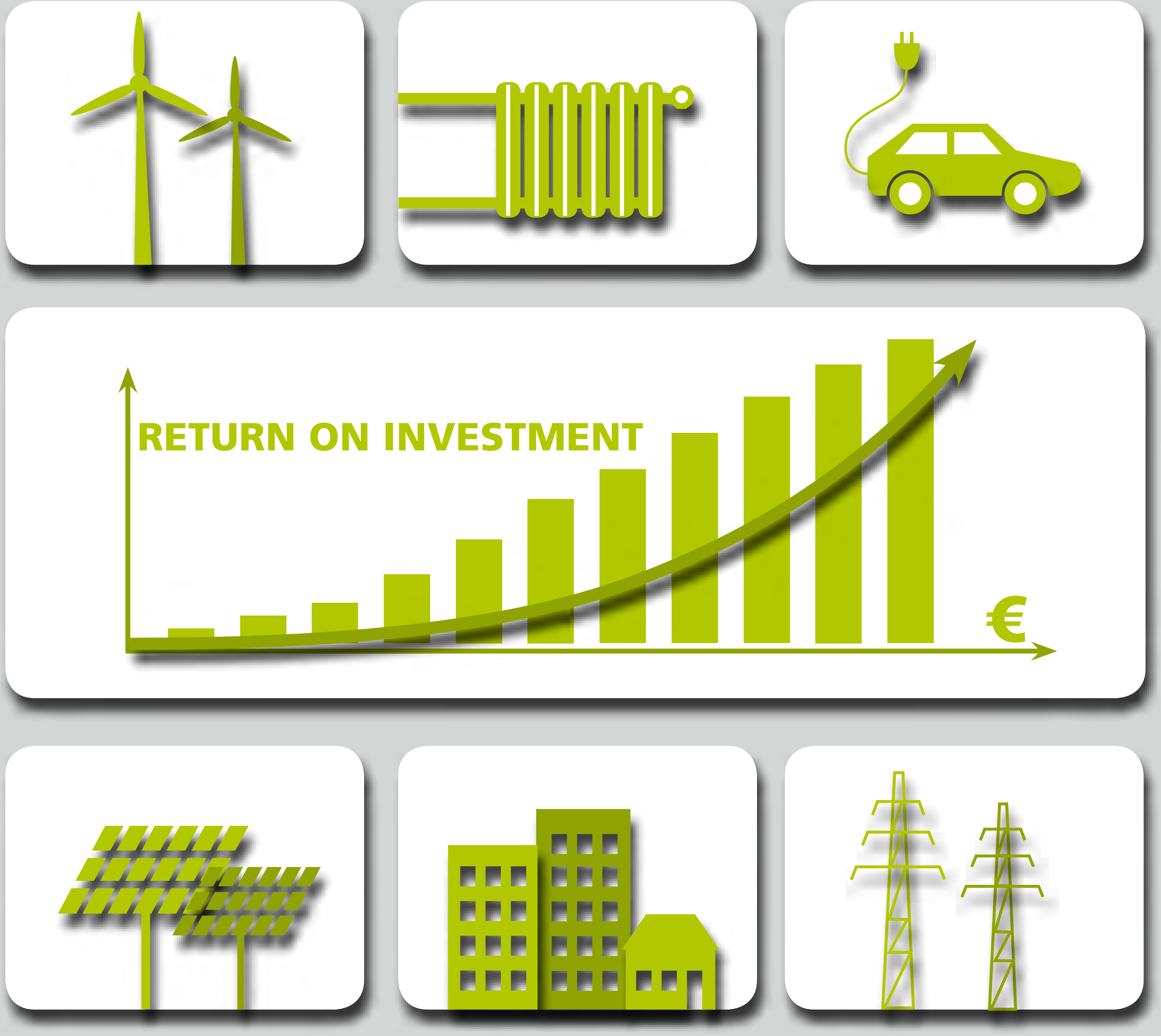
Fraunhofer
IWES

FRAUNHOFER INSTITUTE FOR WIND ENERGY AND ENERGY SYSTEM TECHNNOLOGY IWES

A BUSINESS MODEL FOR THE ENERGIEWENDE

A Rejoinder to the »Cost Argument«



A BUSINESS MODEL FOR THE ENERGIEWENDE

A Rejoinder to the »Cost Argument«

Prof. Dr. Clemens Hoffmann

Norman Gerhardt, Fabian Sandau, Britta Zimmermann,
Dr. Carsten Pape, Dr. Stefan Bofinger
Fraunhofer Institute for Wind Energy and Energy System Technology IWES

1st edition, Kassel, January 2014
Revised 2nd edition, Kassel, April 2015

Inhalt

1
Summary

Current public and political discussion surrounding the »Energiewende« – that is, Germany's broad-based political effort to create an energy economy dominated by renewables – is preoccupied with concerns about costs. But these worries are misplaced. In reality the Energiewende is a low-risk investment with a high likelihood of positive returns. As a response to naysayers, Fraunhofer IWES has worked out a concrete proposal for funding the Energiewende as part of its Hercules project.

Investements in new capital-intensive technologies must be weighed against gradually avoided fossil fuel costs for old technologies with high variable operating costs. In the new energy system envisioned by the Energiewende, wind and solar energy will provide power for the electricity, transportation, and heating sectors. Careful calculations have shown that the Energiewende is financially feasible in its totality, even under very conservative assumptions, in which fuel prices remain constant and environmental damage from CO_2 emissions are ignored. Even ambitious climate targets, such as 100% reliance on renewable energy (let alone the current plan for an 80% reduction in greenhouse gasses) are economically realistic. Hence, as politicians make decisions about climate policy, they must factor in the total savings and benefits along with the costs.

Assuming 2011 prices for primary energy, total investments for the Energiewende are likely to yield an inflation-adjusted rate of return of 2.3% by 2050 (see Fig. 1 and section 4). As we extend the timeframe beyond 2050, expected returns increase progressively – a result of expenditures for repowering renewable energy plants being only a fraction of fuel cost savings.

Assuming that prices for oil and natural gas increase through 2050, returns on investing in the Energiewende will be even greater. If we take into account real price increases in the linear cost projection of Germany's 2014 Grid Development Plan (BNetzA 2013) or the 2050 Climate Protection Scenario developed by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (Oko-Institut, ISI, 2013), total returns will be 4.0% to 6.7%, adjusted for inflation.

This estimate does not include the positive repercussions on the total economy (economic growth, jobs) caused by strong, long-term infrastructure investment. Nor does it factor in subsidies for conventional power stations and fuels still in effect today.

The Energiewende must be approached as a large-scale industrial and political undertaking, and it should be guided by modern project management principles. The objectives, the scope of infrastructure expansion, and the financial blueprint need to be clearly defined in advance. Once the basic economic viability of a specific plan has been established, the next step is to carry out financing. The key is to utilize the fuel savings in the transportation and heating sectors for funding the expansion of renewable energy. For this, Germany's Renewable Energy Act – which passes on annual expansion costs in the electricity sector to consumers – is not the right strategy in the long term. Policy discussion today must consider the long-term distribution of costs and savings beyond the confines of the electricity sector.

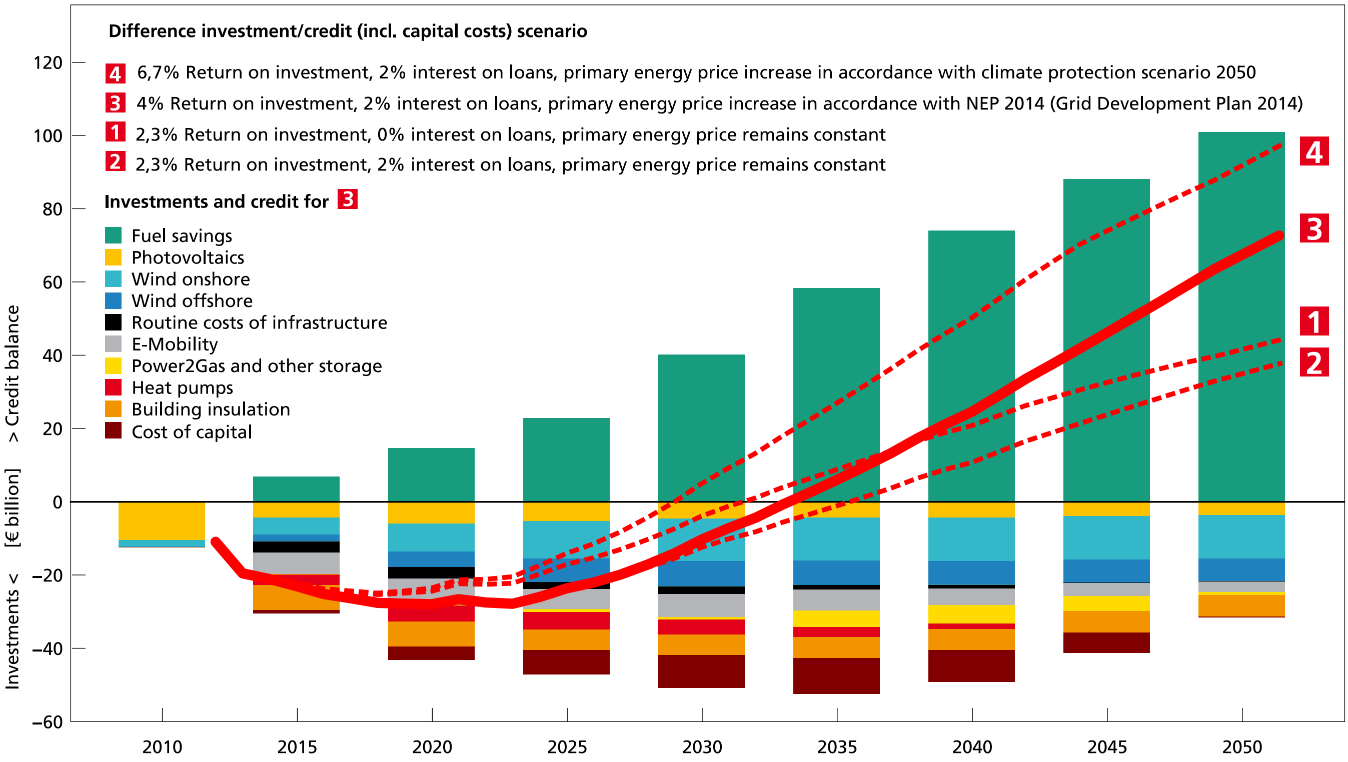


Fig. 1:
Cost and returns analysis for the Energiewende, based on various assumptions

2
Defining the Project

Investing in the Energiewende

Cost concerns currently dominate public and political discussion surrounding the Energiewende. One of the central questions is whether subsidies are justified for the climate's sake or whether consumers should to be protected from bearing additional electricity costs. The pro and contra positions both overlook a basic point, however. The Energiewende is an attractive investment opportunity with an enormous profit potential.

Fig. 2:
Engineering the Energiewende as a large-scale industrial project

The positive returns of the Energiewende

It is paramount that expenditures related to the Energiewende are seen as investments in a new energy infrastructure; thinking about the Energiewende solely in terms of costs is shortsighted. The Energiewende replaces old, OPEX-intensive technologies[1] with new CAPEX-intensive technologies[2]. When calculating expenditures, therefore, investment costs must be offset by savings from reduced primary energy costs and imports. In the long run, the returns on investment are positive. Furthermore, the overall undertaking is backed by the strength and reputation of the German economy, providing a reliable investment for many national and international investors.

The objective of the Energiewende

The objective of the Energiewende is to cover demand in three energy sectors – electricity, heating, and transportation – through renewable energy and greater energy efficiency. Demand in these sectors is almost entirely responsible for CO$_2$ emissions in Germany and makes up the main share of primary energy use. The remainder of primary energy, mineral oil in particular, is for non-energy use in material applications. The aim is to guarantee consumers a constant price relative to levels in 2011, the year that, owing in large part to the Fukushima disaster, the expansion of renewable energy and the phase-out of nuclear power achieved broad consensus in German society.

The Energiewende and Climate Policy

A successful Energiewende in Germany would change the course of future climate conferences. The example of a CO$_2$-free energy system in an industrial nation with a population of eighty million would provide a welcome alternative to the repeated failures that the international conferences in Copenhagen, Cancun, Durban, Doha, and Warsaw have left in their wake. In this way, Germany's energy policies would have a normative effect, lending new force to the fight against climate change.

---

[1] OPEX, or operational expenditures, represent investment costs for operations.

[2] CAPEX, or capital expenditures, represent investment costs for long-term capital goods such as new equipment, machines, and real estate.

3

Project Scope

Is there a master plan?

The word »master plan« has fallen into disfavor in political discussions because it implies a centrally planned economy. But the planning of large-scale national projects need not contradict the principles of market economics. The moon landing would not have been conceivable without the Apollo space program's careful planning and execution. The Herculean task of the Energiewende is incomparably more important than manned spaceflight. It too must be carefully planned to avoid bad investments that fall short of their objectives. German politicians agree that they cannot determine every detail in advance in a project spanning thirty to forty years. Rather, such a project must allow for dynamic adjustments to specific conditions while offering sufficient stability for large investments.

In this section, we present the details of planning for the Energiewende so far. It is organized as follows:

1. Analysis of future energy-use sectors
2. Calculating a 100% renewable energy supply scenario for 2050
3. Determining the renewable power generation mix
4. Energy system infrastructures
5. Calculating total investment volume

On the basis of the 2050 target scenario a financial blueprint can be developed for the Energiewende's transformation of the power supply system. The financing plan is presented in section 4.

3.1

Analysis of future energy-use sectors

Our forecast of future energy use is based on current use structures and those that will arise in the course of the renewable energy revolution. In 2011, total primary energy in Germany (fig. 3) amounted to 3772 TWh. (Adjusted for temperature [+93 TWh] and for international shipping traffic [+31 TWh] the total is 3896 TWh.) The share of non-energy demand came to 285 TWh. This demand consisted mainly of mineral oil for material applications (AGEB 2013; AGEE-Stat 2013).

Direct CO_2 emissions from fuels in the energy sector are the primary source of greenhouse gases. Primary fossil fuels for non-energy use make up a small share of greenhouse gases and come from farming, industry, changes in land use, waste, and sewage. Given the slow rate of climate protection measures worldwide, nations must make significantly greater efforts to reach the goal of limiting global warming to 2 °C (UNFCCC, 2009) above pre-industrial levels. According to the Fraunhofer Institute for Wind Energy and Energy System Technology (IWES), this requires complete coverage of the needs of the electricity, heat, and transportation sectors by renewable energy as well as increased energy efficiency. The minimum target of Germany's National Action Plan (BMWi, BMU 2011) – an 80% reduction of CO_2 emissions – will not suffice. What seems needed is its maximum target: a 95% reduction of CO_2 emissions (Fig. 4).

The total primary energy use for 2011 is shown in Figure 5. Within Germany, only lignite, low shares of bituminous coal, natural gas, and mineral oil were extracted. Costs for primary energy imports totaled €87 billion. Including extraction nationally, costs for primary energy totaled €96 billion (Fig. 5).

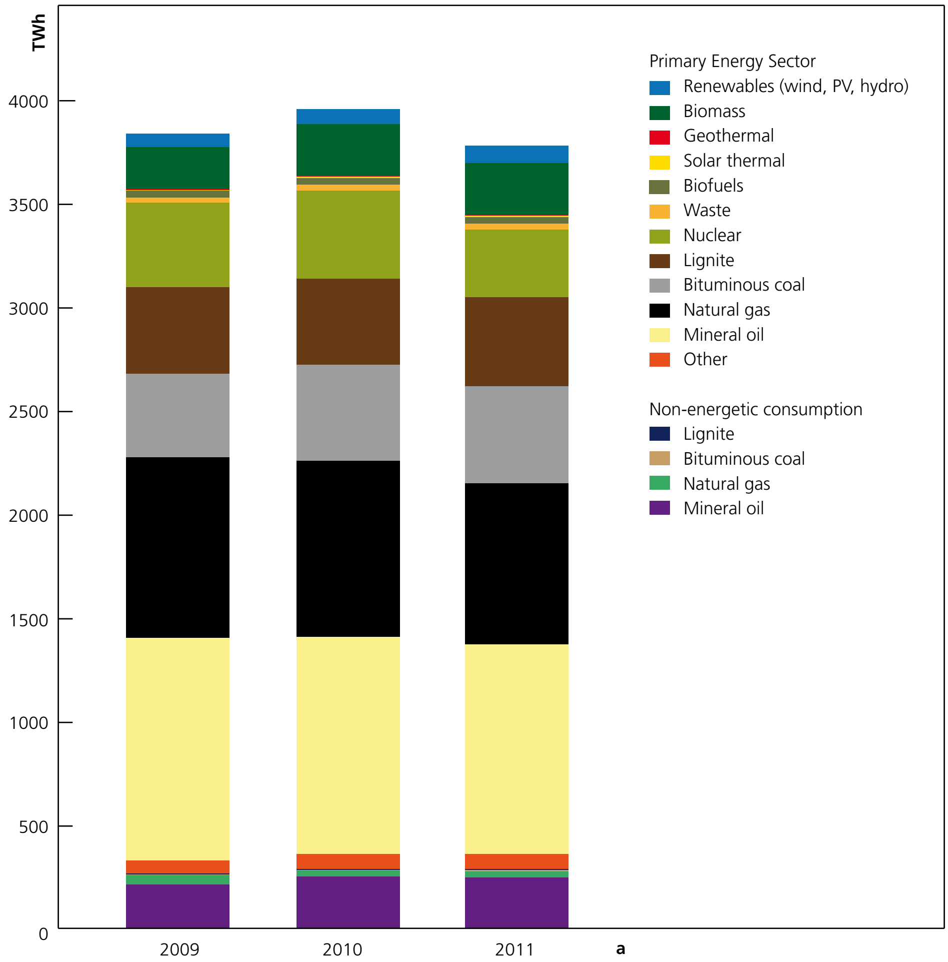


Fig. 3:
Primary energy consumption in 2009, 2010, 2011

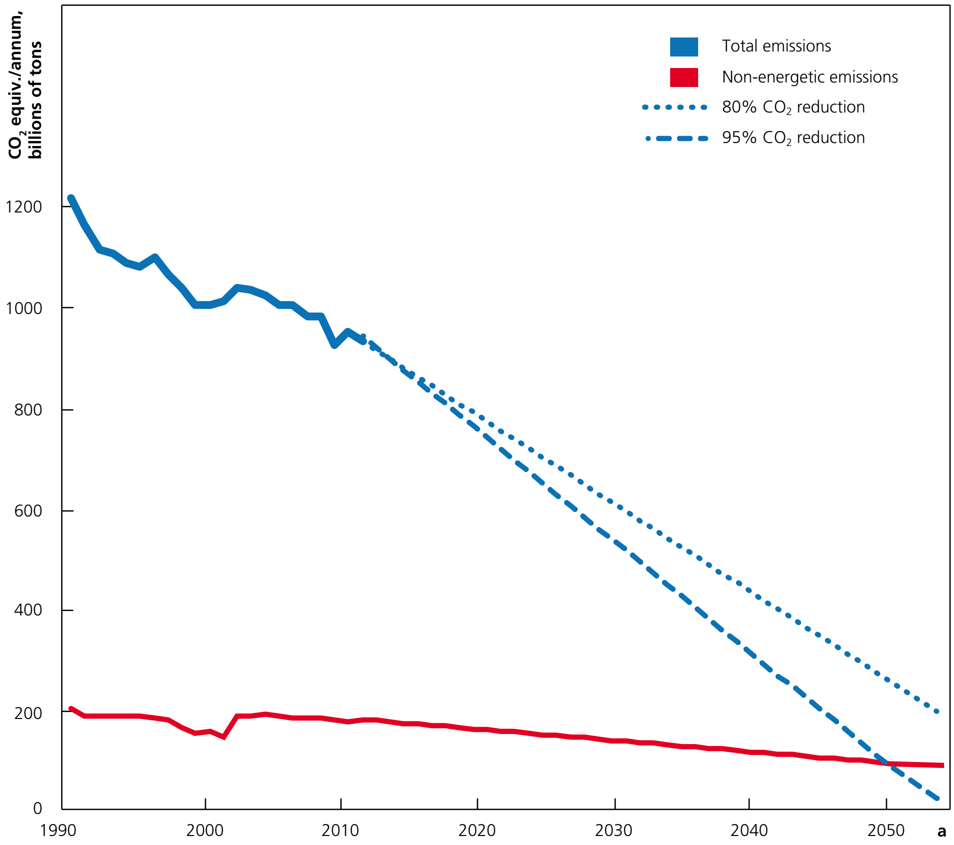


Fig. 4:
Evolution of greenhouse gas emissions

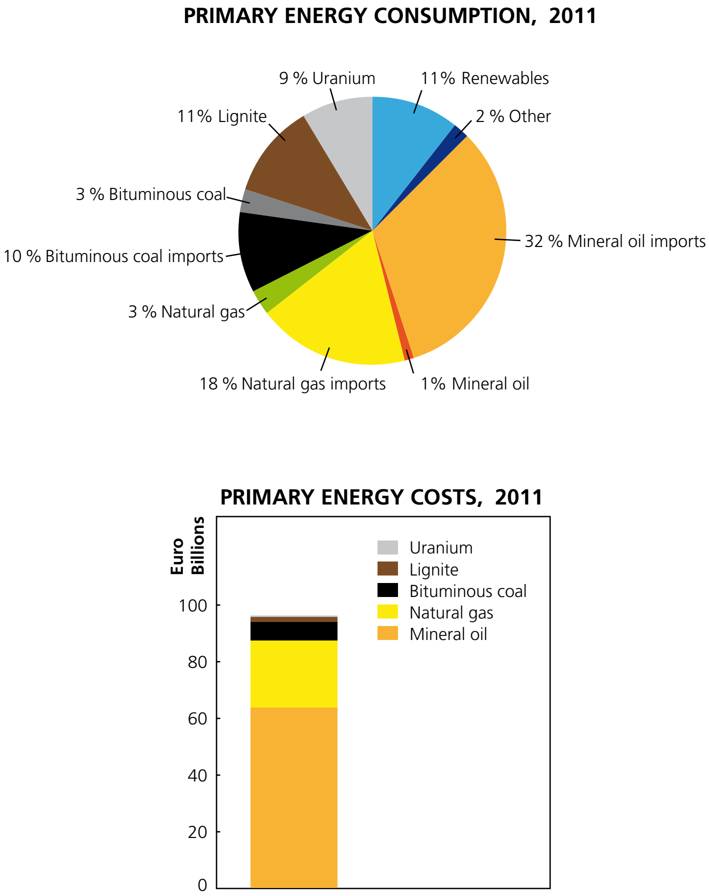
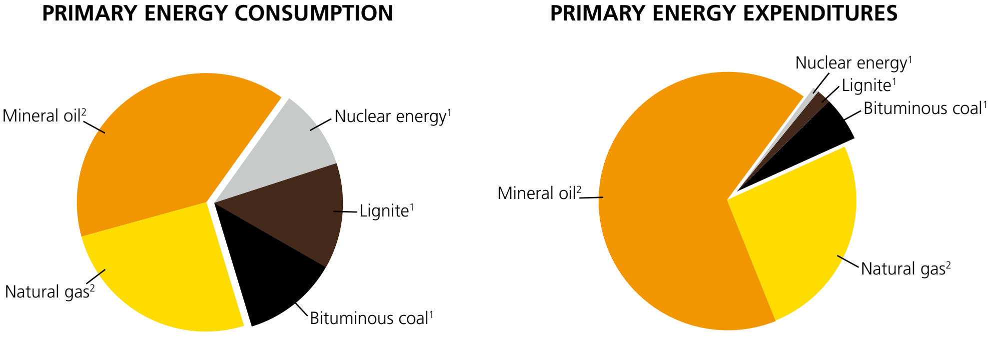


Fig. 5:
Primary energy consumption & primary energy consts, 2011

If we limit the scope to primary energy use in the sectors of electricity, heat, and transportation (€83 billion), we get the following distribution of primary energy by energy source (Fig. 6).



[1] Primarily in the electricity sector

[2] Primarily in the heating and transportation sectors

Fig. 6:
Primary energy consumption & primary energy expenditures

Although the share of primary energy for electricity generation is similar to that for heat and transportation, the acquisitions costs are relatively low. Oil and gas, by contrast, are expensive and difficult to substitute (Fig. 7). These energy sources are used primarily in the transportation and heat sectors, as illustrated in Figure 7, which shows the distribution of primary energy by sector.

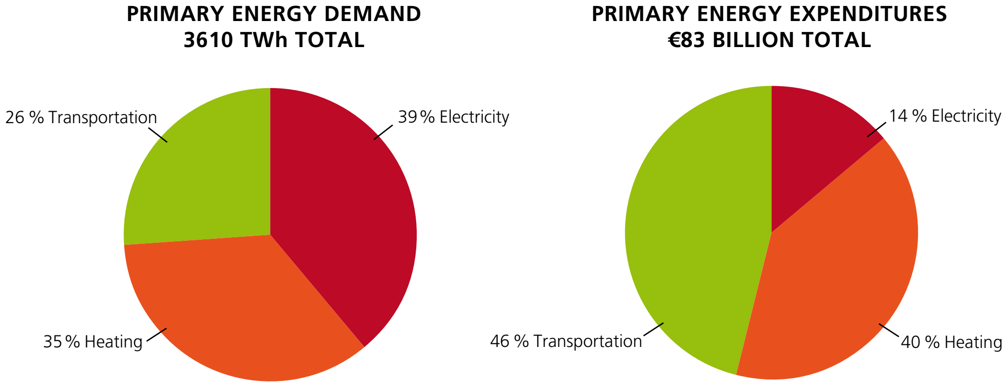


Fig. 7:
Primary energy demand and expenditures: share by sector (adjusted for average temperatures, not including non-energetic consumption)

The current cost-benefit discussion when it comes to the Energiewende continues to be overly focused on the electricity sector. In the electricity sector itself, however, the expansion of renewable energy generates slight cost saving, since it mostly replaces coal and nuclear power. This results in high differential costs (to be covered, for instance, by the EEG surcharge). But this argument doesn't go far enough.

The reduction of CO_2 emissions in the energy sector rests on two pillars: energy efficiency and the deployment of CO_2-free energy sources (Sterner, Schmid, Wickert 2008). Energy efficiency means minimizing the use of energy for achieving a desired product or service. Today, these efforts are focused on the gradual reduction of energy use in production as well as in heat and transportation. In the case of heat supply, two measures are especially expedient: a) improved insulation of all process components and b) the use of heat pumps. Used for low temperatures, heat pumps typically generate 3.5 times more usable energy than it takes to run them.

Wind and photovoltaics represent the primary energy sources for transforming the energy system. Together, they provide a double CO_2 cost-savings effect. The energy-conversion process in a wind turbine and in a PV cell is fundamentally CO_2 free. What is more, to produce the same amount of energy by burning fossil fuels (power plants, internal combustion engines, heating), the combustion process requires additional primary energy due to the laws of thermodynamics. The average ratio between primary energy and final energy in combustion processes in the current energy system is 2 to 1.

In combination, energy efficiency and renewable sources will ensure that future energy demand will only consume a third of today's primary energy use. At the same time, future electricity demand will be significantly higher due to the ever growing number of heating and transportation services that run on electricity. In its optimal »final state«, the energy system should run at the lowest possible costs. This cost minimum requires an increasing electrification through new electricity applications while activating the efficiency potential of electric applications (Fig. 8).

The energy market across sectors

To achieve these economic advantages, the expansion of wind and solar energy must be accompanied by efficient electric applications in transportation and heat that replace high-cost primary energy sources and reduce differential costs. If electricity demand is to be covered for all sectors, dynamic expansion must begin in the electricity sector. Moreover, all potentials for reducing oil consumption must be activated (replacing old heating units, insulation, natural gas vehicles, etc.). All these aspects must be considered before a comprehensive, cross-sector cost-benefit analysis can be carried out.

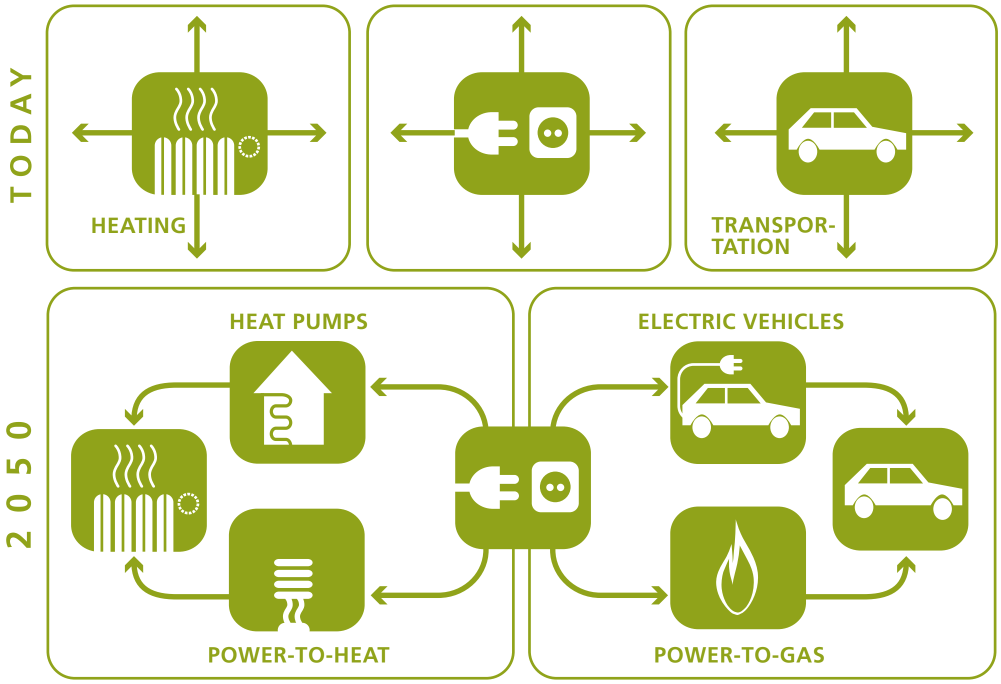


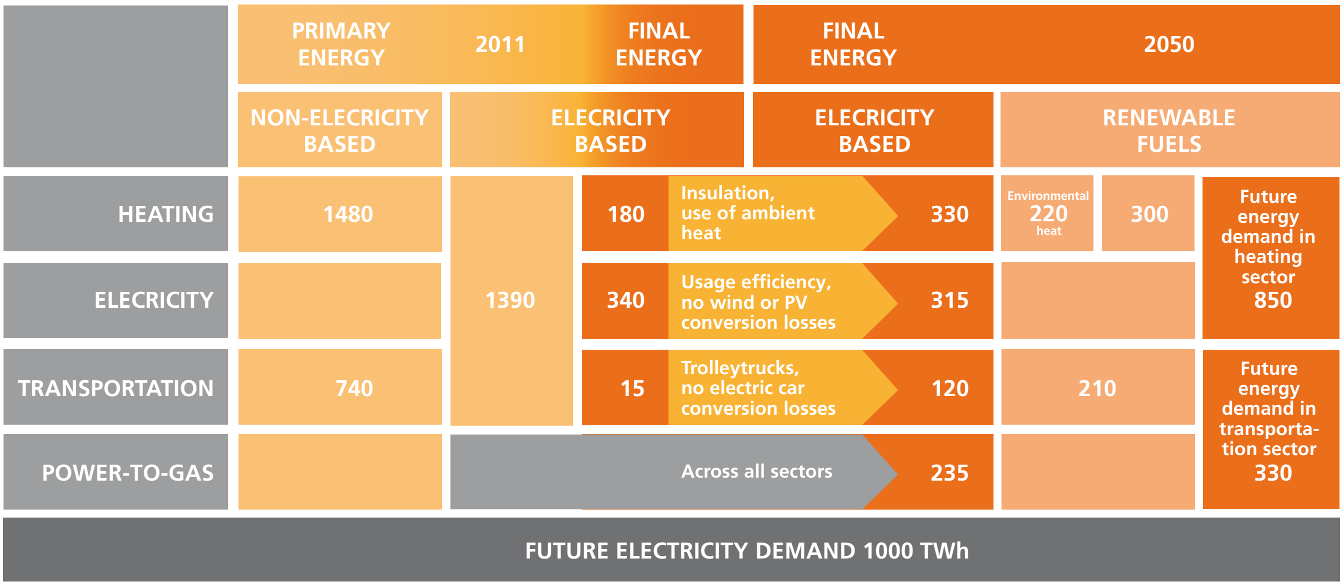
Fig. 8:
Creating a new energy system: a major element is increased electrification through new applications in the heating and transportation sectors

3.2
Calculating a 100% renewable energy scenario for 2050

For the sake of simplicity, we begin by assuming an independent national supply in Germany. Using information from the IWES energy database and factoring in all areas of application and fuel-use, we can calculate energy demand in a future, electricity-based energy supply system. Figure 9 represents primary energy in 2011 (without non-energy use but including international shipping traffic and adjusted for temperature.). It also shows the resulting electricity demand for a scenario with 100% renewable energy supply.

We can see that the future electricity demand amounts to 1000 TWh/a. The transportation sector will require 120 TWh/a in electricity and 210 TWh/a in non-electricity based fuels, for a total of 330 TWh/a. Another 330 TWh/a of electricity is used in the heat

Fig. 9:
Electricity demand in a scenario with 100% renewables (TWh/annum)



	PRIMARY ENERGY	2011	FINAL ENERGY		FINAL ENERGY	2050		
	NON-ELECRICITY BASED	ELECRICITY BASED			ELECRICITY BASED	RENEWABLE FUELS		
HEATING	1480	1390	180	Insulation, use of ambient heat	330	Environmental 220 heat	300	Future energy demand in heating sector 850
ELECRICITY			340	Usage efficiency, no wind or PV conversion losses	315			
TRANSPORTATION	740		15	Trolleytrucks, no electric car conversion losses	120	210		Future energy demand in transportation sector 330
POWER-TO-GAS				Across all sectors	235			
FUTURE ELECTRICITY DEMAND 1000 TWh								

sector. Heat pumps will extract another 220 TWh/a of heating energy from the environment. If we also include non-electricity-based heat energy sources, total future heating use will amount to 850 TWh. Section 3.4 discusses the framework for this scenario and the infrastructure it requires.

3.3

Determining the renewable power generation mix

Next, an optimized power system from renewable energy must be determined for the total electricity demand calculated in the previous section. The criterion for optimization is the minimization of the standard deviation of residual demand. Residual demand is the difference between existing demand and the electricity from wind and solar power, hence demand minus generation, as a time-dependent function over a sufficiently long period (of at least one year). The minimization of the standard deviation is tantamount to minimizing system costs (grid expansion, reservoir power stations, storage). The examined residual loads result from the hourly consumption (time series in 2011) and the simulated renewable energy generation time series, using 2011 weather (as shown in Fig. 10).

It turns out that an annual electricity volume of 1000 TWh from wind and solar energy sources in Germany approaches the limits of the country's available surface area. This fact restricts decision-making significantly more than current political discussions would suggest. The offshore wind energy potential is assumed to be around 50 GW, and the onshore wind energy potential is assumed to be around 230 GW[3]. Solar power has a potential of around 310 GW, including 155 GW from open spaces along highways and railways and 154 GW from rooftops (Fig. 11)[4].

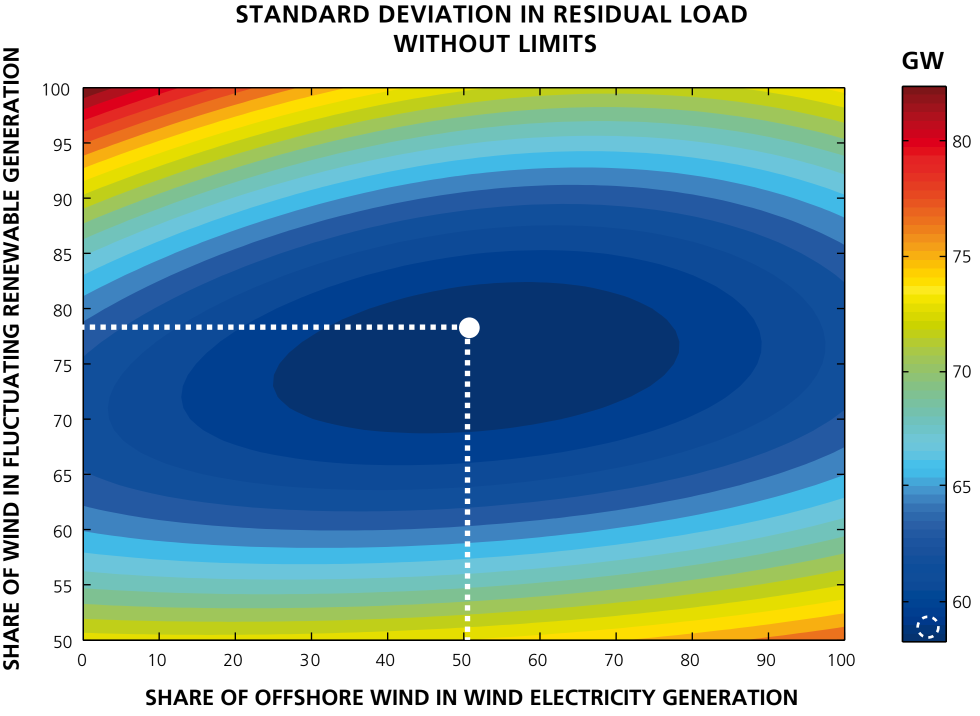


Fig. 10:
Standard deviation in residual load for possible variation in share of energy provided by fluctuating renewables (wind and PV)

The full, unrestricted scenario with optimal residual demand requires more offshore wind energy than can be produced by existing useable surface in the Baltic and North

---

[3] IWES 2013a: Potenzial der Windenergie an Land, ed. UBA. This is a conservative assumption based on a doubling of the distance; reduction of the maximum potential of 940 GW to 25%.

[4] Unpublished calculations by Fraunhofer IWES.

Seas. Under these conditions, therefore, the optimal scenario is a renewable energy mix with the highest possible offshore share within the assumed limits. On a whole, fluctuating renewable energy sources come from solar at 22% (200 GW), from offshore wind at 26% (50 GW), and from onshore wind at 52% (180 GW) (Fig. 11). As can be seen in Figure 10, the optimization minimum is relatively flat so that the indicated ratios with an error range of a 10% energy share can still lie within an acceptable scenario. For the funding considerations discussed here, the accuracy of this generation-mix forecast suffices.

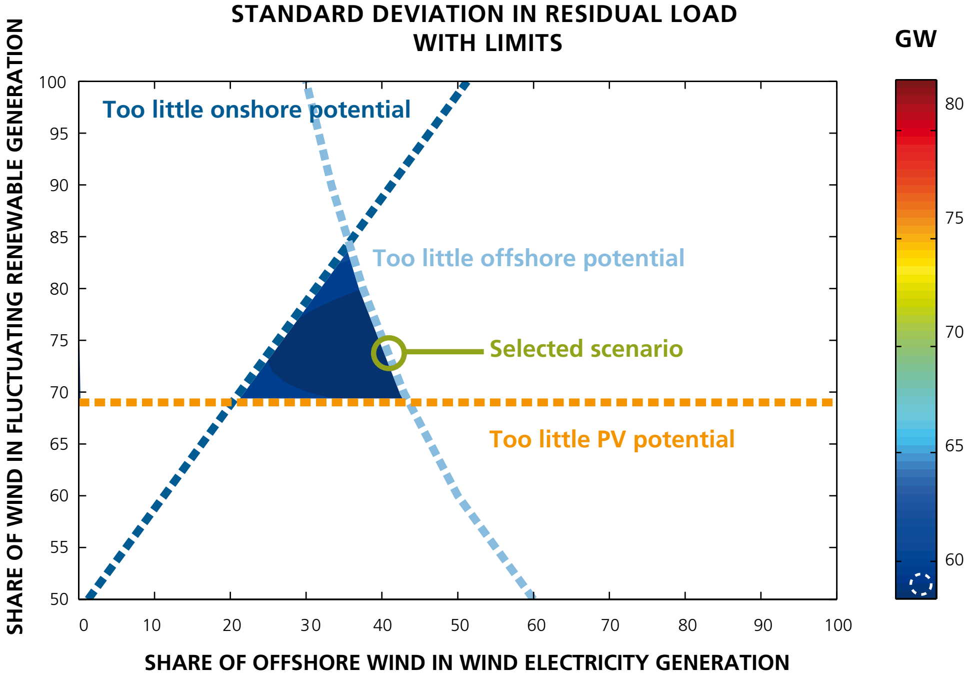


Fig. 11: Selection of the optimal scenario under consideration of available space for deploying fluctuating renewables (wind and PV)

Hydropower delivers only a small amount of energy because of its small – and mostly utilized – potential in Germany. The share of biomass use is already at high level in the area of renewable raw materials. In total, it is assumed that the use of these potentials in the electricity, heat, and transportation sectors remains the same. In the electricity sector, biomass is the fuel that will serve as backup power station (primarily cogeneration on the basis of bio-methane). Other energy sources taken into account are waste-fueled power stations, sewage gas, and electricity generation from coke oven gas and blast furnace gas (Fig. 12).

3.4
Energy system infrastructures

The scenario considered here contains the following assumptions for energy system infrastructures:

a) **Expansion of renewables best suited for the grid**: A high share of energy from PV and wind farms is assumed (50%), which are easier to integrate into the distribution grids. The scenario also assumes a high rotor generator ratio for wind energy and a high share of wind in southern Germany. A more even distribution of generation facilities leads will create a more balanced system and more even feed-in (IWES 2013b).

b) **100% use of electric vehicles** in the automobile sector and the expansion of main highway arteries for trolleytrucks powered by overhead electric cables [SRU 2012].

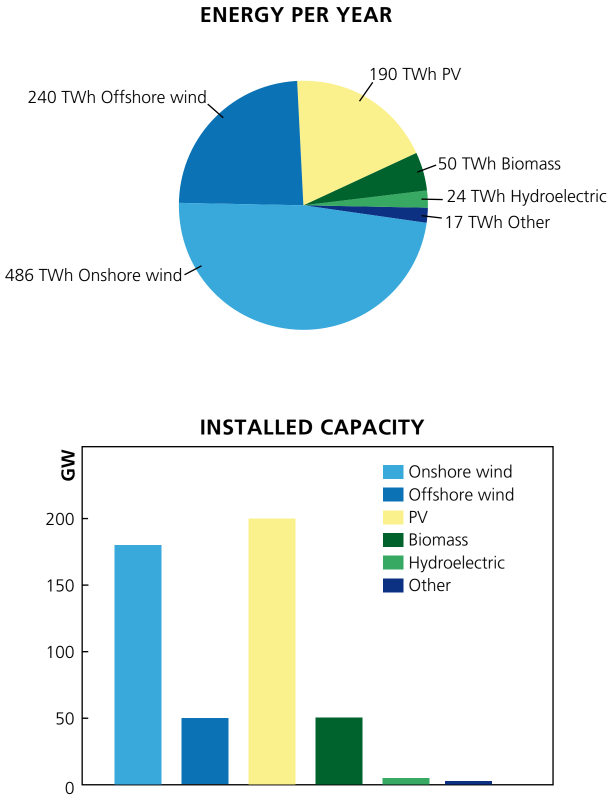


Fig. 12:
Selected energy mix under a 100% renewables scenario (taking necessary generation curtailment for each source into account)

c) **Heat pumps in low temperature zones** for space heat and warm water with a coverage of 75% and **the use of power-to-heat** in high temperature zones.
d) **Smart grids**: utilizing the flexibility of decentralized consumers.
e) **District battery storage**: Economic operation with additional synergies through cost savings in the distribution grid.
f) **Power-to-Gas** to cover remaining cross-sector demand for chemical energy sources.
g) **Biomass**: The scenario assumes a constant demand (or energy use) at today's level. Because biomass is primarily used for material applications and as food for a growing global population, raw materials may have reached their limits for energy use. As with power-to-gas, the scenario assumes that biomass will be used to cover the "positive residual demand" in all energy sectors (electricity, heating, transportation), in the form of gas (bio methane, biogas), liquid (bio fuels), and solid (wood in bivalent heating systems).
h) **Efficiency measures** include the reduction of conventional electricity consumption – by 25% according to Germany's National Action Plan (BMWi, BMU 2011) – building insulation, efficiency increases with industrial process heat and in the transportation sector, more efficient heat technology and waste heat use (borrowing from the German environmental ministry's pilot study 2011 [DRL, IWES, IfnE 2012]).

The scenario is still open with regard to the ratio of small and large thermal power plants in the form of gas turbines and combined cycle stations, block heat and power, and cogeneration power plants for supplying the industry and the public.

3.5
Calculating total investment volume

The following cost assumptions were made for the scenario on the basis of previous studies and our own experience in the sectors (Table 1). Costs that would accumulate in the reference scenario (continuation of business as usual; see section 4.3) are intentionally excluded from the cost analysis. Relevant are the differential costs relative to the reference scenario – the additional costs that accrue through the expansion of renewables over 2011 levels. Examples are the extra costs for electric vehicles versus hybrid vehicles or the extra costs of heat pumps and area heating relative to condensing boiler technology. The scenario assumes relative low costs for energy-efficient building retrofitting in view of the high level of savings expected from new heating technologies, the moderate warming expected from climate change, and the ratio of demolition to new construction.

Given the development of power stations and the repowering needed over a 40-year period, the costs follow the distribution shown in Figure 13. The total investment volume without capital costs amounts to 1.5 trillion euros.

Tab. 1: Cost components for a 100% renewables scenario

	Capacity 2050	**Costs** 2011	**Costs** 2050	Source
Specific Costs		€/kW	€/kW	
Onshore wind	180 GW Minus existing plants			Authors' calculations
- Strong wind	50%	1,160	1,010	Learning rate 3% / 5%
- Weak wind	50%	2,000	1,600	
Offshore wind	50 GW	4,240	2,500	Authors' calculations [Fichtner, Prognos 2013]
Photovoltaic	200 GW Minus existing fleet			[ISE 2013]
- Freestanding	50%	1,075	485	
- Rooftop (small)	50%	1,390	625	
Differential costs Electric heat pumps (incl. heating technology)		2,210	1,475	Authors' calculations [ISE et al. 2013]
Differential costs Electric vehicles (per vehicle)		13,000 €/ vehicle	1,000 €/ vehicle	[EWI 2010]
Expansion of charging stations Electric vehicles (per vehicle)		2,000 €/ vehicle	725 €/ vehicle	[ZEV et al. 2011]
Stationary batteries (8 h capacity)	10 GW	1,934	435	Authors' calculations [ISEA 2012], inter alia
Power-to-Gas	78 GW	2,000	750	Authors' calculations
Power-to-Heat	23 GW	100	100	Authors' calculations
Aggregate Costs	Billion €			
Distribution grid expansion	27			[Enervis, BET 2013]
Transmission grid expansion	15			[Enervis, BET 2013]
Smart grids	7			[Kema 2012]
Trolleytruck overhead wire grid deployment	14			[SRU 2012]
Building insulation	237			[Prognos 2013]

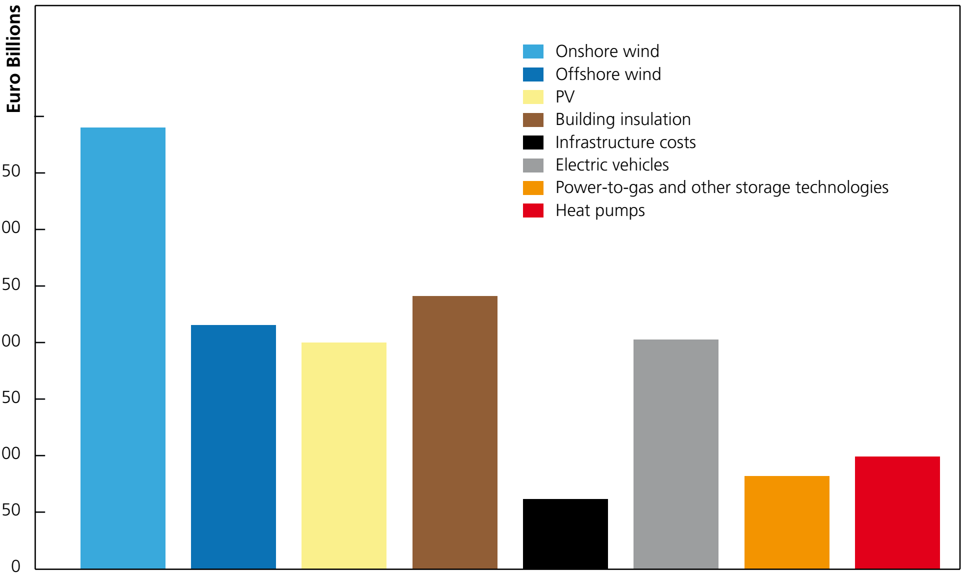


Fig. 13: Breakdown of required investment volumes, 2011–2050

4
A Financial Plan for the Energiewende

4.1
The basic financing model

So far we have estimated the future demand, the ideal generation mix, and the concomitant costs. In the following we develop a basic financing plan. The key parameters of funding the Energiewende are total costs, the period of investment, possible fossil fuel savings, and the interest rate. A variety of possibilities for financing are conceivable. One possibility is presented in Figure 14. Here we have a linearized consideration of 30 years with costs totaling €1200 billion, instead of the 40 years and €1500 billion calculated in section 3.5. The annual investment in this case is €40 billion (green line). The scenario is simplified: only the capital investments are considered; the maintenance costs of existing infrastructures, operational costs, sales margins, etc. are omitted. All curves in Figure 14 must be thought of in terms of this cost base.

We assume that the infrastructure investment in renewable energy generation, grids, storage capacity, new technologies in transportation and heating, etc. can be managed in such a way so that the current acquisitions costs for fossil primary energy of €96 billion annually (€83 billion without the non-energy sector for chemical applications) can be reduced over this period in a linear fashion (red line). As a result, the break-even point – where the sum of the investments plus the costs for acquiring the primary energy become less than today's primary energy costs – is projected to be reached in about 15 years. In addition, only around €300 billion of the €600 billion to be invested in the following 15 years (at €40 billion annually) must actually be paid thanks to the linear cost drop-off until the break-even point (thick blue dotted triangle in Fig. 14 below).

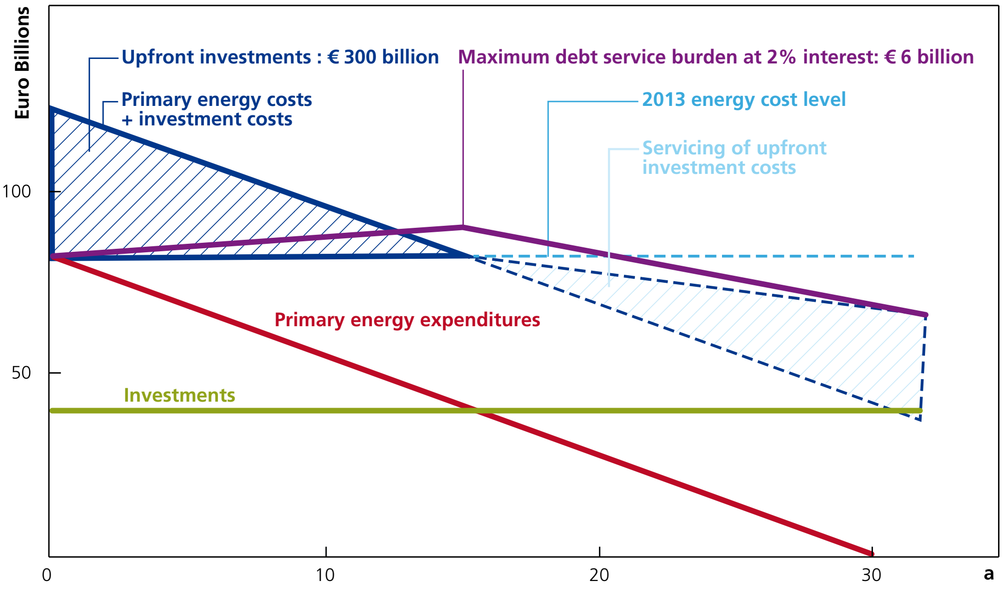


Fig. 14: Financing model

Another possibility is to finance the €300 billion in advance and pay off the debt over the following decades as fossil fuel costs are saved. The figure shows that energy costs sink continuously after the break-even point is reached, lending leeway to the repayment plan (narrow blue dotted triangle in Fig. 14). Assuming an inflation adjusted interest rate of 2%, the debt service increases to €6 billion annually in the first 15 years. This results in an increase of energy costs (electricity, heating, fuel) relative to the €83 billion annually of 7.2%. If we relate this increase solely to the electricity kilowatthour price for households, the initial price level of €0.25/kWh increases by 1.8 cents. If the state provides a credit guarantee, of course, the repayment will be delayed during the first 15 years. In this case, a rise in electricity prices does not take place. In 30 years, at the end of the Energiewende, investment drops to a level needed for maintaining the new infrastructure. We have not yet quantified this noticeably lowered target level for energy costs.

In sum, the key point in financing the Energiewende is to use financial mechanisms to boost the real effect of future savings in operative fuel costs. This can minimize price increases and reduce them for consumer in the long term. In other words: those today who postulate significant price increases for the Energiewende are making a mistake. Keeping prices to a minimum is the standard by which Energiewende proposals must measure themselves.

The general sketch of the aforementioned financing plan is detailed in sections 4.2 and 4.3:

- Stabilizing the new energy infrastructure and industrial sector of the future
- Optimizing the order of investments
- Cost-benefit analysis relative to the reference scenario
- Considering the residual values of investment
- Return on investment
- Influence of increasing costs for primary energy

4.2
Fine-tuning the growth of the energy infrastructure sector: Energy infrastructure

Stabilizing the new industrial sector for energy infrastructure

To keep global warming to within 2 °C, a 100% renewable energy system must be reached by 2050. For this, we need what amounts to a new industrial sector that will produce and maintain a renewable energy infrastructure. The development of this new industrial sector must be for the most part complete by 2040; if construction begins too late, a hasty schedule may lead to overcapacities in production.

If we take the past rates of adding wind and PV energy in Germany as a basis and assume a stable infrastructure (manufacturers, suppliers, installers, cranes, ships, etc.) for repowering the plants after 2050, it becomes clear how little leeway there is for further expansion. For onshore wind energy, new capacity construction must be ramped up from 3 GW/a to around 9 GW/a in order to achieve a permanent wind farm fleet of 180 GW in 2050 (the lifespan of a wind turbine is approx 20 years; see Fig. 15). In the area of PV, the expansion must be accelerated from 3.5 GW/a to 6.7 GW/a in order to reach a sustainable 200 GW (the lifespan of PV systems is 30 years; see Fig. 16). In the area of offshore wind energy, an increase from today's low level up to 2.5 GW/a is needed to achieve 50 GW (the lifespan of offshore wind turbines is 20 years; see Fig. 17).

4.3
Optimizing the order of investment and financing statistics

We have developed an optimized financial plan using the above assumptions on final energy for electricity generation in 2050. For the period from 2011 to 2050, in addition to energy use and costs, the calculations consider €1500 billion in new infrastructure investment costs (section 3.5).

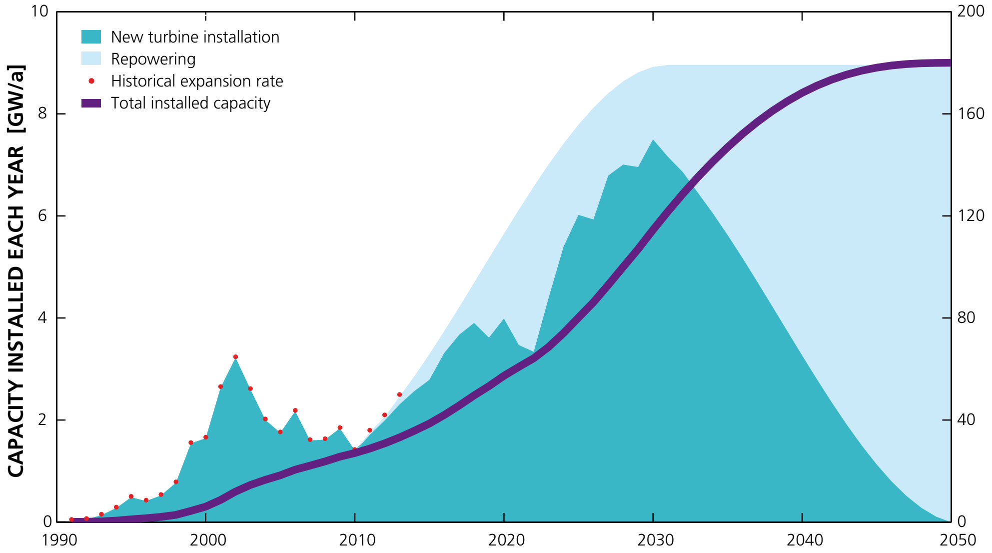


Fig. 15:
Evolution of onshore wind

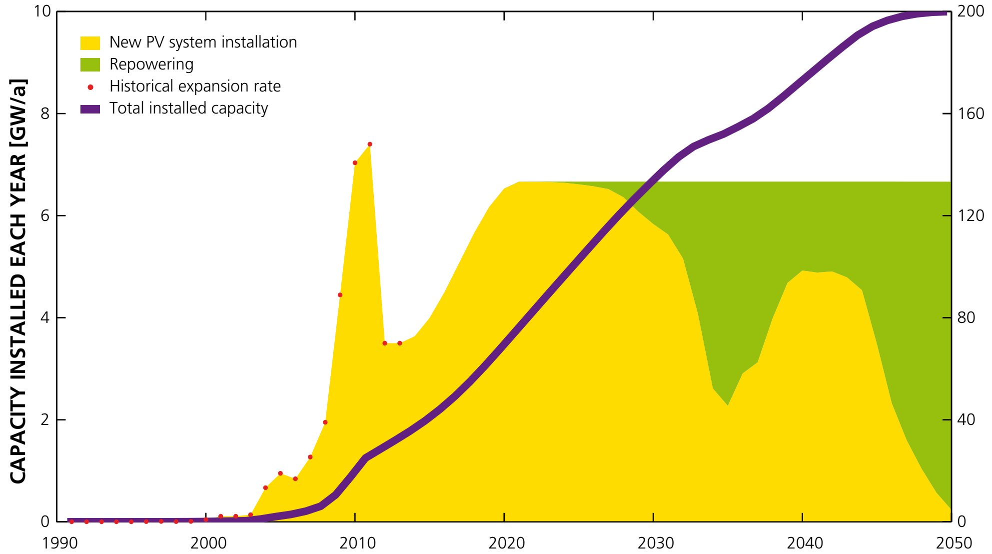


Fig. 16:
Evolution of photovoltaic

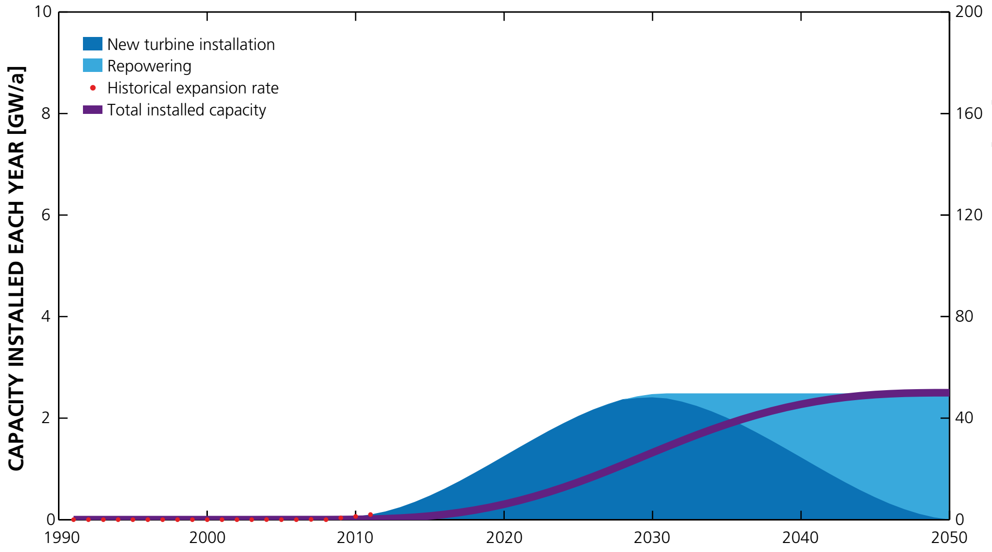


Fig. 17:
Evolution of offshore wind

Energy use, 2011 to 2050

The dynamic expansion of renewable energy – primarily of wind energy and PV – must begin in the electricity sector. But replacing nuclear power and coal with renewables is not economically cost-efficient at this time, at least not directly. To achieve the economic benefits of renewable energy expansion, efficient electric applications must be introduced in the transportation and heat sectors that replace primary energy sources and reduce differential costs. In addition to expanding renewables in these sectors, reduction potentials need to be activated in oil consumption because the phasing out of oil is crucial if the Energiewende is to yield economic benefits. These measures can shorten the initial funding period for renewable energy expansion and reduce the interest burden.

Some medium-term measures for reducing oil and gas consumption:

- Replacing oil heating units with electric heat pumps and replacing natural gas infrastructure with gas connection and condensing boilers.
- Improved building insulation
- General scrapping bonus for old heating units
- Expanding infrastructure for electric trolleytrucks
- Promoting the use of natural gas vehicles
- Use of biofuels

These measures were included in the renewable expansion described in section 4.2 when calculating the 2050 scenario. Other limiting conditions – the phase-out of nuclear power, the build-up of automobile and heating unit inventories, the feasibility of efficiency measures, and other factors – were used to create quantity estimates for energy use through 2050 (Fig. 18).

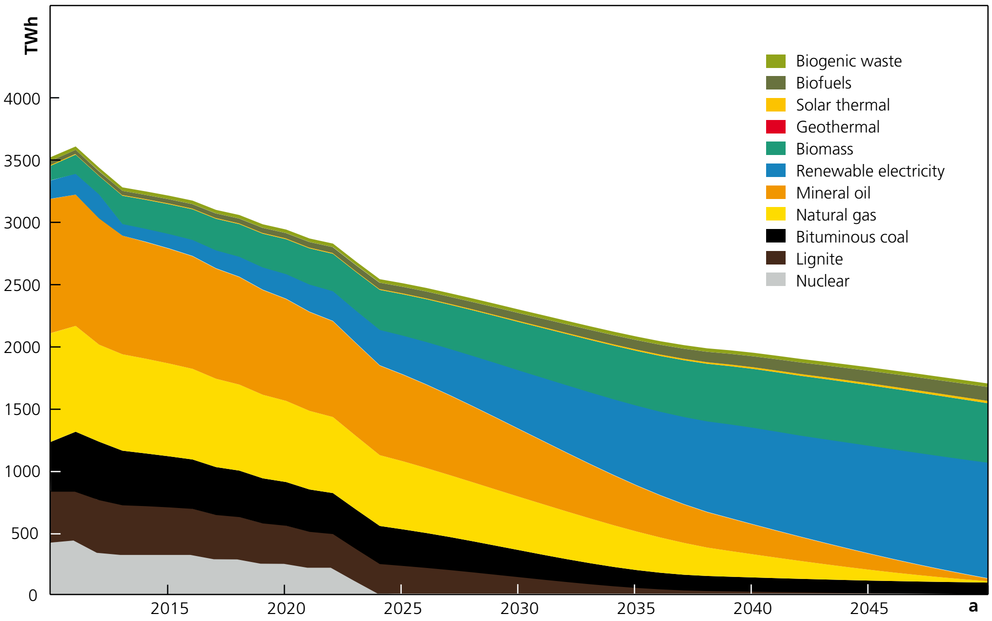


Fig. 18: Evolution of primary energy consumption in the electricity, heating, and transportation sectors (not including non-energetic consumption)

Cost savings relative to the reference scenario

The reference scenario assumes that the rate of renewable expansion in 2011 remains constant. Here too, however, plants are replaced by new facilities at their end of their lifespan. There are also efficiency measures such as the reduction of conventional electricity use, savings in the automobile sector through hybridization, and savings in the heating sector through new heating units, climate change, and the demolition/new construction ratio. By contrast, increased use in the reference scenario – e.g. in air traffic – is very low. These effects will lead to reduced expenditures for coal, natural gas, and mineral oil through 2050 (Fig. 19). Non-energy use is a part of both the reference scenario and the 100% renewable energy scenario and, accordingly, does not accumulate as a positive benefit in the latter. The €83 billion/a paid today for primary energy in the energy sector is the main source of savings for funding infrastructure investments. The cost-benefit calculation is conservative: fossil fuels prices are not assumed to increase and CO_2 costs are not taken into account. Relative to the reference scenario, the differential costs for the Energiewende are only offset by additional savings from primary expenditures.

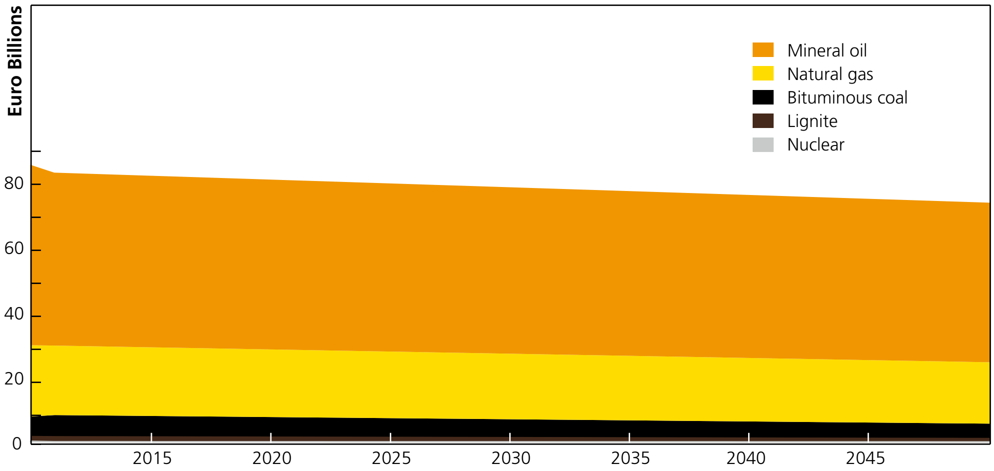


Fig. 19:
Annual primary energy costs in the business as usual scenario (not including non-energetic consumption)

This means that our financing plan considers only fuel cost savings and additional investment costs. The costs in the reference scenario may be higher, as in the case of fossil and thermal power stations (which have comparable output but more expensive base and average demands), but these costs are not counted against the total.
The residual investments in 2050 must be considered for assessing the economic viability of the entire project. Here, too, we make a conservative assumption: we only consider the residual values of wind and PV, and not additional investments in heat and transportation.

Cost-benefit analysis

In the cost-benefit analysis the above fuel cost savings are set off against investments. The contribution margin – the difference between fuel cost savings and investment costs – provides an important indicator for the economic viability of the project (Fig. 20 to 23).

The analysis of the 100% renewable energy supply scenario over a 40-year period projects positive contribution margins – fuel cost savings outweighing investment costs – starting in 2030 (or after 20 years), provided that interest and capital costs are not taken into account and assuming an initial funding of €383 billion. By 2050, a significant surplus is projected, with fuel cost savings totaling many times ongoing investments for repowering older power stations (Fig. 20).

If the interest rate for borrowed capital is considered, it takes longer for the contribution margin to turn positive. With an interest rate of 2%, and an initial investment of €501 billion, positive contribution margins are forecasted to begin in 2035 (or after 25 years) (Fig. 21). The economic viability of the entire project becomes more apparent if we assume increasing costs for primary energy (without CO_2 costs). If we assume prices based on the 2014 Grid Development Plan for Electricity (BnetzA 2013) and a linear progression through 2050, a positive inflow of funds occurs more quickly (Fig. 22). The initial financing then amounts to €380 billion without interest and €485 billion with interest. Here prices are assumed to remain almost constant for natural gas and slightly increase for oil. Another valid scenario for fuel cost prices is the German environmental ministry's current climate protection calculation (Öko-Institut, ISI 2013). The ministry projects even more significant positive inflows (Fig. 23), with positive contribution margins occurring after 15 years without interest and no longer than 19 years with interest. This scenario forecasts an initial financing of €295 billion without interest and €356 billion with interest.

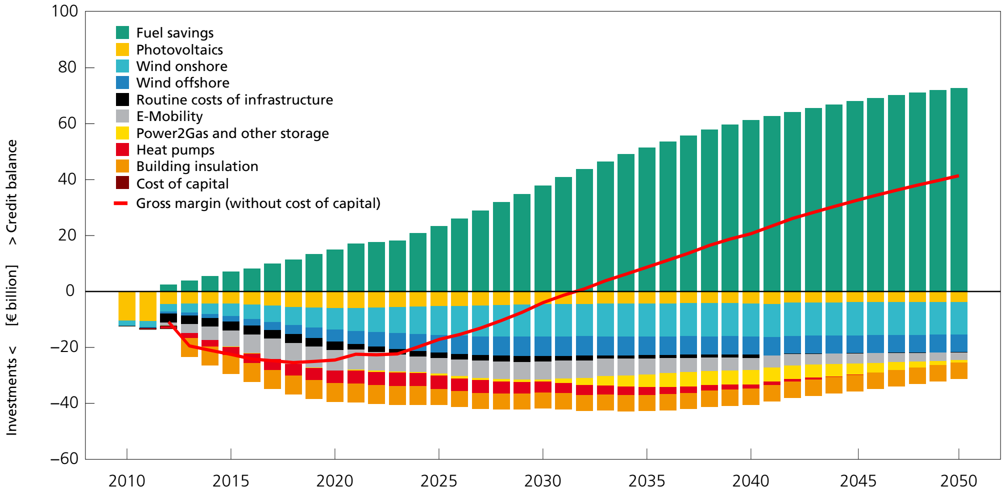


Fig. 20:
Cost and return analysis, Scenario A:
2.3% ROI on all investments, break-even in 2030, €383 billion in upfront investments, 0% interest on borrowed capital, constant primary energy prices

Results

Our calculations indicate that even very ambitious climate targets like a 100% renewable energy system are economically feasible. Concerns about the costs of the Energiewende, therefore, should not play a decisive role in climate policy decisions. Our preliminary assessment shows that the Energiewende as a whole can be financed even under very conservative assumptions (e.g. omitting fuel price increases and the costs of CO_2 damage). Assuming that primary energy prices from 2011 remain constant and using 2050 residual values, the return on total investment is 2.3% after being adjusted for inflation. If the observation period is extended beyond 2050, the projected return increases as expenditures for repowering become a fraction of the fuel cost savings.

If price increases for oil and natural gas are factored in, the rate of return increases. Taking into account either the real increases of NEP 2014 (linear progression) or the projected prices of the environmental ministry's 2050 climate protection scenario, the return on investment – given 2050 residual values – is expected to be between 4.0% and 6.7% (adjusted for inflation). If the observation period is lengthened beyond 2050, the returns increase considerably. This forecast considers neither the positive effects of investments in productive infrastructure (economic growth, jobs, etc.) nor the savings from the subsidiaries still paid for conventional power stations and fuels.

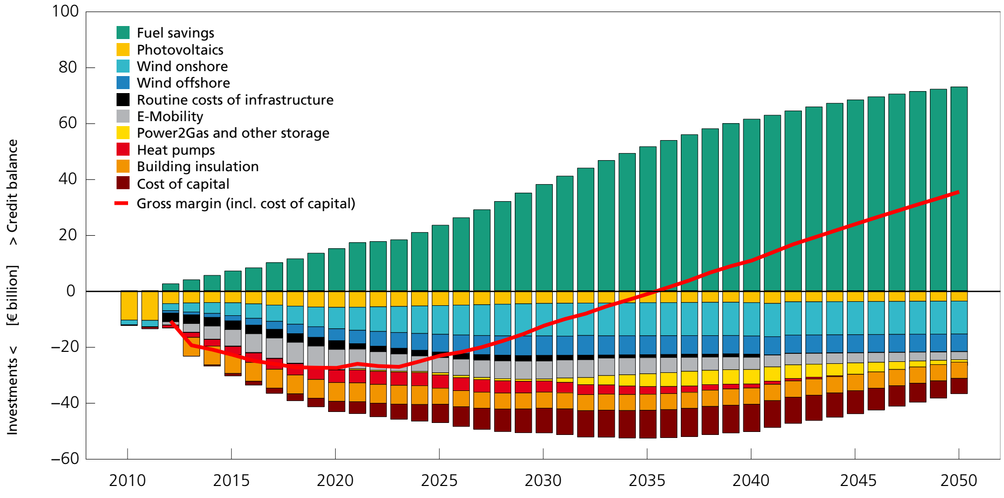


Fig. 21:
Cost and return analysis, Scenario B:
2.3% ROI on all investments, break-even in 2035, €501 billion in upfront investments, 2% interest on borrowed capital, constant primary energy prices

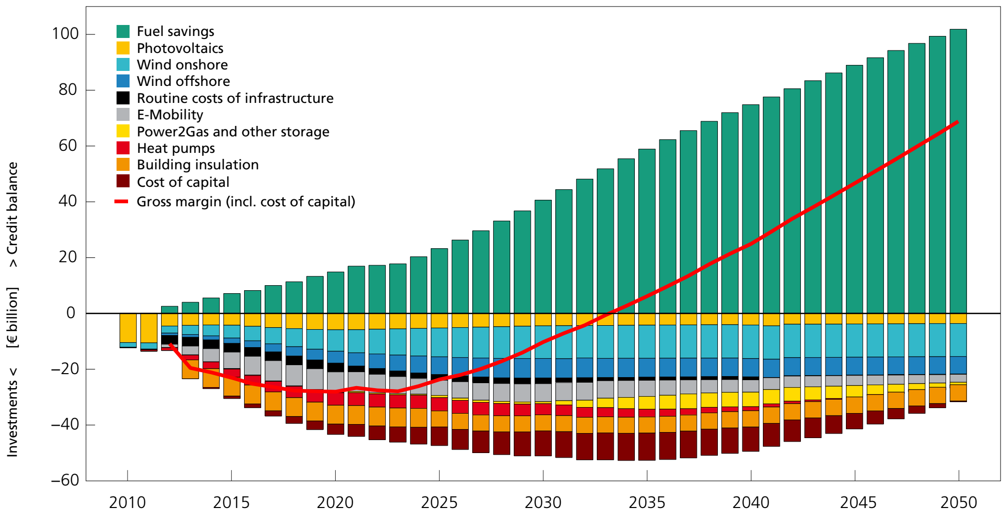


Fig. 22:
Cost and return analysis, Scenario C:
4% ROI on all investments, break-even in 2033, €485 billion in upfront investments, 2% interest on borrowed capital, rising primary energy prices as per NEP 2014

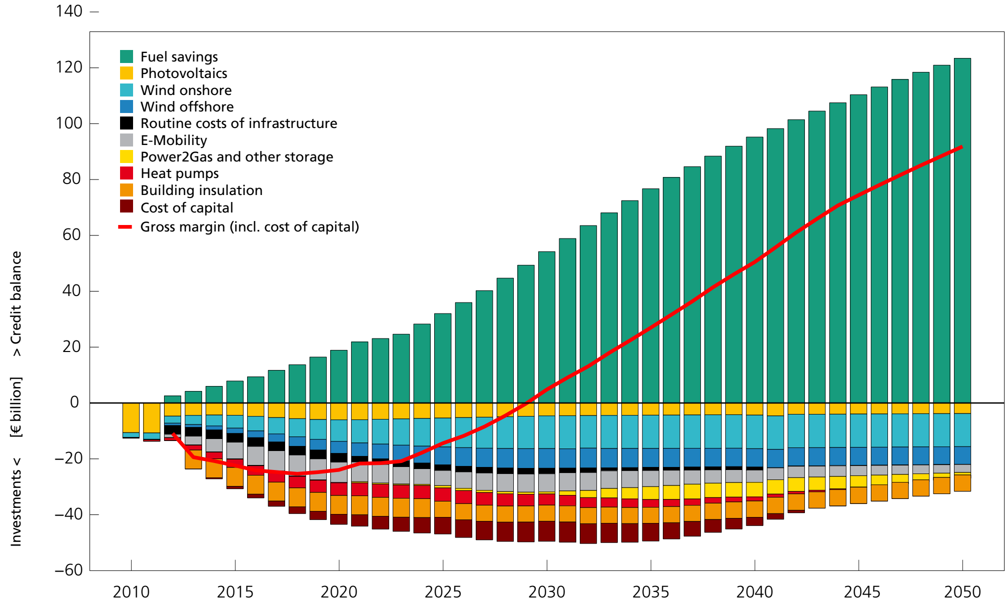


Fig. 23:
Cost and return analysis, Scenario D:
6.7% ROI on all investments, break-even in 2029, €356 billion in upfront investments, 2% interest on borrowed capital, rising primary energy prices as per Climate Protection Scenario 2050

5
Political Implementation

The preliminary calculations we have presented in this report demonstrate that the Energiewende can be funded in principle. Parts of the blueprint described here are already being tried out by local actors. Calculations from smaller municipal energy providers show that energy price guarantees for 100% renewable energy supply can be made. This scenario laid out in this assessment presupposes top-down policies (legislation, regulation, loan guarantees) that create the conditions needed to provide investment certainty. It is crucial to understand that this model includes all energy-use sectors. On account of primary energy costs (Fig. 6 and 7) the largest savings occur with oil and gas, which accumulate almost entirely in the transportation and heat sectors. In determining the precise details of Energiewende financing, policymakers must duplicate these effects in the electricity sector, which will dwarf other energy-use sectors in the future. This means offering private and industrial customers products in combined heat and power, combined transportation and power, and combined heat, power, and transportation. These products guarantee stable energy costs while permitting the needed investments.

Various economic studies have shown that infrastructure investment – especially productive infrastructure – has a decidedly positive effect on economic development (Lehr, Lutz, Pehnt 2013; DLR, ZSW, GWS, Prognos 2013). It creates jobs, increases demands for goods and services, boosts growth and domestic consumption, and, as a result, augments tax revenues.

The capital for funding the Energiewende is there, and there are multiple ways for putting it to use. One good option is to mobilize reserves from investment funds; another is to establish citizens' funds – both provide incentives for long-term infrastructure investment. The Energiewende can play a very important role in surmounting the challenges caused by the recent financial crisis. This is especially true for the current devaluation of private savings due to inflation and the falling interest rates for government bonds, with the concomitant economic pressure on insurance providers (life insurance, pension insurance, and reinsurance). These areas contain large sums of money for which low-risk investment is best – and which offer the potential for financing renewable energy infrastructure from private equity. Investment in renewable energy can be guaranteed through revenue generated by productive infrastructure. Other interesting effects from private equity financing that need to be discussed are the creation of real value through infrastructure investment and its stabilizing effect on monetary policy. Discussions must also focus on possible regulatory frameworks, such as state-guaranteed infrastructure funds that assume liability for risks and fulfill regulatory requirements for insurance companies.

Another example that needs to be considered in the area of financing is the scrapping bonus included in Germany's 2009 stimulus package (which was later copied in the US, where it was known as the »cash-for-clunkers« program). Such a model, where the state itself acts as investor, could be used to replace old heating units. Another example that bears mentioning is the fund to pay for liabilities arising from old renewable energy subsidy guarantees (Töpfer, Bachmann 2013). The financing for these liabilities can be stretched out over an extended period. Another form would be a fund for old debts that can be passed onto electricity users to guarantee a constant electricity price. Other questions under discussion are whether the EEG surcharge can be passed on via an energy tax or whether a fundamental reform of the European emissions trading system and an expansion from the electricity sector into the heat and transportation sectors can balance costs and savings effects.

The options for political implementation must be further sounded out. Playing a role here are issues such as fair distribution (within the population and between generations) and long-term risks (such as energy price fluctuations). The calculations in this study are meant to provide quantitative data for future discussions and decision-making.

The positive news is that the Energiewende is not only affordable; it is also a major global business opportunity and an economic stimulus for Europe as it weathers the eurozone crisis. Indeed, its greatest potential for development lies in the region that was hardest hit: Southern Europe.

6
Conclusion

»A Business Model for the Energiewende« shows that investment in renewable energy infrastructure can be managed so that the current annual costs for primary fossil fuels – €83 billion per year – drop to virtually zero over 40 years.

Based on current forecasts, it will take 15 to 20 years until expansion costs for renewable energies and acquisition costs for fossil energies drop below today's primary energy costs. Around €350 to 500 billion must be invested in advance and later paid off. In around 30 years, most of the costs will only be for maintaining the infrastructure, as with repowering. Even if price levels for fossil energy sources remain constant, the investment is projected to earn an inflation-adjusted return of 2.3% by 2050. This may reach as high as 4% to 6.7% if prices for oil and natural gas increase. And this figure ignores the cost of damage caused by greenhouse gas emissions.

All in all, then, the Energiewende represents an attractive capital investment that is guaranteed by the strength and reputation of the German economy. Investors both domestically and abroad can profit from long-term stability, low risk, and a high likelihood of return. Long-term stability is assured because the infrastructure to be built is technologically advanced. The associated economic energy depends on local factors: industrial organization, sound legal protection, and high educational quality. Furthermore, the investment is low risk because it is not subject to hard-to-control fluctuations in the fossil fuel market. Finally, the expectation of positive returns is tied to global market growth in renewables – a growth that Germany is spearheading

7
Further Literature

UNFCCC 2009
United Nation Framework Convention on Climate Change.
Decision 2/CP.15, Kopenhagen, 12.2009

Sterner, Schmid, Wickert 2008
Effizienzgewinn durch erneuerbare Energien. BWK. Das
Energie-Fachmagazin 60 (2008), No.6, pp.48-54.

Öko-Institut, ISI 2013
Klimaschutzszenario 2050, Rahmendaten; BMU
unveröffentlicht

DRL, IWES, IfnE 2012
Langfristszenarien und Strategien für den Ausbau der
erneuerbaren Energien in Deutschland bei Berücksichtigung
der Entwicklung in Europa und global; BMU, 03.2012

BMWi, BMU 2011
Das Energiekonzept der Bundesregierung 2010 und die
Energiewende 2011; BMWi, BMU, Berlin 10.2013

BnetzA 2013
Genehmigung des Szenariorahmens zum NEP/O-NEP 2014;
Bundesnetzagentur Bonn, 08.2013

AGEB 2013
AG Energiebilanzen: Historische Daten zum
Primärenergieverbrauch und Auswertungstabellen,
http://www.ag-energiebilanzen.de/

AGEE-Stat 2013
Arbeitsgruppe Erneuerbare Energien-Statistik: Historische
Daten zur Entwicklung EE,
http://www.erneuerbare-energien.de/die-themen/datenservice/agee-stat/

IWES 2013a
Potenzial der Windenergie an Land;
Hrsg. UBA, Dessau-Roßlau 09.2013

IWES 2013b
Entwicklung der Windenergie in Deutschland;
Hrsg. Agora Energiewende, Berlin 06.2013

SRU 2012
Umweltgutachten 2012, Verantwortung in einer begrenzten
Welt; Erich Schmidt Verlag, Juni 2012

ISE et al. 2013
Erarbeitung einer Integrierten Wärme- und Kältestrategie,
Abschlussbericht BMU; ISE, ISI, Öko-Institut, IREES, BEI 2013

ISEA 2012

Technology Overview on Electricity Storage - Overview on the potential and on the deployment perspectives of electricity storage technologies; ISEA, RWTH Aachen 06.2012

Fichtner, Prognos 2013
Kostensenkungspotenziale der Offshore-Windenergie in Deutschland; Hrsg. Stiftung Offshore-Windenergie, Varel, 2013

Enervis, BET 2013
Ein zukunftsfähiges Energiemarktdesign in Deutschland; Enervis, BET, 03.2013

Kema 2012
Anpassungen und Investitionserfordernisse der Informations- und Kommunikationstechnologie zur Entwicklung eines dezentralen Energiesystems, DNV Kema 2012

Prognos 2013
Ermittlung der Wachstumswirkungen der KfW-Programme zum Energieeffizienten Bauen und Sanieren, Prognos, 03.2013

EWI 2010
Potentiale der Elektromobilität bis 2050, EWI, 06.2010

ZEV et al. 2011
A portfolio of power-trains for Europe, commissioned by McKinsey & Company, 09.2011

ISE 2013
Stromgestehungskosten Erneuerbarer Energien; Freiburg, 11.2013

Lehr, Lutz, Pehnt 2013
Volkswirtschaftliche Effekte der Energiewende: Erneuerbare Energien und Energieeffizienz; GWS, IFEU - Osnabrück, Heidelberg, 2012

DRL, DIW, ZSW, GWS, Prognos 2013
Bruttobeschäftigung durch erneuerbare Energien in Deutschland im Jahr 2012; Hrsg. BMU Berlin, 03.2013

Töpfer, Bachmann 2013
Kostenschnitt für die Energiewende. Die Neuordnung der Stromkosten ist die Voraussetzung für die Reform der Energiepolitik; Hrsg. Nachhaltigkeitsrat, 09.2013