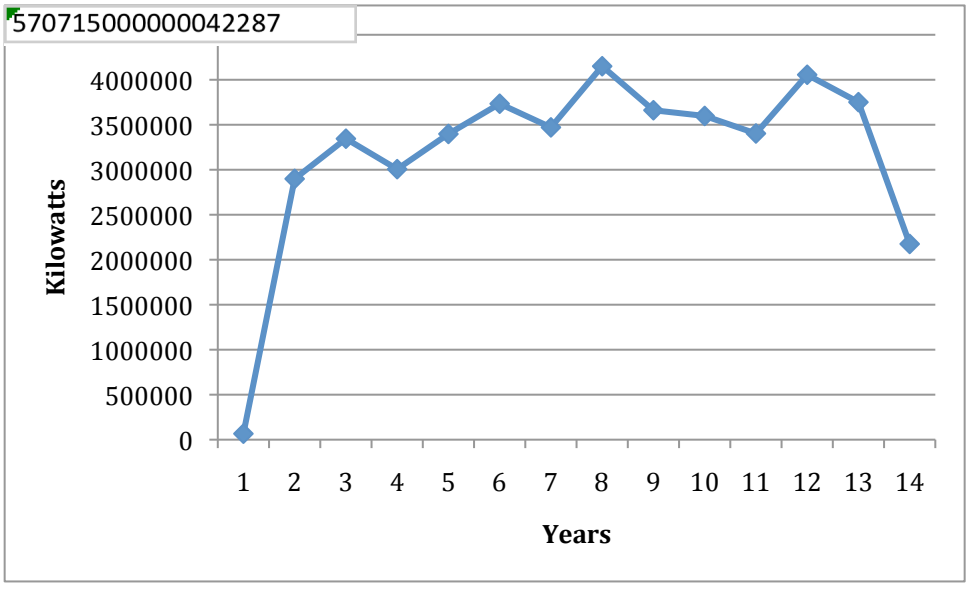


Fig 6, GSRN 570715000000042287, Commissioned on Dec 15, 2000 and Decommissioned on Sep 5, 2013 manufactured by Vestas as Type V 66 1.75.

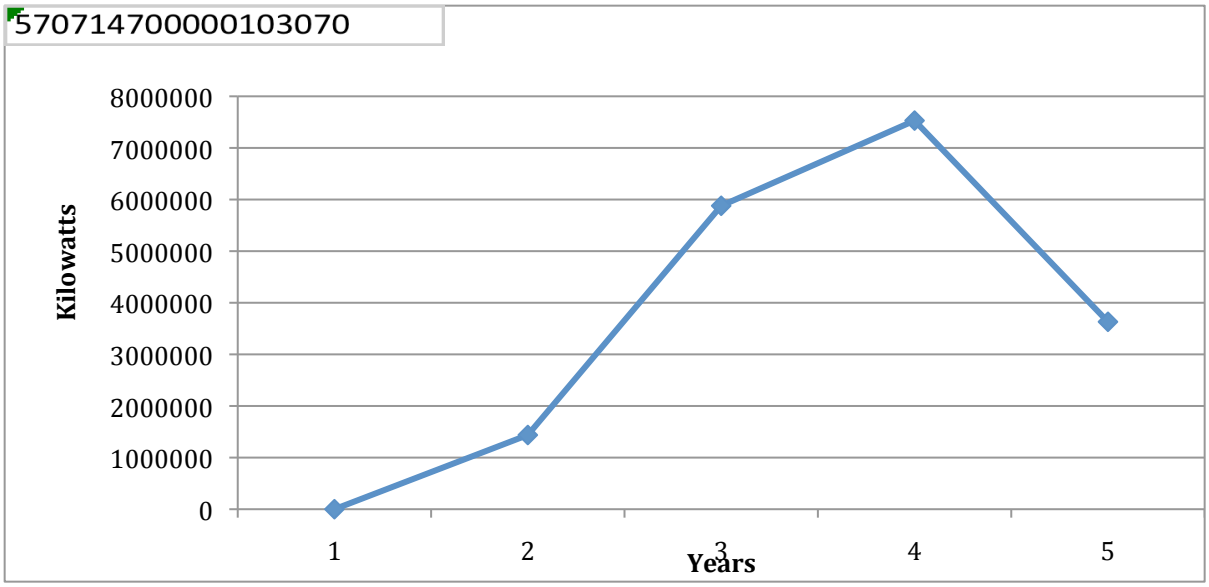


Fig 7, GSRN 570714700000103070, a Bonus Manufactured WT Capacity 2200 Kilowatts, Listed as Offshore. Located in Lolland. Commissioned 13th September 2002. Decommissioned 18th of July 2005. Located on shore .Type Listed as 2,3 MW Offshore. Note however Lolland is an Island

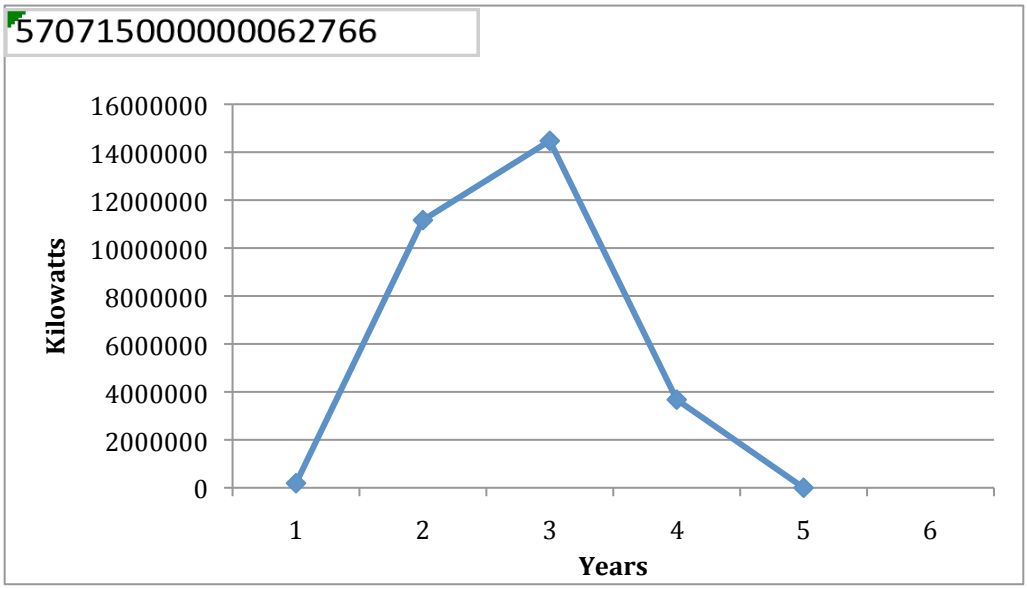


Fig 8, GSRN 570715000000062766. Capacity 4200 kilowatts. Located in Lemvig. Manufacturer NEG Micon. Type NM 110 Commissioned Nov 1st 2003. Decommissioned Nov 21st 2007

GSRN 570715000000062766, Commissioned on Nov 1, 2003.Decommissioned on Nov 21, 2007 The rated capacity being 4200 kilowatt's, the manufacturer NEG Micon. It was located in Lemvig. Which is in Jutland.

Note, NEG Micon was taken over by Vestas in 2004

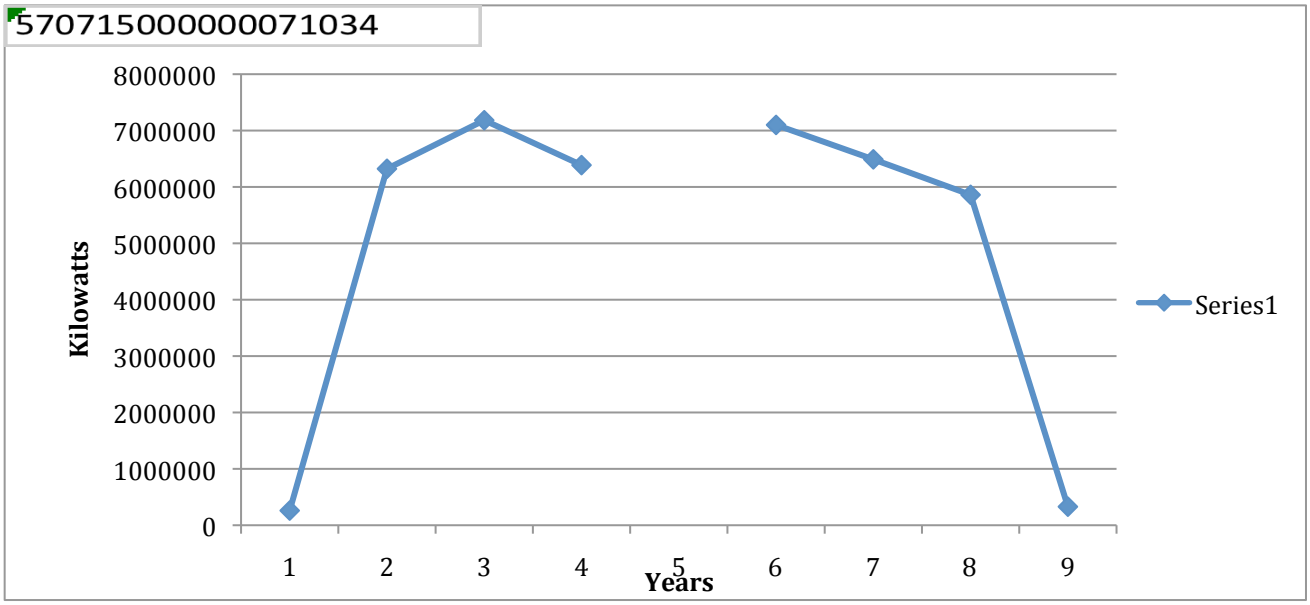


Fig 9, GSRN 570715000000071034,Manufacturer Vestas. Type V 80 2. Capacity 2000 kilowatts, Located in Lemvig. Commissioned on December 11th 2003, Decommissioned on January 12th 2011

GSRN 570715000000071034, Commissioned on Dec 11, 2003 Decommissioned Jan 12th, 2011 capacity 2000 kilowatt's. Manufacturer Vestas, type V 80 2 location Lemvig. A total of 4 Vestas V80 2 Megawatts were decommissioned from the 9th to 14th November 2011. They were commissioned from December 11th to December 19th 2003. As you can see data is missing for 1 year. This applies to all Vestas V80's commissioned in Lemvig on those dates

Other Large Capacity Wind Turbines with short operating lives.

GSRN 570715000000062667 ,Commissioned on Dec 22, 2003 ,Decommissioned on. Aug 11, 2004, 2300 Kilowatts, Manufacturer BONUS , Type 2,3 MW, Location Lemvig

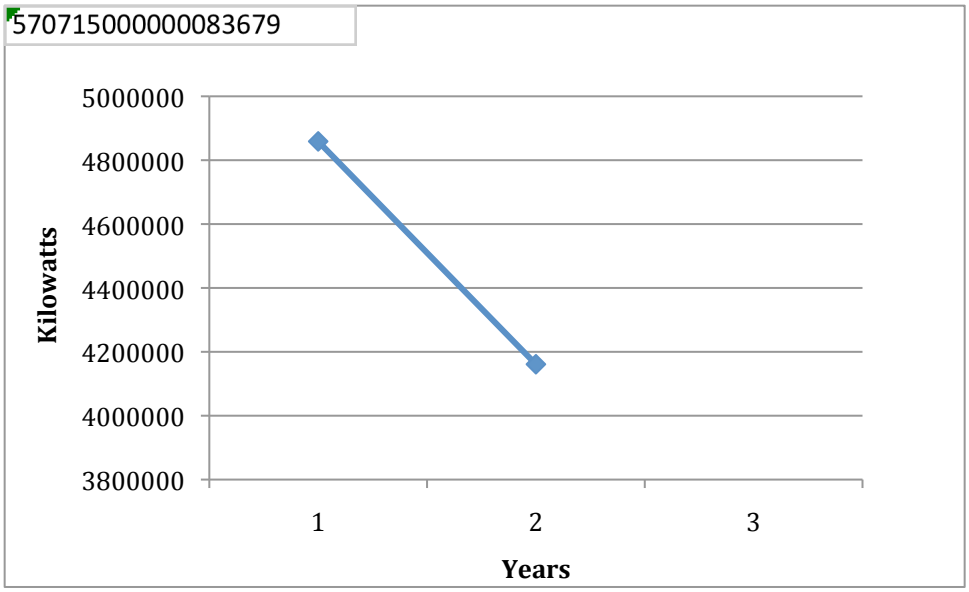
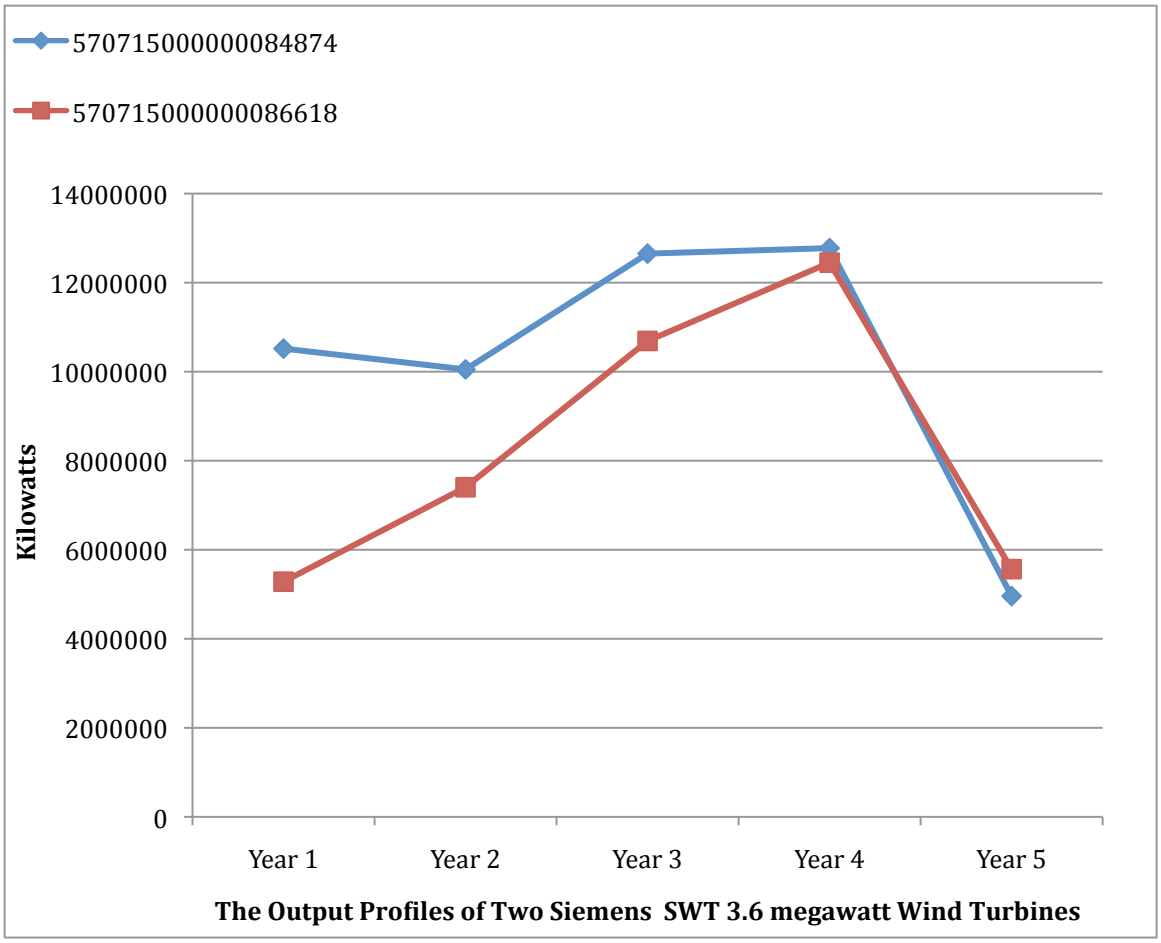


Fig 10, GSRN 570715000000083679. A Vestas V90 3000 kilowatts Commissioned February 26th, 2008. Decommissioned October 29th2009. Located in Lemvig



Fig, 11, GSRN 570715000000084874, GSRN 57071500000618
2 Siemens SWT 3.6 megawatt Wind Turbines 874 was Commissioned on January 6th 2009 . Decommissioned on July 3rd 2013 618 was decommissioned on July 15th 2013

Two Siemens swt 3.6 -107

Two Siemens were commissioned in the same location Ringkøbing-Skjern a few months apart.
GSRN 57071500000618, Commissioned on May 18th, 2009 Decommissioned on July 15, 2013, SIEMENS SWT 3.6-107. **GSRN 570715000000084874**, Commissioned on Jan 6, 2009 Decommissioned on July 15th, 2013.Manufacturer Siemens,
Wind Turbine Type No. SWT 3.6-107.Capacity of the wind turbines was 3600 kilowatts.

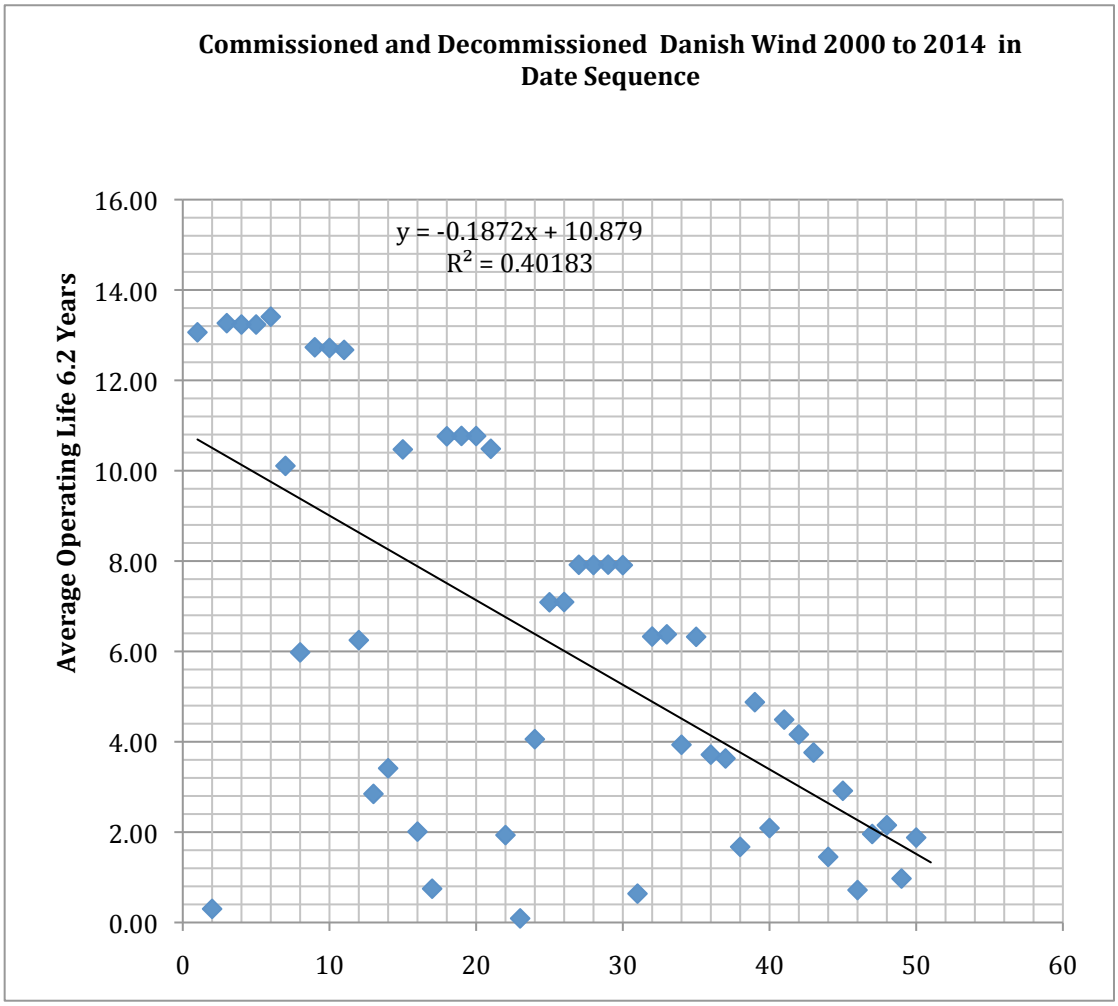
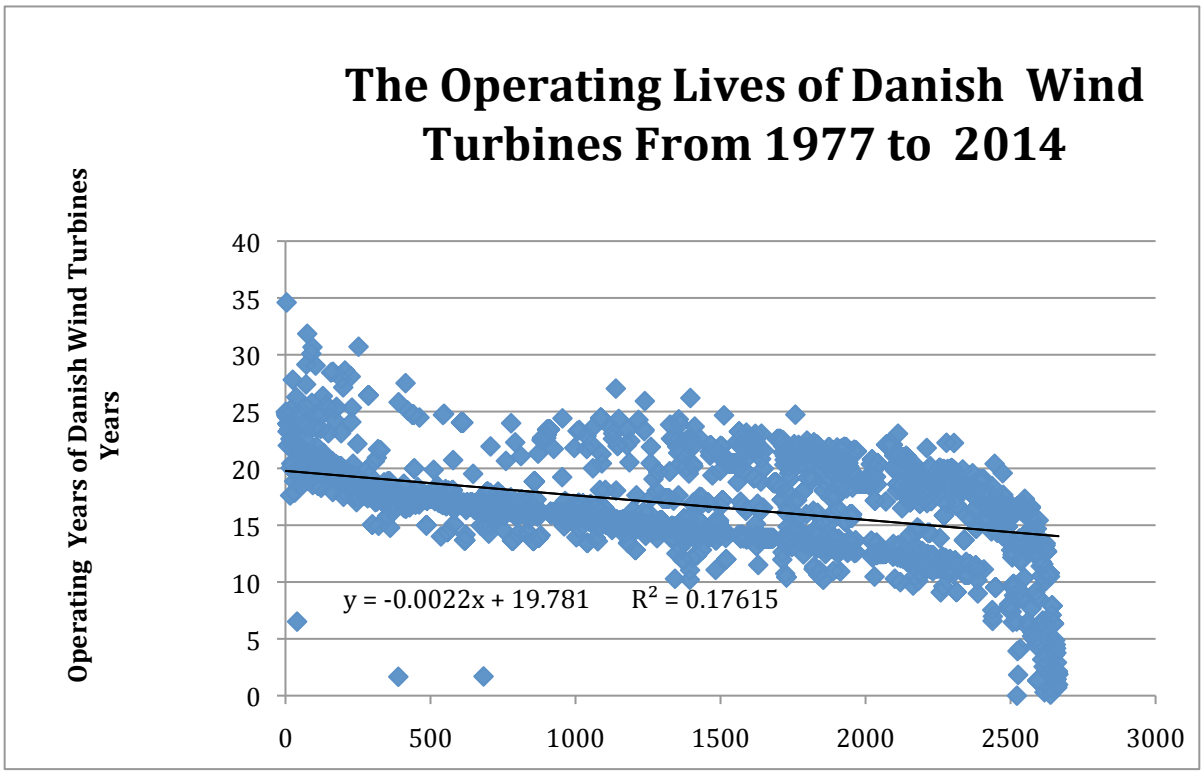


Fig 12, The operating life trend line for Wind Turbines Commissioned between 2000 and 2014. Dramatic data scatter and steep decline in operating lives. A total of 49 Wind Turbines were decommissioned during this period. The largest being 3600 kilowatts in capacity. This being the equivalent to 180 20-kilowatt wind turbines the predominant commissioned type of capacity between 1977 and 1990.The impact on output of the decommissioning of 1 large multi megawatt is the same as nearly 200 of the smaller capacity wind turbines.



Fig, 13 .The overall trend line from commissioning to decommissioning of all Danish commissioned and decommissioned Wind Turbines from 1977 to 2014. The over all trend is negative and there is poor correlation between individual WT operating lives.

Conclusion

The trend in the development of almost all new products is for complexity to increase, accompanied by increasing levels of product reliability. This however is not the case with Industrial WT's commissioned and decommissioned in Denmark from1977 to 2014. The straight line Trend is negative and there is an extremely low performance correlation, a high degree of operational variability, between the WT's produced over this period. Despite the fact that the type certification is based on a twenty year operational life for each WT which is approved as meeting its type certification. This is probably unique in modern industrial history in that the performance of mass type of machinery decreases overtime. Thus claims that Industrial WTs performance improves over time as the technology used in design and construction improves are not borne out by the Danish Governments own data. If this trend continues, these multi megawatt industrial wind turbines, which populate the later part of the period analyses, will have average operating lives of less than 10 years. The technology development for wind turbines occurs in an environment of high government subsidies which is not the case for normal commercial product development. Demand is essentially driven by the desire to access massive subsidies rather than the products economic utility..

As can be seen from the trend line graph for the periods in question the average operating life of the WT's declines overtime in parallel to an increase in WT capacity. There is theoretical benefit in increasing WT over time as it should reduce the number of sites required to achieve higher levels of output .The real issue however is whether a WT's output can be increased without decreasing the operational its life. It can be clearly seen from the data that as WT's increase in capacity their operational lives are significantly reduced . This could be related to or driven by the massive subsidies and the need to meet, from a normal perspective, artificial deadlines to develop and commission WT's with insufficient time to develop proper design programmmess, stable manufacturing and adequate testing program's**.** Whilst one has to accept that many of theses multi megawatt WT's, in the data, are new initial prototype versions being tested. Their early decommissioning raises significant questions as to their reliability. Especially as there is now a body of evidence suggesting premature component ware is reducing their actual operational of these lives. Therefore the likely poor operational performance of these larger WT's certainly raises a major question mark of the ability of the Danish Wind Industry to achieve the target, of 50% wind penetration by 2020, set by the Danish Government.. It certainly makes its achievement extremely expensive as these larger wind turbines will likely show significant drops in output over their relatively short live's. Significantly increasing the capacity required to be installed by 2020 to meet the specified target.

John Dooley

I am a retired Industrial Engineer who worked, contracted or consulted ,for nearly two decades with mainly U.S multinational corporations operating in Ireland.I was for nearly two decades a member of American Institute of Industrial Engineers. I am currently a member of The Chartered Institute of Logistic and Transport and The Lean Enterprise Institute. Being certified in Lean Six Sigma and other Lean related techniques