Rachel Carson Center
Perspectives

How to cite:

Heymann, Matthias, and Kristian H. Nielsen. "Hybridization of Electric Utility Regimes: The Case of Wind Power in Denmark, 1973–1990." In: "Energy Transitions in History," edited by Richard W. Unger, *RCC Perspectives* 2013, no. 2, 69–74.

All issues of *RCC Perspectives* are available online. To view past issues, and to learn more about the Rachel Carson Center for Environment and Society, please visit www.rachelcarsoncenter.de.

Rachel Carson Center for Environment and Society
Leopoldstrasse 11a, 80802 Munich, GERMANY

ISSN 2190-8087

SPONSORED BY THE

Federal Ministry of Education and Research

Deutsches Museum

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Matthias Heymann
Kristian H. Nielsen

Hybridization of Electric Utility Regimes: The Case of Wind Power in Denmark, 1973–1990

Historian of technology Thomas P. Hughes has argued that as technological systems mature they become difficult to transform. The process of maturation involves an expansion of organizational as well as technical networks. Mature systems, therefore, are analogous to heavy bodies, "obeying" the law of inertia. The "mass" of technological systems consists of rules and regulations, decision-making routines, technical expertise, educational programs, private and public policies, enterprises, funds, and technological artifacts. Hughes refers to this as "technological momentum": eventually the systems appear autonomous, each following its own path of technological development.

In virtually all modern industrialized societies, electric power systems have developed a technological momentum of their own: centralized power production that benefits from economies of scale; extended networks of high-voltage transmission lines; big electric utilities and their networks of suppliers; and highly diversified consumption units, from private homes, through small and medium-sized businesses, to large-scale, year-round manufacturing plants. Consequently, shifting the technological path of electric power systems can be very difficult. In the course of the twentieth century, the electric utility system became an energy regime in its own right, replacing traditional forms of energy production.

Since the 1970s, however, the electric utility system has been subject to significant changes. Technological limits and economic crises ended the "golden years" of electricity production typified by high annual growth rates. Furthermore, from the early 1980s onwards a traditional source of energy, initially promoted by energy activists and environmental movements, began to penetrate the electric utility regimes in an increasing number of countries. Wind power use involved a radical shift from centralized to decentralized electricity production and from utility-owned to privately-owned electricity production. While the share of wind power use appeared marginal initially, it quickly rose in subsequent decades, accounting in 2010 for approximately 22 percent of Danish, 16 percent of Spanish, 9.5 percent of German, and 2.3 percent of US electricity produc-

tion. The question is whether the system has in fact changed radically or whether the changes are ultimately insignificant to the system as a whole.

Based on our research into the contemporary history of wind power in Denmark, we want to argue for a third way: the hybridization of electric utility regimes by means of innovative adaptation of wind power. Today, wind power accounts for a significant amount of Danish electricity production, and the current national energy policy projects up to 50 percent wind power penetration by 2020, defined as the fraction of energy produced by wind compared with the total available generation capacity. Around 5,200 wind turbines, including offshore wind power plants, are currently installed, with a total capacity of 3.8 Gigawatts (GW). In order to reach the 50 percent goal, the government in power as of November 2012 will be inviting new tenders for 1.2 GW of offshore and 1.8 GW of land-based wind power.

The development of wind turbine manufacturing and wind power penetration in Denmark has engaged many diverse actors:

- Small-scale manufacturers of farm equipment, who took up wind turbine manufacturing during a crisis in Danish agriculture in the 1970s and created the world's leading wind turbine industry.

- Wind engineers at the former Test Station for Windmills at Risø, who not only managed the system approval scheme that began in 1991 but also assisted manufacturers in their research and development (today, wind turbine approval is managed by the Danish Energy Agency and the Department of Wind Energy at the Technical University of Denmark).

- Meteorologists at the National Atomic Research Facility in Risø, where the Test Station was located, who developed the Wind Atlas methodology on a contract from the national energy research program that began in 1976. This methodology facilitated relatively easy and reliable projections of local wind energy resources for wind turbine owners and wind park developers.

- The Danish Association for Wind Turbine Owners, which began collecting statistics in 1979 for all wind turbines erected in Denmark, including information on

ownership, manufacture, and monthly production. These statistics enabled a high degree of market transparency from an early stage.

- A relatively strong energy movement, which combined opposition to nuclear power with many grass roots initiatives within renewable energy, the most visible of which was the 2 MW Tvind Mill, completed in 1978.

- Energy planners and policy-makers, who integrated wind power along with other renewable energy sources in Danish energy policy as early as 1976, and who have since expanded the portfolio of Danish wind power policies.

The role of the utilities in Danish wind power development has been ambiguous. Many utility managers during the 1970s, 1980s, and 1990s opposed wind power, at times even working against the integration of wind turbines into the power grid. On the other hand, the research departments of the Danish utilities companies were engaged in wind turbine development, and many utility companies (although sometimes more or less forced to by government) have erected wind power plants.

Moreover, when wind power development took off in the early 1980s, the utilities helped to establish voluntary purchase agreements, perhaps the single most critical requirement of a successful wind turbine project. The voluntary agreements lasted until 1992, when the government had to intervene in a conflict between the utilities and the Association of Wind Turbine Owners. At the time, it surprised most people that the government followed the advice of the wind turbine owners, fixing the wind power tariff at 85 percent of normal residential electricity prices. In 2000, the fixed wind power tariff was abandoned as a result of electricity liberalization. Today, wind electricity is sold on the open electricity market, but wind turbine owners still receive an additional payment from the government based on when they were connected to the grid and the number of kilowatt hours supplied to the grid.

A high degree of local support for wind power is one of the characteristics of wind power development in Denmark. Although there is a National Society of Windmill Neighbors resisting the erection of land-based wind turbines and arguing that the support of the Danish wind industry is bad for the economy, this type of resistance is not widespread. In addition to the high degree of environmental consciousness in Den-

mark, wind power receives widespread support because of ownership structures that empower individuals and communities. As of 2001, when compulsory registration of ownership was discontinued, more than half of the installed wind capacity was owned by private individuals. Wind turbine cooperatives owned about 20 percent, while the remaining 10–15 percent was controlled by the utilities. The Danish government has tried to restrict ownership to people living close to their own wind turbine, based on the idea that wind turbines should benefit the local communities where the wind turbines are erected, and not local or foreign investors.

The ability of a traditional energy source such as wind power, which has been used to produce local power for many centuries, to find its way into the modern electric utility regime based on large-scale central power production and a widely dispersed grid of power consumers, is surprising. The consequences for the grid are equally unexpected.

We maintain that the increasing penetration of wind power into the utility regime has depended on, and will depend on, three types of innovation:

- Technical innovations enabling more efficient transformation of wind power into electricity, the gradual scaling-up of wind turbine designs, and the management of decentralized and unstable sources of energy.

- Organizational innovations facilitating the public support of wind power and the continuing adjustment between new industrial and organizational forces on the one hand, and existing technological systems on the other.

- Market innovations that make it possible to assess the real price of wind electricity.

As a result of such innovations, wind power has become a hybrid energy source that integrates traditional and modern features. It is based on a traditional mode of energy conversion that uses rotating blades turned by the wind, and it continues to feature traditional characteristics like decentralized energy production and distributed ownership. At the same time, today's wind turbine technology has very little in common with the windmills of previous centuries. It is fully adapted to a highly complex electric utility regime, it responds to technical and economic system needs, and it contributes

to system momentum, for example by rapid scaling-up of turbine power that exploits economies of scale.

At the same time, the electric utility regime has been subject to hybridization. In the late 1960s, the Danish electric power system depended more or less exclusively on imported fossil fuels, and the dominant organizational structure was the medium-scale, consumer-owned utility company. The 1970s energy crises, and to some extent what historian of technology Richard F. Hirsh has called the technological stasis in the development of steam power plants, provided the incentive to experiment with renewable energy technologies. For a number of reasons, and with the mediation of many different actors, wind power in Denmark proved to be a viable addition to the power system. Not only wind technology had to be adapted. The electric power system had to be adjusted to accommodate small-scale, decentralized power production units with variable power output, mostly in private ownership. The inclusion of wind power in the Danish electric utility regime did not radically transform the system, nor did it leave the system unchanged. Today, and in the foreseeable future, wind power and the electric utility regime merge to form hybrid energy systems.

Further Reading

Hausman, William J., Peter Hertner, and Mira Wilkins. 2008. *Global Electrification: Multinational Enterprise and International Finance in the History of Light and Power, 1878–2007.* Cambridge and New York: Cambridge University Press.

Heymann, Matthias. 1995. *Die Geschichte der Windenergienutzung 1890–1990.* Frankfurt am Main: Campus.

———. 1998. "Signs of Hubris: The Shaping of Wind Technology Styles in Germany, Denmark, and the United States, 1940–1990." *Technology and Culture* 39 (4): 641–70.

———. 1999. "A Fight of Systems? Wind Power and Electric Power Systems in Denmark, Germany, and the USA." *Centaurus* 41 (1–2): 112–36.

Hirsh, Richard F. 1989. *Technology and Transformation in the American Electric Utility Industry.* Cambridge and New York: Cambridge University Press.

Hirsh, Richard F., and Adam H. Serchuk. 1996. "Momentum Shifts in the American Electric Utility System: Catastrophic Change—Or No Change at all?" *Technology and Culture* 37 (2): 280–311.

Hughes, Thomas Parke. 1983. *Networks of Power: Electrification in Western Society, 1880–1930*. Baltimore: Johns Hopkins University Press.

Nielsen, Kristian. H. 2005. "Danish Wind Power Policies from 1976 to 2004: A Survey of Policy Making and Techno-Economic Innovation." In *Switching to Renewable Power: A Framework for the 21st Century,* edited by Volkmar Lauber, 99–121. London: Earthscan.

———. 2010. "Technological Trajectories in the Making: Two Case Studies from the Contemporary History of Wind Power." *Centaurus* 52 (3): 175–205.