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Book Review: Renewable Energy Systems

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The development of renewable energy and integration in today's electricity systems is a complex issue. Fortunately, many scholars have given a lot of thought into the issue, one of which is Professor Henrik Lund of Aalborg University in Denmark. His recent book, Renewable Energy Systems: The Choice and Modeling of 100% Renewable Solutions, provides useful insights in barriers to technological change, the modeling of electricity systems, and case examples of energy planning. The book's audience due to this broader setting ranges from scientists to civil servants working on energy systems, and people working in the electricity sector. Professor Henrik Lund will speak about his work at the ASPO 9 conference April 27-29 2011 in Brussels, Belgium.

The first part of the book, deals with what Lund calls choice awareness theory. The concept is introduced because often no choice is offered in case of societal decisions on energy planning. Illustrated via a number of Danish examples where power companies offered politicians and the public only a single choice, such as building a more efficient coal power plant, instead of considering a variety of alternatives. He briefly analyses the reasons behind this behavior in terms of strategy, societal structures, perception, and different power distribution between companies, government, and citizens. In his experience there is first a need to create awareness of multiple choices for society. These alternatives need to be outlined using a rigorous scientific approach using technical and economic feasibility studies, and an analysis of public regulation measures and proposals. To make this process more easy Lund proposes to use a modeling tool, one of which described in detail in the book is his freely available EnergyPlan which has been under constant development at Aalborg University since 1999.

The use of this part of the book is particularly for those not initiated that well in energy systems who still have difficulties grasping the complexity of the issue. One of the aspects that brought back memories when reading the book was that alternative systems need to be made comparable in terms of capacity and energy production. Often I have come across confusion on solar power capacity, watt-peak capacity, and actual power production in discussing energy at lecture evenings and debates in the Netherlands.

The second part of the book is more interesting for energy experts interested in technical feasibility of renewable electricity integration in the grid. The technical feasibility study of a Danish electricity system running 100% on renewable electricity is presented, developed with the EnergyPlan tool. The analysis starts with a reference scenario from the Danish Energy Authority for the electricity system in 2020. To understand the problem of renewable intermittency Lund analyses patterns of sunshine, wind, and waves in West Denmark during a number of years, shown for wind energy in figure 1.

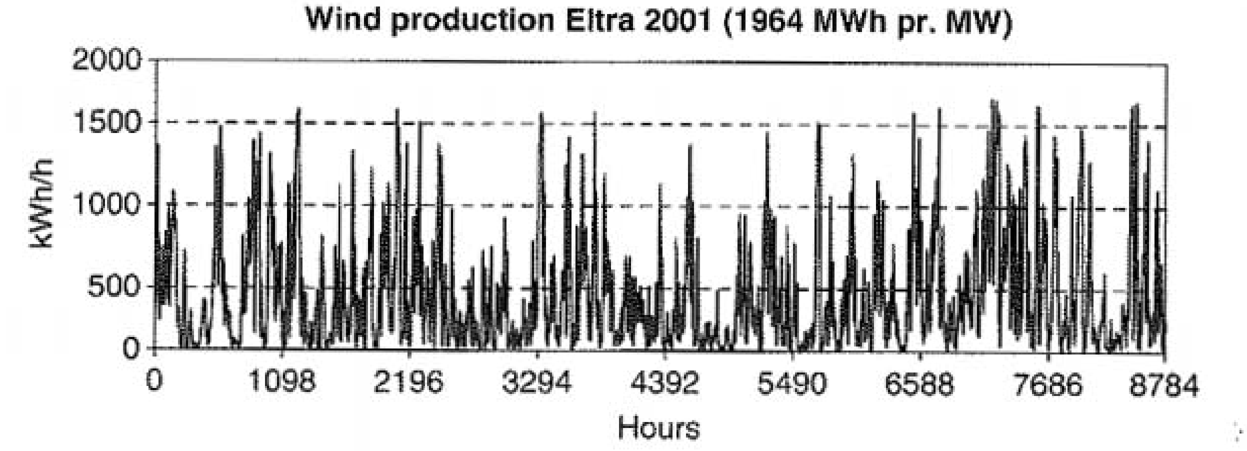

Figure 1 – Wind electricity production in 2001 in West Denmark per hour. Figure from Renewable Energy Systems.

Based on such an hourly distribution patterns a number of analyses are made and conclusions are drawn. First, excess electricity production is analyzed. This measures how much electricity from intermittent sources is produced above electricity demand on an annual basis, with as a variable the amount of renewable energy source production. The analysis shows that to meet demand it doesn't help much to combine wind, solar, and wave electricity, shown in figure 2. The idea that the wind blows when the sun doesn't shine is incorrect, at least for West-Denmark, as the optimal mixture of sun, wind and wave power only leads to a marginal decrease in excess production. The results show that without other measures going beyond approximately 10% of renewable electricity production in the electricity mix mainly leads to excess production not to useful electricity. The variety between years on this point are only marginal. The conclusion of Lund on this part is similar to that from Hannes Kunz and Stephen Balogh in their fake fire brigade analysis on electricity.

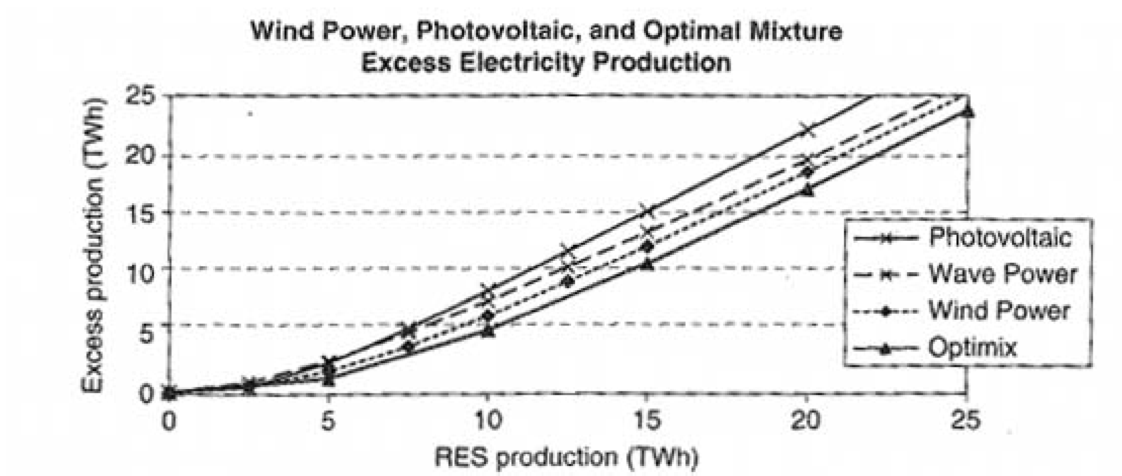

Figure 2 – The integration of individual renewable sources compared to the optimal mixture. Figure from Renewable Energy Systems.

Next, the variability per hour is modeled and how intermittency on an hourly basis can be overcome for various renewable electricity shares. Professor Lund analyses a number of solutions:

- To regulate CHP stations to address fluctuations in wind power next to heat demand. In this system CHP stations would be partially replaced by boiler heat production when excess electricity is produced. The consequences is lower fuel efficiency of CHP systems

- Investing in heat pumps and heat storage capacity equal to approximately 1000 MW of electric power in 2030 and one day of heat consumption storage. These can be used instead of boilers to restore fuel efficiency while also decreasing excess electricity production.
- Grid stabilization via CHP and wind power which has traditionally only been done via large power stations.
- Integrating the electricity sector and the transport sector by introducing electric vehicles which can deliver a battery discharge to the grid when in stationary mode at the parking lot.

A combination of these options and their effects on excess electricity production are modeled using excess wind electricity, of which a few are shown in figure 3. In that figure S0 refers to the reference scenario, S1 refers to (de)-activating small and medium-sized CHP stations along wind electricity production using boilers as a replacement, S2 refers to adding heat pumps instead of using boilers, S3 refers to adding electric vehicle batteries to the system which replace 20% of oil consumption.

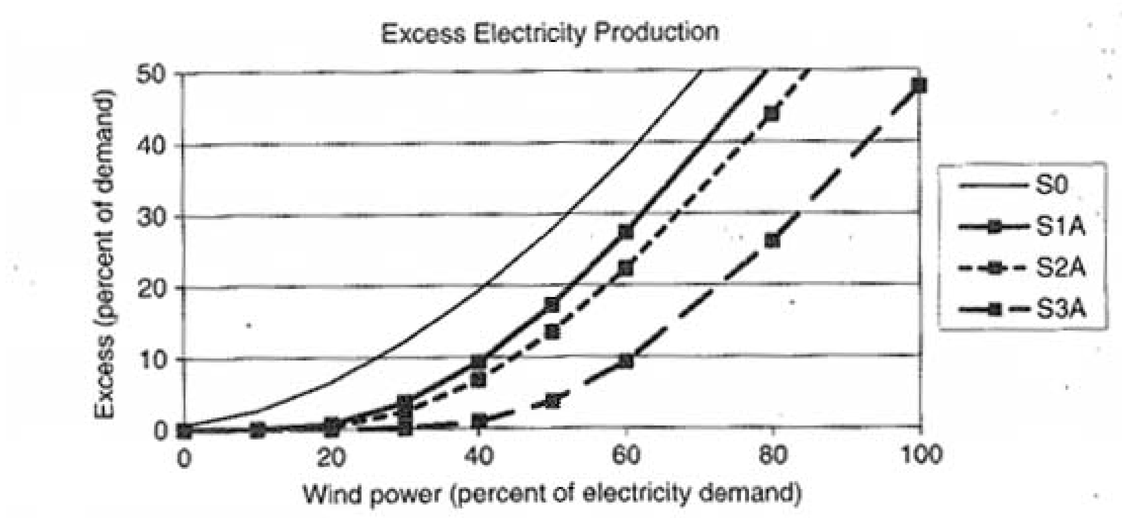

Figure 3 – Excess electricity production in percentage of demand under the references scenario and S1 to S3 described in the text. [Figure from Renewable Energy Systems.]

In modeling electric vehicles in the scenario of figure 3 it was assumed that in 2030 in West Denmark about 3.2 TWh of electricity had substituted 9.8 TWh of oil via electric and hydrogen fuel cell vehicles. Based on a national level assumed electricity to oil substitution of about 20.8 TWh of oil consumption, which is 40% of all transport fuel used in 2030 in the reference scenario. This would be replaced by 7.3 TWh of electricity used in electric and hydrogen fuel cell vehicles. The much lower consumption level in terms of energy comes from the higher efficiency of these vehicles types. Further assumptions are that electric vehicles load during the night where they reduce excess electricity, and that hydrogen electrolyzers operate 4000 hours per year at hydrogen electrolyzer stations. More detailed analyses are available in the book on a specific chapter on transport integration of the electricity grid, where other options such as intelligent battery electric vehicles which charge after signals from the grid when excess electricity is available.

To end this part the costs of electricity and different storage options are discussed. The cost aspects is a comparison of the costs of wind investments versus the money earnings of selling wind power on the Nordic Nord Pool electricity market. The time period is based on a 7 year historical period where the average price on the market is taken to smooth out variability in hydro-power availability. The analysis shows that without investments in flexibility of the system such as heat pumps, the benefits of wind power quickly drop below the costs as too much excess electricity is produced, at around a 7% wind electricity share of electricity demand. That can be extended using heat pumps according to Lund. I found the description of this part to be too brief to be very insightful however, as many of the involved factors such as investment costs and fuel costs are not described quantitatively, and only the outcomes of the analysis is displayed.

Finally, the book ends with a number of case examples of renewable electricity implementation and renewable energy scenarios including Los Angeles, Denmark, Thailand, and Germany. These are helpful to illustrate the ideas and theory with real life examples, to get an idea where things can go right and wrong in terms of energy planning. Overall I found the book very helpful in describing approaches to analyze electricity systems, and getting more insights into the technical feasibility of large renewable electricity shares. I am not convinced, however, about the economic possibilities of large shares of renewable electricity systems. Especially because the focus in the book lies on Denmark which has a favorable situation of hydro-power and interconnectedness between other countries.