THE DANISH MODEL, by Willem Post, dated 5 April, 2010
http://www.coalitionforenergysolutions.org/

INTRODUCTION
Denmark has huge wind power potential. It started to develop it after the oil shock of 1973. In 1996, Denmark, Norway, Sweden, and Finland created Nord Pool, which trades in and manages power flow between these nations. The main sources of power are hydro (56.9%), nuclear (21.9%), coal (6.3%), biofuel (5.1%) and wind (2.6%, mostly Danish); only about 13% is from fossil fuels. As the generating modes differ and are distributed differently in the various nations, the need for power will vary from nation to nation and at different times. Nord Pool helps to optimize the use of available power and reduce local deficits. Electricity prices would be higher if all the Nordic nations had to build enough generating capacity to be individually self-supporting.

Denmark has about 5,500 wind turbines (about 89% are from VESTA), total capacity about 3,125 MW; this capacity has not changed by more than 1% since 2004. All wind turbines are controlled from a single center. Denmark has two electric grids: West grid (about 4,300 wind turbines, capacity 2,430 MW, output 5.6 TWh/yr) and East grid (about 1,200 wind turbines, capacity 695 MW, output 1.6 TWh/yr). They are not interconnected. The West grid has robust connections to Norway, Sweden and Germany. The East grid has robust connections to Sweden and Germany.

As a result of Denmark's early start in wind power, VESTA has become the No. 1 turbine supplier in the world with about 19.8% of the world market; GE is No. 2 with 18.6%. VESTA has about 4,900 wind turbines with a total capacity of 2,434 MW in Denmark. It has about 39,000 wind turbines worldwide with a total capacity of 35,400 MW. It installs one turbine every 3 hours around the clock, as does GE.

WIND POWER PRODUCTION, CONSUMPTION and EXPORTS
Denmark's 5-yr average wind power PRODUCTION is about 19-21% of its total production; wind varies year-to-year. Denmark's 5-yr average wind power CONSUMPTION is about 9% of its total consumption. After 30 years of rebuilding its two electric grids and using nationwide electric demand/supply management (smart meters, smart appliances, load control switches), Denmark's grids are capable of accommodating about 10% of variable, intermittent wind power. During windy periods and when electric demand decreases in Denmark, etc., selected wind farms are idled, as part of electric supply/demand management. Any production beyond about 9%, and production due to future increases of Denmark's wind capacity, currently mostly offshore, are/will be exported. Denmark's production cannot rise quickly because modifications to the grids of Germany, Sweden and Norway would need to occur in tandem requiring major coordination and "horse trading" to move forward.

Graphs of the daily power supply profiles and the daily production and exports of wind power for both grids show that more than 50% of all wind power is exported to the grids of Norway (total production 137 TWh/yr of which 27,528 MW of hydro plants provide 98% = 135 TWh/yr) and Sweden (total production = 135 TWh/yr of which nuclear plants provide 47% = 63.5 TWh/yr and 16,209 MW of hydro plants provide 44% = 59.4 TWh/yr) and Germany (total production = 606 TWh/yr of which mostly coal-fired thermal plants provide 62% = 375.7 TWh/yr and nuclear plants provide 28% = 169.7 TWh/yr).

The only reason Denmark's high level of wind power production "works" is because robust connections exist to LARGE nearby grids that are willing to cooperate (by modulating the outputs of their hydro plants and pumped storage) and because the exported wind power is mostly sold about 5-10% below spot prices; i.e., a mutually beneficial arrangement.

However, the spot prices for wind are below Danish production costs, i.e., Danish households are subsidizing wind power exports which has contributed to Denmark having the highest RESIDENTIAL electric rates in Europe (energy $0.15/kWh + fees, taxes, transmission 0.19/kWh = 0.34/kWh, about double the price in the UK and about triple the price in France which gets about 80% of its power from its load-following nuclear plants and most of the rest from hydro. France has one of the lowest residential electric rates in Europe. The Danish COMMERCIAL rate is kept at about 1/3 of the residential rate for international competitive reasons; an illegal trade subsidy?

FUTURE WIND POWER PLANS
Denmark has a population of 5.5 million with about 2.5 million households connected to district heating loops. Denmark has about 550 distributed small (coal, gas, biomass) combined heat power, CHP, plants, a.k.a. cogeneration plants. Instead of exporting all of the excess wind power, it has been proposed to use some of it for heating HTHW loops of the district heating systems, i.e., a form of thermal storage. Denmark's announced goal of 50% of its electricity PRODUCTION from wind by 2025 means that nearly all of it will be exported and/or used for augmenting hydro power in Sweden and Norway, for heating HTHW loops (proposed), and for charging hybrid/all-electric vehicle batteries (far into the future).

If it took Denmark, the paragon of energy efficiency in Europe, 30 years to accommodate about 10% of variable power with help from Norway and Sweden, how will all this play out within the NEEG? Where is the mutually beneficial arrangement? Is Hydro-Quebec, HQ, needed for "smoothing" variable power? Will NEEG-wide supply/demand management systems be needed? See IMPACTS OF VARIABLE, INTERMITTENT POWER ON GRIDS by Willem Post.

IAEA data for 2004, 2005; Danish Annual Energy Statistics 2007; Danish Energy Authority October 2008.
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