Reality Math
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Wind Power

1. Revenue from a Wind Turbine

In order to know how many kilowatt-hours of electricity this turbine can produce, we need to know something about the reliability of wind. If you have already done the PV unit, questioning the reliability of the wind is like finding out how many peak hours of sun are available. Sometimes the wind is strong enough to produce the rated maximum 1.5 MW that the turbine is sized for, but sometimes the wind blows at lower speeds with less electricity produced, or the wind might not be blowing enough to produce any electricity at all.

Because wind turbines aren't cheap, large turbines are only installed in areas with good wind potential. The industry estimates an average production of 25% of rated maximum. 25% is called the **capacity** factor for wind. Some turbines have a less than 25% average production and some, especially off-shore in the ocean, have a lot more than 25% capacity factor.

1000 KW = 1 MW 1000 MW = 1 GW kw x hrs = kWhr MW x hrs = MWh

1. (a) How many MW of electricity will a 1.5 MW wind turbine produce on average all the time? (Answer is not 1.5 MW)

(b) How many kW of electricity will a 1.5 MW wind turbine produce on average all the time?

2. Households in the US use about 1 kW of electricity, so this turbine would provide electricity for how many average US households?

2. (a) About how many kWh of electricity would a 1.5 MW wind turbine produce in one year?

(b) If electricity sells for 10¢/kWh retail, calculate the annual revenue from a 1.5 MW wind turbine.

(c) Could a utility afford to pay a farmer $5000/yr to have the wind turbine in his corn field?

Probably you are wondering how much these wind turbines cost! A reasonably authoritative source on Google Answers claims that wind turbines over 1 MW cost about $750 per kW **rated maximum** to buy and install.

4. (a) Estimate the cost for a 1.5 MW wind turbine including installation.

(b) Ignoring variable costs (overhead, maintenance, etc.), estimate how many years it would take to payback the cost of the wind turbine from its revenues.

2. Comparing Household Electrical Usage in Scotland and the US

These wind turbines are in Scotland. Scottish households use about 4000 kWh of electricity per year on average.

5. (a) Using 1 kW as average US household electrical demand (which is actually a bit of an underestimate), an average US household consumes how many kWh of electricity in a year?

(b) On average, US households use how many times the electricity of Scottish households?

(c) Reflect. Why do US households use more than twice the electricity of those in Scotland? (Don't just say we are wasteful. There are several other reasons for this difference. Give one.)

(d) If Scottish households use 4000kWh per year, how many kilowatts are they using steadily on average?

(e) The turbines in the picture are in Scotland, how many Scottish households can a 1.5 MW turbine support?

(f) How many US households would be supported by this turbine?

3. California's Alta Wind Energy Center – World's Largest

Tehachapi Pass, Kern County, California
1,020 MW 2,680.6 GWh per year (estimated)
Estimated capacity factor 30%
52 million metric tons CO2 offset per year
$1.85 billion cost

6. (a) Calculate the GWh per year. Is their figure reasonable?

(b) Check the 52 million metric tons CO2 prevented.
1 ton is about 0.9 metric tons. 2000 lbs = 1 ton. Use 1.4 lbs CO2 offset per kWh of electricity generated by wind.

3. Offshore Wind in Denmark

7. Look at the table on the next page.
http://energynumbers.info/capacity-factors-at-danish-offshore-wind-farms

(a) Which Danish wind farm has the highest capacity factor?

(b) How many MW is it's maximum output? Round off.

(c) Use MW x hours x capacity factor to estimate total electrical output MWh/year for Anholt I.

(d) Does your answer agree with their Total elec. Gen. (GWh)?

8. From the same table.

(a) Which is the smallest Danish wind farm?

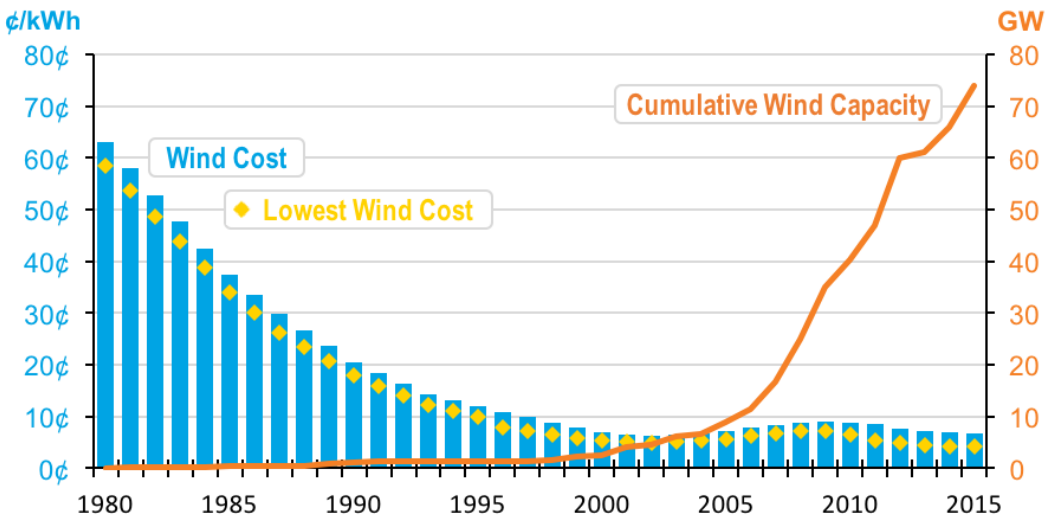
(b) Show how to calculate the lifetime capacity factor for

All numbers are to the end of December 2018. Analysis by EnergyNumbers.info. Raw data from ens.dk	Latest rolling 12-month capacity factor	Life capacity factor	Age (y)	Installed capacity (MW_p)	Total elec. gen. (GWh)
Anholt 1	**47.8%**	49.0%	5.7	399.6	9 864
Avedøre Holme	**35.4%**	38.1%	8.5	10.8	306
Frederikshavn	**26.1%**	30.3%	15.6	7.6	315
Horns Rev I	**30.0%**	41.2%	16.2	160	9 347
Horns Rev II	**47.6%**	48.0%	9.3	209.3	8 213
Middelgrunden	**19.6%**	25.2%	18.0	40	1 592
Nissum Bredning	**39.5%**	39.5%	1.0	28	97
Nysted (Rødsand) I	**34.9%**	37.1%	15.5	165.6	8 370
Nysted (Rødsand) II	**40.6%**	43.5%	8.5	207	6 747
Rønland I	**40.9%**	44.3%	16.0	17.2	1 066
Samsø	**37.8%**	39.1%	14.5	23	1 253
Sprogø	**29.4%**	33.5%	9.2	21	566
Tunø Knob	**27.8%**	30.2%	23.6	5	313
Vindeby (closed)		22.0%	25.5	4.95	244
Total	***40.8%***	***41.7%***		***1271***	***48 294***

"The Danish energy plan, Energi21, set up a target for 4,000 MW offshore wind power in 2030. These 4,000 MW are expected to produce 13.5 TWh per year equivalent to 40% of the Danish electricity consumption."
http://www.windpower.org/en/pictures/offshore.htm

1000 MWh = 1 GWh 1000 GWh = 1 TWh

9. Estimate the annual production of 4000 MW of off-shore wind turbines. Use the average lifetime off-shore capacity factor from the table above.
   (a) in MWh
   (b) in GWh
   (c) in TWh
   (d) How does your calculation compare with theirs?
   (e) If 13.5 TWh/year is 40% of annual Danish electricity consumption, what is annual Danish electricity consumption?



https://www.energy.gov/articles/6-charts-will-make-you-optimistic-about-america-s-clean-energy-future

10. (a) The cost of wind electricity decreased what percent from 1980 to 2015?

(b) The installed GW of wind increased what percent from 2005 to 2015?