

Christina Newinger, Christina Geyer, Sarah Kellberg (Eds.)

# energie.wenden

Energy Transitions as Chance  
and Challenge in Our Time





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Christina Newinger  
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Deutsches Museum 

 oekom

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# Foreword by the Director General

In the exhibition “energie.wenden”, the Deutsches Museum once again takes on one of the most important issues facing societies all over the world today—the energy transition—and makes it accessible to a broad audience. This time, it is even designed to go on tour after its run at the Deutsches Museum is finished. The tremendous success of our previous special exhibition (“Welcome to the Anthropocene: The Earth in Our Hands”) convinced us that it is possible to do justice to such a complex topic, which affects every one of us. The *Energiewende* currently under way in Germany will mean dramatic changes for both our technological systems and our social structures in order to bring about a planned transition from the fossil-fuel age to a more sustainable energy system. It is an enormous *global* challenge as well, for not only climate change, but also the increasing pressure on resources mean that this transition will be necessary everywhere in the world. At the Deutsches Museum we feel a duty to contribute—through projects like this exhibition—to ensuring the energy transition is a success.

Naturally, the exhibition will throw light on the historical background of our current energy system and the foundations of modern technology and its worldwide effects—just as our visitors have come to expect from our exhibitions. They will not be disappointed. In the best Deutsches Museum tradition, visitors can explore the triad of energy generation, distribution and consumption with the help of unique objects and exciting demonstration models. The items on display will include both important historical artefacts and examples of the latest technological innovations.

But energy is not just a matter of technology; it is a political and social issue as well. We have therefore come up with a new and innovative exhibition concept that encourages visitor participation to an unprecedented degree. Visitors can assume the role of policy makers and explore the complex interdependencies

at play in our *Energiewende*, learning through game-like scenarios about the numerous factors that make the energy transition necessary and discovering what options are available for solving this difficult problem, both for us as a society and as individuals. The exhibition encourages us to reflect on our social responsibility, and aims to motivate each of us to take action. This approach is mirrored in the original title of the exhibition “energie.wenden”, which literally means: turning energy around. Thus, the main focus of the exhibition is the question: “Let’s make the energy transition happen—but how?”

The topic of energy has been an omnipresent theme in the exhibitions at the Deutsches Museum since its beginnings, for without energy the technology that our society is based on would not be possible in the first place. This is of course particularly true for the digital age we are living in today. Thus, energy features at every turn in our exhibitions on topics such as physics, power systems engineering, electrical machinery, hydraulic engineering, and many others. But in addition to the technical aspects familiar to visitors to the museum, the project we refer to as the *Energiewende* includes social, political, and economic aspects that we feel are just as important to incorporate into our exhibitions, in the spirit of our mission to educate and inform. This helps contextualize the physical and technical facts that—looked at in isolation—are not always easy for visitors to make sense of.

This is why we were determined to make this a participatory exhibition. With these novel ways of presenting ideas, the Deutsches Museum aims to break new ground—and has explicitly designed the exhibition to travel and serve as inspiration elsewhere. The special exhibition is also an important milestone in the Deutsches Museum’s Future Initiative, our project to comprehensively update and redesign the museum, as the new approaches and the experience gained from this exhibition will serve us well in the future.

The global importance of the topic, and Germany’s leading role in attempting to find solutions to the energy problem—we are, after all, in the midst of a huge national experiment that is without precedent anywhere in the world—were key factors in our decision



to that this project in particular should take the form of a travelling exhibition so that it could reach audiences in other countries. With “energie.wenden”, the Deutsches Museum has created a travelling exhibition that will be in great demand by major museums of science and technology around the world. Designing an exhibition with this in mind posed great challenges in terms of form, organization, and curatorial management, which the exhibition team has solved with creativity and determination.

A transition from fossil fuel energy to alternative energy sources and a more responsible stewardship of resources can only be successful if science, the broader public, business, and politics work together in the pursuit of common goals. It will also require close disciplinary collaboration. We therefore gathered a committee of experts from many different disciplines to provide advice on the content and design of the exhibition. In addition to natural scientists and engineers it included historians, sociologists, and other specialists. At a workshop entitled “Globale Energiewenden” (“Global Energy Transitions”) on 5–7 March 2015, these experts convened for the first time and discussed with one another and with the curators how such a complex and multifaceted topic could best be presented in a museum context. They made their knowledge and experience available in discussions and additional workshops throughout the development of the exhibition.

This volume documents the exhibition and supplements it with an introduction and essays that further explore this complex topic. Experts in various fields provide clear explanations of different aspects of sustainable energy provision. The catalogue opens with a historical overview of energy transitions of the past and traces the development of the term *Energiewende*. This is followed by in-depth discussions of the technological challenges posed by a sustainable energy system, and of the possibilities opened up by the latest developments in science and technology. The essay section concludes by examining questions of moral responsibility, social acceptance of the *Energiewende*, and how to implement new technologies while minimizing negative effects on local citizens. The second section of the catalogue presents ten major aspects of the energy transition, as

displayed in each of the “thematic rooms” of the exhibition. These cover the entire scope of the energy system, from production to distribution and consumption, and are illustrated using objects from the exhibition. In the final section, you can learn more about the concept behind the design of the exhibition and explore selected highlights from among the items on display.

Finally, we would like to express our gratitude to the public and private organizations who, recognizing the urgent relevance and significance of the topic, responded by providing donations and financial support. These include not only government bodies such as the German Federal Ministry for Economic Affairs and Energy in Berlin and the Bavarian Ministry of Economic Affairs and Media, Energy and Technology in Munich, but also supporters from the business community such as Linde AG and the innogy Foundation for Energy and Society.

Our heartfelt appreciation also goes out to the many departments here at the Deutsches Museum—exhibition design, graphic design, and photography, as well as educational outreach, communications, and publications—without whom this project would not have been possible. We are similarly indebted to our curators, an interdisciplinary team from the fields of engineering, natural sciences, sociology and anthropology, and food sciences, as well as to the project manager. We also want to acknowledge our external designers, the company Space4 from Stuttgart and teamstratenwerth from Basel, who were committed and inspiring partners in this project.



Professor Dr Wolfgang M. Heckl  
Munich, November 2016

The transition from the fossil fuel age to a climate-friendly and socially acceptable energy system is the great challenge of our age, and one that involves the entire world. This transformation can only be successful if business, politics, science, and the wider public join in discussing options for achieving common goals.

Prominent scientists reflect on the topic of Germany's *Energiewende* and energy transitions in general from a variety of perspectives; their essays provide a broad overview of the possibilities and challenges of this global project, as well as progress being made towards this goal.

# E S S



AYS

**History**

Energy  
Generation  
Distribution  
and Use  
Challenges





# History

The Development  
of an Idea

# Energy and Progress

## Understanding Energy Transitions from a World History Perspective

by Patrick Kupper



1 *The Industrial Revolution, driven in part by the invention of the railway, marked the transition from a solar to a fossil energy regime.*

Photo: danm / Moment Open / Getty Images

Since the Fukushima nuclear accident in Japan in spring 2011, and the change of course in German energy policy that followed, *Energiewende* has become a ubiquitous term. It has even been added to Duden, the leading German linguistic reference books. Derived from “Wende”, literally a “turnaround”, but used in an extended sense to refer to sudden and significant political or social change (the reunification of Germany

is referred to as the “Wende”, for example), the term has become well established in the German speaking world—in Austria and Switzerland as well as Germany—but there is no equivalent in other languages. In English and French, people speak of an “energy transition”, which is not quite the same thing: *transitions* happen, whereas a *Wende* is consciously pursued and (ideally) successfully implemented. This difference in meaning has not gone

unnoticed: in English, people have begun to speak of the “German *Energiewende*”. Will the term establish itself in English? And in years to come, will it be positively connotated, or will it instead be taken to refer to a peculiarity of the Germans, like *Angst*? To begin with, it is important to note that the term is not as new as recent discussions might lead us to think. In 1980, the Institute for Applied Ecology (Öko-Institut) in Freiburg published a report with the title “Energiewende” (see the contribution by Felix Chr. Matthes in this volume).<sup>1</sup> Its subtitle, “Growth and Prosperity without Petroleum or Uranium”, makes it clear that the meaning of the term has changed little since then; this is underlined by the Duden online definition as “the replacement of the use of fossil and nuclear energy sources by an ecological, sustainable energy supply”.<sup>2</sup> If the word *Energiewende* is taken to be the conceptual basis for the phenomenon, then the historical review can end here—or at least, it would have to be limited to the last fifty years. Here, however, a different approach will be adopted, one in which the historical dimension is extended as far as possible. From the perspective of the entire history of humankind, the question will be raised whether at other periods in the past there have been revolutionary changes in how societies have ensured their energy supply. How should such past changes best be described—as transitions, or as turnarounds? How does the *Energiewende* under discussion today fit into a long-term historical perspective? Limited space means that only a very general sketch of historical developments can be given here.<sup>3</sup>

### The Development of Sedentary Societies

At the beginning of the world’s energy history stands fire. The art of making fire opened up a whole new realm of possibilities to shape the lives of the fire-makers and their communities. Fire enabled humans to warm themselves and cook food, vastly expanding their dietary options. In addition, fire could be used to manufacture tools and weapons, or to drive animals as part of the hunt. Finally, fire played an important role in clearing forests to enable the cultivation of the land: the practice of shifting cultivation—once widely used both in tropical and temperate regions—involved the periodic burning of areas of land, which were then cultivated for a number of years before they were allowed to revert to wilderness. In some parts of the world, this practice continues today; in others, after being prohibited by the authorities in the twentieth century, it has recently been reintroduced as a sustainable form of cultivation in landscapes such as steppes or savannahs. This takes us to the beginning of another new stage in the progress of human history, generally termed the Neolithic Revolution. This period is characterized principally by the adoption of agriculture, which produced higher yields than the hunting and gathering



**2** In some places, as in this picture of rice fields in Madagascar, shifting cultivation is still commonly practised.

Photo: picture alliance/  
Mint Images/  
Frans Lanting

practised until then. Agriculture required a settled lifestyle and enabled the production of surpluses and thus of stores of provisions. A higher rate of population growth became possible, as did the establishment of larger settlements, even cities. Along with agriculture, the second fundamental innovation was the domestication of livestock, which substantially increased the labour power available. However, in both cases—agriculture and domestication—the term “revolution” is misleading. These were gradual transitions, which lasted hundreds of years, and which took place at different times in different regions of the world, progressing at different speeds and with different rates of adoption. Hunter-gatherer societies continued to coexist with agricultural societies for thousands of years. In a few cases, agriculture was later abandoned entirely; such cases were usually associated with the collapse of a civilization and of the local population. Without agriculture, a lifestyle that depended on a higher energy input could not be maintained, nor could densely populated settlement forms. Both hunter-gatherer and agricultural societies were built on a solar energy regime founded on the photosynthesis of plants. Up until the nineteenth century, collecting wood and edible plants, or the cultivation of food and fodder plants, provided the great majority of their energy resources, which were consumed in the form of heat and human and animal muscle power. The power of wind and water was also harnessed to power mills and facilitate the transport of goods and people over longer distances. Waterways were by far the most convenient transit route: ships navigated them (assisted by wind and sails), and logs could be floated downstream or bound into rafts for transport. Over the centuries, improvements were made in the various technologies used, although sometimes knowledge and skills were later lost again. Nonetheless, the contribution made by water and wind to the overall energy usage of pre-modern societies remained small. Even in countries like the Netherlands, where such technologies were comparatively widely established, their share was probably less than 10%, and in most regions less than 1%. In some regions peat and coal were also important, but from a trans-regional perspective the use of fossil energy sources was insignificant.<sup>4</sup>

## History

Energy  
Generation  
Distribution  
and Use  
Challenges

**3** *The Hoover Dam in the US state of Nevada was constructed between 1931 and 1935 on the Colorado River. The hydroelectric plant's 17 turbines have a capacity of 2,080 MW.*

Photo: Andrew Zarivny/  
Shutterstock.com



### The Advent of the Fossil Fuel Era

Starting in the late eighteenth century, a fundamental socioeconomic and ecological reconfiguration was ushered in by the Industrial Revolution, which transformed the solar energy regime into a fossil one. The Industrial Revolution too was not a rapid upheaval, but instead a long-term process that took hold in different societies and regions at different times and in different forms. It is therefore more appropriate to talk of industrialization, or of industrializations in the plural, transforming many parts of the world directly or indirectly since the nineteenth century. The energy that drove these processes was fossil fuels, initially coal, later supplemented by petroleum and more recently natural gas. Key technological innovations were, first, the coal-fired steam engine, which made it possible for the first time to convert heat into mechanical energy and paved the way for the rise of heavy industry and of steamships and the railways in the nineteenth century; and second, the combustion engine, which created the foundation for a revolution in the transportation of people and goods in the twentieth century. Electricity was added to the technologies of the fossil energy regime from the late nineteenth century onwards, quickly proving indispensable to modern societies on account of its broad spectrum of applications, from lighting to driving motors and machines to communications and heating. The fossil energy regime brought about multiple transitions. The large-scale use of fossil fuels was crucial in overcoming the limits to growth that had existed

up to then. The same fossil fuels made it possible to massively increase transport capacity and make it much cheaper, so that societies became increasingly less dependent on the resources available in their immediate vicinity. The exploitation of these “subterranean forests”, as environmental historian Rolf Peter Sieferle called the coal deposits, made it possible for a country to consume far more resources over a given period of time than it could produce—more than even the entire world could produce, in fact.<sup>5</sup> This resulted in a transition to an economic model that was unsustainable, not only regionally, but globally as well. In addition, the rapid acceleration in resource use after 1950 caused global environmental problems.<sup>6</sup> Towards the end of the twentieth century, it became clear that the sharp increase in greenhouse gas emissions was altering the climate around the world. Furthermore, the question of who was controlling and supervising the increasingly globalized resource and energy flows became a matter of the greatest geopolitical significance. Freedom from dependence on local resources was bought at the cost of new forms of dependence at the supra-regional and international levels; these became particularly noticeable when the resources failed to flow in the manner to which people had become accustomed—when war and conflicts disrupted their movement, or even brought it to a complete standstill. The oil crisis of 1973/74 opened the eyes of Western societies to their dependence on petroleum from the volatile, crisis-prone Middle East, and during the years that followed, it prompted a reconsideration of energy policy. The current *Energiewende* follows on from that.<sup>7</sup>



p. 88–93



## Today's *Energiewende* in the Context of the Past

As this brief tour through the last several thousand years makes clear, energy transitions have always coincided with major transitions in society. This is hardly surprising when we consider the social importance of energy. Social ecologists Fridolin Krausmann and Marina Fischer-Kowalski, following on from Marx, speak of the “necessity for human beings to secure their livelihood through an exchange with nature in a socially organized process involving labour”.<sup>8</sup>

Inspired by classical mechanics, energy can be understood as the capacity to do work. Socially mobilized energy thus indicates the capacity of a society to actively shape the world it lives in. The term “transition” (in German: *Übergang*) seems a more apt description of the process of change than a *Wende* or turnaround, since the changes generally took place over long periods of time and were relatively uncoordinated and undirected. Furthermore, individuals and societies clung doggedly to earlier forms of energy use to which they were accustomed and adapted, and which they had also invested in, regulated and managed. New forms did not supplant their predecessors, but rather supplemented and overlaid them, which is why transitions have always led to an expansion of energy supply.<sup>9</sup>

Nonetheless, history provides two plausible candidates for an earlier *Energiewende*, both of which required substantial investments and thus drew governments into planning. The first is hydroelectricity, which was pursued on an ambitious scale in the first half of the twentieth century by systems as different as the USA during the New Deal, Nazi Germany, and the Soviet Union under Stalin;<sup>10</sup> China and countries of the Global South followed suit in the latter half of the century, with Western support. The second is the civilian use of nuclear power, which during the postwar decades seemed to promise a solution to the energy problem—and at the same time to the food problem—once and for all. But these grand hopes were soon dashed.<sup>11</sup> While some still cling to the promises proffered by the atom, everyone else—including many future generations—has to deal with the radioactive material reality of this technology.

This includes the adherents of today's *Energiewende*, which aims to develop an energy supply that does not use nuclear energy and produces substantially lower carbon dioxide emissions. The vision that underlies this *Energiewende*, however, is fundamentally different from those behind the earlier ones (hydroelectricity and nuclear power) in at least two ways. Firstly, it relies not on one large-scale solution, but on a great many small ones, thus leaving room for local variations. Secondly, it does not envision another increase in energy consumption, but rather a reduction. More



prosperity for all, while using less energy, sustainably—this is both the great promise and the epochal societal challenge represented by the German *Energiewende* going global.

**4** Locating factories next to rail lines allowed for the quick and easy transport of coal into the factory and goods out of it.

Photo: National Railway Museum/SSPL/Süddeutsche Zeitung Photo

- 1 Krause, Florentin; Bossel, Hartmut; Müller-Reißmann, Karl-Friedrich. *Energie-Wende: Wachstum und Wohlstand ohne Erdöl und Uran; Ein Alternativ-Bericht des Öko-Instituts/Freiburg*. Frankfurt a.M. 1980.
- 2 Duden. *Energiewende*, [www.duden.de/rechtschreibung/Energiewende](http://www.duden.de/rechtschreibung/Energiewende) (accessed 10. 1. 2017).
- 3 Cf. Burke, Edmund. *The Big Story: Human History, Energy Regimes, and the Environment*. In: Burke, Edmund; Pomeranz, Kenneth (eds.). *The Environment and World History*. Berkeley 2009, pp. 33–53. Krausmann, Fridolin; Fischer-Kowalski, Marina. *Gesellschaftliche Naturverhältnisse: Energiequellen und die globale Transformation des gesellschaftlichen Stoffwechsels*. Vienna 2010. Smil, Vaclav. *Energy in World History*. Boulder 1994.
- 4 Cf. Kander, Astrid; Malanima, Paolo; Warde, Paul. *Power to the People: Energy in Europe over the Last Five Centuries*. Princeton 2013.
- 5 Siefert, Rolf Peter. *The Subterranean Forest: Energy Systems and the Industrial Revolution*. Cambridge 2001.
- 6 McNeill, John R.; Engelke Peter. *Mensch und Umwelt im Zeitalter des Anthropozän*. In: Iriye, Akira; Osterhammel, Jürgen (eds.). *Geschichte der Welt: 1945 bis heute – Die globalisierte Welt*. Munich 2013, pp. 357–534. Pfister, Christian (ed.). *Das 1950er Syndrom: Der Weg in die Konsumgesellschaft*. Bern 1995.
- 7 Graf, Rüdiger. *Öl und Souveränität: Petroknowledge und Energiepolitik in den USA und Westeuropa in den 1970er Jahren*. Berlin 2014.
- 8 Krausmann; Fischer-Kowalski, *Gesellschaftliche Naturverhältnisse*, p. 1.
- 9 Cf. Kupper, Patrick; Pallua, Irene. *Energierregime in der Schweiz seit 1800*. Bern 2016.
- 10 Hughes, Thomas P. *Networks of Power: Electrification in Western Society 1880–1930*. Baltimore 1983.
- 11 Kupper, Patrick. *From Prophecies of the Future to Incarnations of the Past: Cultures of Nuclear Technology*. In: Nowotny, Helga (ed.). *Cultures of Technology and the Quest for Innovation*. Oxford, New York 2006, pp. 155–166.



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p. 94–99

# The History of the *Energiewende*

## The Origin and Adoption of an Energy Policy Concept for the Future, and Its Current Prospects

by Felix Chr. Matthes

When the book *Energiewende: Wachstum und Wohlstand ohne Erdöl und Uran* (“Energiewende: Growth and Prosperity without Petroleum or Uranium”) was published as an “Alternative report by the Institute for Applied Ecology (Öko-Institut) in Freiburg”<sup>1</sup> in 1980, it introduced a new term into the energy policy debate in Germany. But not only that; it laid the foundations for a concept that—with slight variations of emphasis in meaning over time—would decisively shape the energy debate for the next three decades and more, and would ultimately become the dominant term within German energy policy. And yet the basic elements of a “gentle path” towards an energy supply that would remain viable over the very long term (the current standard term for this, “sustainable”, established itself in the wider debate only after the publication of the Brundtland Report of the UN World Commission on Environment and Development in 1987<sup>2</sup>) did not originate in the German context at all. In fact, they were taken over from the work of pioneering theorists of energy policy in the United States such as Amory Lovins and adapted and systematized for the debate in Germany. Lovins’ 1976 article “Energy Strategy: The Road Not Taken?”<sup>3</sup>, still highly relevant today, dramatically ignited the debate in the United States and abroad about the *Energiewende*—without however being able to create a term with comparable power and concision.

### The Concept of the *Energiewende*

The basic concept of the *Energiewende* ultimately derives from two insights. First, the recognition that the course of energy policy and strategy to date is in urgent need of fundamental change. Second, the calculation that an energy system structured and oriented in a fundamentally different way, using already available—or at least foreseeable—technologies, can deliver equal levels of

growth and prosperity while being more effective and affordable and enjoying greater social support. The original 1980 report stated that “the thesis of this book is that a fundamental and radical turnaround [*Wende*] in energy policy has become absolutely imperative in the Federal Republic of Germany (and in the industrialized nations more generally). We would like to present a new strategy for future energy supply, which after careful examination we believe to be technologically feasible and economically and politically advantageous, and

