

Outline of the history of energy project, supported by the Danish Agency for Research and Innovation with funds from Danish State Lottery Endowment.

The goal of the project is to write a manuscript for a book on the subject, in English language. The book will concentrate on energy history in the 20th century, but will contain an attempt to follow energy use all the way through human history. Denmark offers a particularly rich energy history, which in recent times is particularly interesting because it deviates substantially from that of most other countries, due to early rejection of nuclear power and introduction of large-scale on-shore and off-shore wind power, currently covering 25% of Danish power needs. Although the book will concentrate on Danish energy history, it will discuss global implications and hopefully find interesting similarities/differences by comparing with the energy history of Japan.

Early energy history (12000 to 1000 years before present)

In a period of temporary warming during the last glacial period (the Allerød-period some 11500 years ago), the first evidence for settlements (as opposed to traces of passing hunters) appears in Denmark. The annual mean temperature was 3-4°C lower than today, implying a need for fire, clothes and shelter in order for humans to survive. Indications are available for the kinds of food eaten, but not for determining details of housing in use. More solid evidence for permanent settlements become available after the recession of the ice about 10000 years ago, and a period of warmer climate (½-1°C above the present) prevails until about 3000 years ago. Neolithic energy use comprise animal power from livestock and transportation energy (muscle energy) used in boats, and some 6200 years ago, agriculture was introduced to the region, with the associated use of solar energy in addition to larger amounts of animal power, including riding and plowing from some 4800 year before the present. The bronze age sees increasing trade and contact with other parts of Europe, and from the onset of the iron age some 2500 years ago, sharply increasing amounts of fuelwood is used for industrial purposes. Agriculture is further developed, and the Viking period (1300 to 950 years ago) is characterized by the construction of some of the technically most perfected ships at the time, now using wind energy for propulsion. The average temperature is falling to about ½°C under the current one, but with increasingly large excursions. A quantitative estimate of the development in per capita energy use during the entire period described will be attempted.



Use of draft animals. Rock painting from Tegneby, ca. 2300 years ago. (E. Sharpe, pp. 178-187 in Mythology; Cavendish, R., ed. Barnes & Noble, New York 1982).

From medieval times to the industrial revolution

From 900 years before the present, per capita energy use in Denmark grows substantially, with components of all the then established energy forms: solar and animal power (now employing wheel plows), human muscle power, wind power (sail ships) and biomass (combustion). Large projects include building several thousand churches for the newly introduced Christian relig-

ion, entailing activities such as excavation of stone and clay materials, firing of bricks and transportation of building materials to the building sites. The average temperature is now about 2°C lower than at present, and from 1300 years ago, written historical source material is available, allowing a more precise assessment of the actual energy use.

500 years ago, the fraction of the Danish surface area used for agriculture is strongly increased, allowing a considerable export of agricultural produce to other European countries. At the same time, the agglomeration size of cities increases. These developments require increased energy provision, and new techniques such as windmills and water mills are introduced. The following 200 years are often called “the little ice age”, because average temperatures fell to 3°C below the current one. The consequence of this was greater exploitation of forest wood resources, which together with clearing of forest areas for establishing new agriculture leads to a veritable “energy crisis”. Felling of forest in near-coastal areas has a particularly negative ecological impact, because wind can now carry sea salt spray particles into the agricultural land areas, with reduction in yields as a result. Also the sand erosion and particulate transport by wind leads to deteriorating conditions for agriculture, and the King’s scientific advisors are being asked how the erosion of coastal areas can be stopped. They reply with a request for replanting trees, particularly plantations near the sea and generally requiring a tree to be planted every time one is felled. Before tree plantation makes sense on the sand dunes now occupying most coastal areas, other crops capable of adhering to and grow in pure sand has to be found, and wild roses are found to be the best solution. It takes about 200 years to re-establish the ecological balance and stop the loss of coastal land. The following years see highly organized provision of energy from state forests in rotation, now deep inland, but due to the inconvenience of land transportation at the time, canals are dug to allow fuelwood to be floating to or barged to the sea shore, for subsequent transportation by ship to the major cities.



Windmills outside the Copenhagen city walls (F. Hogenberg: Scandinavia, 1587; reprinted 1987 by Borgen (van Mingroot & van Ermen, eds), Copenhagen.

The 19th and 20th century.

The industrial revolutions had from the early 19th century brought weapons and textile industry to Denmark, with energy initially provided by waterwheels, peat and woodfuel, but soon to be replaced by imported coal. Transportation of freight and people by ship became an important Danish business area, and towards the end of the 19th century, the cooperative movement changed agriculture and retail trade to allow a considerably more equitable distribution of wealth than in many other European countries. In the 20th century, agriculture saw an accelerated intensity leading to yields per square meter of land that grew by an order of magnitude. The food processing industries grew in importance, cities and transport demand likewise, and horse-driven carriages were replaced by trains, bicycles and cars, as new road construction gradually allowed it. Electricity was introduced, first seeing a fierce competition between coal- and wind-produced electricity, but from 1930 to 1950 only coal and then from 1950 oil, but going back to coal after the 1973 oil supply crises. Per capita energy use and distribution

between sources are well documented through official statistics.

The second half of the 20th century sees increasing efforts to establish a comprehensive planning of energy supply. After the oil crisis in 1973 these efforts are moved from the power utilities to a new energy department established by the Danish government. The exponentially increasing energy demand (1950-1970) has already led to a discussion of the finiteness of the fossil resources, and at the start of the 1970ies, the Danish power utilities submit a request to the government, asking permission to build 5 gigawatt of nuclear power stations. The procedure turns out more complicated than expected by the electricity companies, as the new Department of Energy does not want to grant the permission without investigating safety and environmental issues, and perhaps more importantly because of the change in society, which during the same years lead to the formation of grassroot movements including one focussed on the nuclear issue. After some years of discussion, the nuclear option was officially abandoned. The debate also touched upon the importance of self-reliance and decentralization. The first was temporarily achieved, when Danish off-shore oil and gas deposits were developed, while the decentralization is a continuing process that so far has led to establishment of several thousand local combined heat-and-power plants and wind turbine installations.



Record-efficiency coal-based power plant with natural gas and biomass as alternative fuels, built in 1998 at Avedøre near Copenhagen (photo: BS)