Introduction: What Is This Book About? 1

1.1 Five Questions

In Germany, few political concepts have penetrated so deeply into the public consciousness as the *Energiewende*. This German term describes the transition to a sustainable energy economy and literally means "energy turnaround", although it is usually translated as "energy transition". And it is unlikely that there exists another political project—or political vision—that enjoys such a wide-ranging, fundamental consensus in German politics, business and society as the *Energiewende*.

Internationally, too, the *Energiewende* certainly appears to have received more attention than most other projects by the German government. Many countries respect, even admire, Germany for this project and its—in global comparison—very ambitious goals. The main reason for the *Energiewende*'s remarkable popularity is undoubtedly the fact that it can essentially be regarded as the German response to *climate change*, which is perceived as one of the greatest challenges, if not *the* greatest challenge, that humanity faces today.

In marked contrast to this picture, ever since the official launch in 2010/2011 Germany has struggled through years of ongoing and intense public controversy around the *Energiewende*, including repeated and severe criticism of the project—with the result that many citizens (while maintaining a positive attitude to the *Energiewende* itself) are now skeptical with respect to its implementation.

Similarly, seeing the way that the *Energiewende* has developed over the last 5 years, the mood within the global debate about this project has likewise become more skeptical. Earlier in the decade, the majority of comments ran along the lines of: "The *Energiewende* is very demanding, especially from a technological perspective, but the Germans can do it". Today the tune has often changed to: "Germany's approach just isn't going to work—the *Energiewende* is far too expensive and too inefficient" (and sometimes international observers venture so far as to say "The Germans must be crazy if they go on like that").

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Looking closer, key critical statements made about the *Energiewende* in the course of Germany's public debate turn out to be the same as those made at the international level:

- The *Energiewende* will cost an incredible amount of money; it is too expensive for the German economy.
- The *Energiewende* places too high a burden on private households (electricity prices are too high).
- The *Energiewende* threatens the international competitiveness of German industry (electricity prices are too high).
- German CO_2 emissions have barely decreased despite the *Energiewende*, and, in any case, the effect of the *Energiewende* on climate change is practically zero.

Are these statements true or false? Is this criticism of the *Energiewende* justified or not?

The first essential purpose of this book is to present a comprehensive, systematic and impartial account of the *Energiewende*—on the basis of which these questions can be answered objectively, i.e., drawing on the relevant facts, figures and reliable arguments.

Even though the *Energiewende* is *in its design* the transition to a sustainable energy economy *in all three energy sectors*—electricity, heating and transportation—in this book we confine ourselves throughout to the electricity sector. The main reason for this is the fact that *in the implementation* of the *Energiewende* so far (i.e. in the past 5 years), most of the political efforts, measures and discussions, most of the public debate in Germany as well as (consequently) most of the international attention have been devoted to the electricity sector. In a nutshell, in the first years of the project, the *Energiewende* in Germany was essentially not an *energy transition*, but (only) an *electricity transition*.

(It is certainly justified to criticize this state of affairs, i.e. to demand of the energy policy that similar emphasis be placed on the heating sector and the transportation sector. It would also be possible to point out why it is, on the other hand, certainly understandable that the German *Energiewende* policy has been one-sided so far in the above sense. And one can ponder the question when/to what degree this has to change in the coming years. But such considerations go beyond the scope of the book.)

Hence, in the following we will use the term "*Energiewende*" to mean the German energy transition in the electricity sector.

In addition to the above-mentioned change in the attitude of many international observers towards the German energy transition, the last 5 years have seen a second global development that is important with respect to the aims of this book: a growing awareness among many governments and in the international community of the urgency of the climate problem, which led to the Paris Climate Agreement in December 2015. Through this agreement, all major countries have committed themselves to pursuing the so-called "2 °C target", i.e. to cut their CO_2 emissions by the middle of the century to a level close to zero. And despite their differing attitudes toward nuclear energy, almost all countries agree that this target should mainly be achieved by way of renewable energies.

But this means nothing less than that a vast number of countries must undergo a fundamental transformation of their own electricity sector within the next 35 years. And since the electricity sectors in many of these countries have characteristics similar to Germany's before its *Energiewende*—at least 60% share of fossil fuels, electricity generation concentrated in relatively few large power plants, mostly close to electricity consumption centres—the challenges for these countries are actually quite similar to those posed for Germany, despite all the differences in detail.

This raises the following key question: If an *Energiewende* as discussed in this book (i.e. an energy policy with the primary goal of comprehensively replacing fossil fuels with renewable energies in the electricity sector) is essentially indispensable, or in other words, *if the German energy transition project is to a certain extent a prototype for similar projects in other countries*—what lessons can these countries learn from the German example?

Now it is clear that each such individual energy transition project depends heavily on the specific economic, political and technical conditions in the country, and so each country must find its own path. Nevertheless, since learning from mistakes is the best way to learn, we believe it will be helpful and important for national energy transformation processes in other countries to avoid a number of defects in the German energy transition project; in other words, not to commit again what now, with the benefit of 5 years of experience, can reasonably be considered essential political mistakes in the course of the *Energiewende*.

Therefore, **the second essential purpose** of this book is to identify these mistakes, again on the basis of the systematic account of the *Energiewende* we will present here.

The compostion of the book emerges from the two purposes outlined above. In the first part, we provide a clearly structured description of the basic concepts and the concrete design of the *Energiewende* as well as an analysis of its inevitable consequences for the German electricity system. The second part looks at the current status, mainly comparing the planned milestones of the *Energiewende* goals with the actual data of 2015 and 2016. This allows us to identify successes as well as shortcomings and failures.

The third part is devoted to the crucial issue of the costs of the *Energiewende*, likely to be the most controversial and critical topic—in the national debate as well as in the assessment of international observers. We present a reliable overview of the key figures (without going into too much detail), also covering the period up to 2030, and we discuss the essential effects on the main stakeholders of the national economy, private households and businesses. On this basis, we develop a rough but solid estimate as to the cost of an energy transition in any industrialised country, in relation to its GDP.

At the end of the book, in the fourth part, we will then sum up the issues outlined above; that is to say, we will comment on the following **five questions**:

1. Is the *Energiewende* too expensive for Germany's national economy?
2. Can private households and businesses cope with the financial burden resulting from the *Energiewende*?

(continued)

3. What are the actual effects of the *Energiewende* on CO_2 emissions?
4. What are lessons to be learned from the design of the *Energiewende*?
5. What are lessons to be learned from the implementation of the *Energiewende*?

1.2 Units

In this book, apart from € = Euro, $ = US dollar and t = metric ton, we use only two (energy-related) units: kilowatt and kilowatt-hour.

Kilowatt (kW)
It is a measure of the power output or capacity (maximum power output) of a power plant or the power consumption by a device or customer.

Typical power plant ratings are:

Rooftop PV system	5 kW
Wind turbine	2000–3000 kW = 2–3 MW (megawatt)
Conventional large-scale power plant	1 million kW = 1 GW (gigawatt)

Typical power consumption ratings in the electricity sector are:

Light bulb	0.06 kW
Hairdryer	1 kW
Large industrial facility	10,000–100,000 kW
Germany total (peak)	80 million kW

In this book we have generally used the unit GW (gigawatt) = 1 million kW.

Kilowatt-Hour (kWh)
It is a measure of the quantity of electricity a power plant produces (e.g. in 1 year) or that a device or customer consumes (e.g. in 1 year), respectively.

Typical quantities of electricity produced by a power plant are:

Rooftop PV system	5000 kWh per year
Wind turbine	3–5 million kWh per year
Conventional large-scale power plant	5–7 billion kWh per year = 5–7 TWh per year

Typical dimensions of electricity consumption are:

Refrigerator	70–100 kWh per year
Typical German household	3000 kWh per year
Large industrial facility	50–500 million kWh per year
Germany total	600 billion kWh per year

In this book we have generally used the unit TWh (terawatt-hour) = 1 billion kWh.

Table 1.1 Primary energy consumption in Germany (in TWh) in 2015

Primary energy sources	Quantity of energy (TWh)	%	Import quota
Oil	1250	34	98%
Natural gas	780	21	91%
Hard coal	470	13	89%
Lignite	440	12	0%
Nuclear energy	280	7	100%
Renewable energies	465	13	0%
Others	15	0	0%
Total	**3700**	**100**	**70%**

[1]

Table 1.2 Metrics for primary energy consumption (PEC), 2015

	World	Germany
PEC	170,000 TWh	3700 TWh (= 2.2%)
GDP/PEC	€ 0.4/kWh	€ 0.8/kWh
PEC per capita	23,000 kWh per capita	45,000 kWh per capita

GDP gross domestic product (at 2015 prices); [1, 2]

1.3 Basic Facts and Figures: Germany

1.3.1 Energy Consumption

In 2015, Germany consumed a total of 3700 TWh of primary energy (i.e. energy sources that are converted into either electricity, heat or transportation; Table 1.1).

A brief comparison with the worldwide primary energy consumption is shown in Table 1.2.

Regarding the three main sectors of energy consumption—electricity, heat and transportation—the final energy consumption of about 2465 TWh in 2015 is broken down as shown in Table 1.3.

1.3.2 Electricity Consumption

The approximately 600 TWh of electricity produced per year in Germany in recent years (2011–2015) to meet domestic demand for electricity (i.e. not including electricity exports)—the so-called *gross electricity consumption*—is broken down between the major consumer groups as shown in Table 1.4.

A brief comparison with worldwide gross electricity consumption is given in Table 1.5.

The development of (gross) electricity consumption in recent decades is shown in Table 1.6.

Table 1.3 Final energy consumption in Germany by sector (in TWh) in 2015

Sector	Quantity of energy (TWh)	%
Electricity	520	21
Heating	1230	50
Transportation	715	29

Heating = excluding heat from electricity; transportation = excluding electricity-based transportation; [1, 3]

Table 1.4 Gross electricity consumption by consumer group in Germany (in TWh) in 2015

Consumer group	Electricity (TWh)	%
Industry	230	44
TSS	80	15
Private households	130	25
Public sector and others	80	16
Final energy consumption—electricity	**520**	**100**
Power line losses/power plants	75	
Gross electricity consumption	**595**	

TSS Trade and service sector; [1]

Table 1.5 Metrics for gross electricity consumption (GEC), 2015

	World	Germany
GEC	24,000 TWh	595 TWh (= 2.5%)
GDP/GEC	€ 2.8/kWh	€ 5/kWh
GEC per capita	3300 kWh per capita	7400 kWh per capita

GDP gross domestic product (at 2015 prices); [1, 2]

Table 1.6 Development of gross electricity consumption in Germany (in TWh)

1990	2000	2010	2015
550	580	615	595

[4]

Table 1.7 German CO_2 emissions (in mio t)

CO_2 emissions	1990	2000	2010	2015
Energy related	990	840	780	750
Other	60	60	50	50
Total	**1050**	**900**	**830**	**800**

[5, 6]

1.3.3 CO_2 Emissions

Over the last 25 years, German CO_2 emissions have developed as shown in Table 1.7.

Add to this further greenhouse gas of currently about 100 million tons.

Table 1.8 Energy-related CO_2 emissions in Germany by energy consumption sector, 2015

Energy sector	CO_2 emissions (mio t)	%
Electricity (including exports)	310	41
Heating	280	38
Transportation	160	21
Total	**750**	**100**

[6, 7]

Table 1.9 Metrics for CO_2 emissions, 2015

	World	Germany
CO_2 emissions	36,000 mio t	800 mio t (= 2.2%)
CO_2 emissions/GDP	0.54 kg/€	0.27 kg/€
CO_2 emissions per capita	4.9 t per capita	9.8 t per capita

[2, 5]

Table 1.10 Development of CO_2 emissions from electricity generation excluding electricity exports (in mio t)

1990	2000	2010	2015
360	330	305	270

Electricity exports assumed to stem mainly from hard coal power plants; [7]

The next table (Table 1.8) shows a breakdown of energy-related CO_2 emissions to the three key sectors of energy consumption.

Table 1.9 gives a brief comparison with global CO_2 emissions.

The development of CO_2 emissions from electricity generation (excluding electricity exports) in recent decades is shown in Table 1.10.

1.3.4 Energy Imports

As illustrated above, Germany currently imports around 70% of its primary energy sources; the average cost of these imports in recent years is shown in Table 1.11.

The cost development in recent decades is given in Table 1.12.

In 2015, the sharp decline in global prices for primary energies led to these costs falling again to a level of about € 60 billion.

1.4 Basic Facts and Figures: OECD Countries

1.4.1 Energy Consumption

In recent years, primary energy consumption and energy efficiency for a number of OECD countries looked like as shown in Table 1.13.

Table 1.11 Average annual import costs for energy between 2010 and 2014 (€ billion)

Primary energy source	Costs
Oil	61
Natural gas	18
Hard coal	5
Nuclear energy	0.3

[1, 8]

Table 1.12 Cost development of German energy imports (in € billion per year, averaged)

	1990–1999	2000–2004	2005–2009	2010–2014
Energy imports	Approx. 20	Approx. 35	Approx. 60	Approx. 85

[1, 8, 9]

Table 1.13 Primary energy consumption (PEC) and energy efficiency in the OECD in 2014/2015

Country	Primary energy consumption (1000 TWh)	Energy efficiency (GDP/PEC) ($/kWh)
Germany	3.7	1.05
USA	26	0.7
UK	2.1	1.3
Australia	1.5	0.75
Canada	3.0	0.5
Mexico	2.2	1.0
Japan	5.1	0.95
OECD	61	0.85

GDP gross domestic product, in $ on the basis of 2015 Purchase Power Parities; [10, 11]

Table 1.14 Electricity mix in the OECD in 2014, shares in %

Country	Fossil fuels	Nuclear energy	Renewable energies
Germany	57	16	27
USA	67	19	14
UK	60	19	21
Australia	85	0	15
Canada	22	18	60
Mexico	79	3	18
Japan	85	0	15
OECD	59	18	23

[10, 11]

1.4.2 Electricity Generation

Turning to electricity, let us look at the current electricity mix of OECD countries in Table 1.14.

Table 1.15 Gross electricity consumption (GEC) and electricity efficiency in the OECD in 2014/2015

Country	Gross electricity consumption (TWh)	Electricity efficiency (GDP/GEC) ($/kWh)
Germany	600	6.0
USA	4300	4.2
UK	350	7.7
Australia	250	4.4
Canada	640	2.5
Mexico	300	7.3
Japan	1000	5.1
OECD	10,800	4.8

GDP gross domestic product, in $ on the basis of 2015 Purchase Power Parities; [10, 11]

Table 1.16 Key figures on CO_2 emissions in the OECD, 2014/2015

Country	CO_2 emissions (mio t)	CO_2 emissions/GDP (kg/$)	CO_2 emissions/capita (t)	Development of CO_2 emissions since 2000
Germany	800	0.2	10	−11%
USA	5600	0.31	17	−7%
UK	440	0.16	7	−22%
Australia	390	0.35	16	+12%
Canada	570	0.36	17	−24%
Mexico	470	0.21	4	+22%
Japan	1200	0.26	10	+5%
OECD	12800	0.25	10	−4%

GDP gross domestic product, in $ on the basis of 2015 Purchase Power Parities; [10, 11]

1.4.3 Electricity Consumption

If we look at the gross electricity consumption and at electricity efficiency within the OECD, the emerging picture is shown in Table 1.15.

1.4.4 CO_2 Emissions

Finally, we list important figures relating to CO_2 emissions in the OECD (Table 1.16).

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