Energy market scenarios and future energy and commodity procurement options

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1 INTRODUCTION

On the international, European and national level Germany is facing various climate protection targets. Although these targets are manifold – and frequently not aligned with each other – the overarching target is to mitigate greenhouse gas (GHG) emissions. In that respect, Germany is very likely to miss its 2020 national climate target of reducing GHG emissions by 40% compared to 1990 levels.[1] Furthermore, Germany is not on track for achieving the EU target of reducing GHG emissions by 14% until 2020 (compared to 2005) in the sectors not covered by the EU Emission Trading System (EU ETS).[2]

Given Germany's difficulties in reaching targets in the near future, the question arises how the existing problems could be overcome, i.e., which options are available and cost efficient to reduce emissions. Recent studies that analyze scenarios for the future trajectory of Germany's GHG emissions typically focus on normative scenarios, i.e., they sketch how a pathway towards a target might look like, assuming all necessary steps can be accomplished. In contrast, exploratory scenarios (often also referred to as reference or business-as-usual scenarios) are scenarios that describe how the future might evolve based on past trends and observed system behavior. In prevalent studies, they are typically used as benchmarks but not analyzed to the same extent as the normative scenarios.

Against this background, this study seeks to shed light on three aspects concerning the future development of the energy system: First, what are barriers towards achieving future climate protection targets? Second, how will the energy system possibly evolve if the current level of ambition cannot be increased? And third, how will the energy demand - especially concerning gas - look like in that case and what procurement options are available?

The study is structured as follows: In chapter 2, we develop an understanding of the existing EU and national climate targets – including their shortcomings - as they form the basis for prevalent energy market studies. In chapter 3, the objective is to identify key components for achieving climate targets. We pay special attention to how the key components are addressed in prevalent studies and what barriers might prevent taking the envisioned pathways. In chapter 4, we design a thought experiment of how future energy demand might look like if the historical trend prevails. This serves as a basis for deducting an upper bound of future gas demand and evaluating possible procurement options. Chapter 5 concludes.

[1] In the recent coalition agreement it was announced, that measures to close the gap towards reaching the target shall be implemented. In other words, it is acknowledged that the target will not be reached.
[2] See Klimaretter 2018

2 EUROPEAN AND NATIONAL CLIMATE TARGETS

Germany's climate policy aims at complying with two different climate targets: the German national and sectoral targets according to the Climate Action Plan 2050 of the German government as well as the targets of the European Union, including the Nationally Determined Contributions (NDC)-commitments made under the UN Framework Convention on Climate Change (UNFCCC). These two targets are not independent of each other, but interact and may even be conflicting. In the following, targets and related mechanisms will be described and potential interactions will be analyzed.

2.1 EU climate targets

The European Union aims at reducing its GHG emissions by 20% in 2020, by 40% in 2030 and by 80 to 95% in 2050, compared to 1990 levels.[3] To achieve the overall targets, sectors are assigned to two categories: sectors covered by the EU Emissions Trading System (EU ETS) and sectors regulated within the framework of effort sharing. The energy sector, energy intensive industries and European aviation fall under the EU ETS, while the building sector, other firms, the remaining transportation sector, waste and agriculture are covered by the effort sharing regime.[4] The main reason for this division is that the ETS sectors comprise large GHG emitters, while emitters in the effort sharing sectors are decentralized households as well as small and medium-sized firms. Therefore, ETS regulation is directed towards companies while the effort sharing regime addresses the member states.

EU Emissions Trading System

Participants in the ETS have to turn in European Emission Allowances (EUA) for their yearly emissions. Member states issue EUA via auctions or free allocation (with the aim to protect domestic industries and prevent carbon leakage). Excess allowances can be traded among ETS participants. Firms reduce their emissions whenever abatement is cheaper than the EUA price. Because allowances obtained for free can be sold if not needed, the incentive to reduce emissions is not affected by free allocation schemes.[5]

The EU ETS is currently undergoing major changes as a reaction to annual emissions being well below the ETS cap since 2009 and prices below the values that might have been expected.[6] While some (for instance Elkerbout et al. 2017) argue that market forces in the ETS have been working fine according to economic theory, others demand a higher EUA price to foster energy efficiency

[3] See European Commission 2018a
[4] Emissions from land use, land use change and forestry (LULUCF) are not directly considered under the two regimes, but ex post accounted for (see ESD art. 9).
[5] See Elkerbout et al. 2017
[6] The consequences of a possible withdrawal of the United Kingdom from the EU in 2019 are not considered in this study.

and technological innovation for GHG abatement (for instance Carp 2017). As a first measure to induce a price increase, the “back-loading” of auctions held back 900 million EUA between 2014 and 2016. To regulate the excess of allowances in the long run, from 2019 onwards a share[7] of excess allowances will be transferred to a Market Stability Reserve (MSR) where they are held with the possibility to be transferred back to the market in case of scarcity. A mechanism to delete allowances held in the MSR will be established after 2023. Essentially, this results in a reduction of total emission allowances.[8]

Furthermore, in the recent trilogue negotiations, the European Parliament, the Council and the Commission agreed on details for the fourth ETS trading period (from 2021 to 2030).[9] The emissions cap will decrease per year by a linear reduction factor of 2.2% based on 2005 levels (currently 1.74% per year).[10] In order to provide a framework for member states seeking to phase out fossil power plants, the agreement explicitly allows for a cancelation of allowances.[11] Without this measure, a phase-out policy has no impact on GHG emissions as free allowances can be used for emissions in other countries or sectors (the so-called waterbed effect).[12]

Non-EU ETS sectors

Except of emissions from land use, land use change and forestry (LULUCF)[13], the Effort Sharing Regulation (ESR) comprises all polluters not regulated under the EU ETS. It allocates to each member state an emission reduction target according to its economic performance. For the current period from 2010 to 2020, the Effort Sharing Decision (ESD 2009) aims at reducing GHG emissions by 10% compared to 2005; Germany is supposed to reduce emissions by 14%. For 2021 to 2030, a follow-up regulation aims at a reduction of 30% with a German target of 38%.[14]

Table 1 summarizes European climate targets relevant for Germany. In 2017, all European targets for 2020 were on track to be achieved. Germany, in contrast, had only reduced its emissions by 1% in 2017 relative to 2005. A further reduction of 13% until 2020 would be required to meet its Effort Sharing obligations on its own, i.e. without acquiring surplus allowances from other states.

[7] 24% from 2019 to 2023 according to trilogue negotiations%.
[8] See European Commission 2018c
[9] See Council of the European Union 2017
[10] Determined based on the overall reduction target.
[11] See Sørhus et al. 2017
[12] This holds only true if there is no excess of allowances. If there are more allowances available than needed, a phase-out policy might also have an effect without the cancelation of allowances.
[13] LULUCF emissions are regulated separately in EU legislation, but within the EU 2030 climate and energy framework. For further information see European Commission 2018b.
[14] See ESR 2018

TABLE 1: EUROPEAN GHG REDUCTION TARGETS

	Legal basis	Base year	2017 (historical data)	2020	2030	2040	2050
Overall GHG emissions	EU 2050 Roadmap	1990	-24%	-20%	-40%	-60%	-80%
EU ETS	Directive 2003/87/EC	2005	-26%	-21%	-43%	-67%	-90%
Effort sharing	ESD 2009 ESR 2018	2005	-10%	-10%	-30%	-	-
thereof Germany		2005	-1%	-14%	-38%	-	-

Source: EC 2011, ESD 2009; ESR 2018; EU ETS directive 2003/87/EC; 2017 values from EEA 2018a, 2018b.

2.2 German climate targets

The first domestic climate target of Germany dates back to the year 1990, when a GHG emission reduction of 25% until the year 2005 was envisioned.[15] German targets, therefore, precede the European targets. They evolved continuously during the years and were last confirmed and specified in November 2016 in the Climate Action Plan 2050.[16] It fixes national emission reduction targets for 2020, 2030 and 2050 as well as sectoral targets for 2030. Legally, it is a statement of intent by the former federal government without binding character.

Table 2 gives an overview of the different national and sectoral targets as well as their degree of achievement as of 2014. It emphasizes two points: First, all sectors have to make a significant contribution to the national climate targets. However, second, sectoral targets vary in their ambition in terms of relative reduction in GHG emissions.

TABLE 2: NATIONAL CLIMATE TARGETS IN GERMANY

	Base year	2014	2020	2030	2050
Total	1990	-28%	-40%	-55-56%	-80-95%
Energy	1990	-23%	-	-61-62%	-
Buildings	1990	-43%	-	-66-67%	-
Transportation	1990	-2%	-	-40-42%	-
Industry	1990	-36%	-	-49-51%	-
Agriculture	1990	-18%	-	-31-34%	-
Others[17]	1990	-69%	-	-87%	-

Source: Climate Action Plan 2050.

[15] For a summary of German climate targets see bpb 2013.
[16] See BMUB 2016
[17] Among others, waste and LULUCF.

While the overall target for the transport sector is low in comparison, it is the only sector that has not reduced its emissions significantly since 1990. Similarly, the emissions in the energy sector have been decreasing at a relatively low rate. Therefore, the energy and transport sectors have to achieve a disproportionately high reduction in the upcoming years. The buildings and industrial sectors reduced their emissions considerably between 1990 and 2014. The specified target for further reduction is thus relatively low.

The coalition contract of the grand coalition between the Christian Democratic Union (CDU), the Christian Social Union (CSU) and the Social Democratic Party of Germany (SPD) proclaims the commitment to all national and European climate targets. While the contract admits the existence of a gap of action to achieve the national target of 2020, it states that the 2030-target should be achieved in any case and will passed as law in 2019. Furthermore, a commission for "growth, structural change and employment" will be set up with the assignment to prepare a plan for a phase out of coal-fired power plants including a final closing date.[18]

2.3 Inefficiency and conflicts arising from parallel climate targets

Parallel climate targets at different levels (European vs. national) or for different sectors (EU ETS vs. Effort Sharing, transport vs. industry) interact; they may partially be in conflict and cause inefficiency. Adverse effects can be mitigated if a high degree of flexibility is ensured. For EU ETS sectors, additional national targets may lead to a deviation from the efficient distribution of abatement within Europe: Emissions may simply shift to another country but no additional abatement takes place (without the additional cancellation of allowances) or/and abatement options with lower costs in other countries may be neglected. The total costs of abatement potentially increase from a European perspective. National measures for EU ETS sectors are only effective in terms of reducing overall GHG emissions if they are accompanied by a cancellation of allowances from the system. In this case, a pure cancellation of EUA without national action could be a preferable option from an economic point of view. The cancellation would reduce the emissions cap and the abatement would take place in the country and sector with the lowest costs.

For non-EU ETS sectors, the initial distribution of Effort Sharing obligations is by construction not cost efficient. National Effort Sharing targets are assigned according to economic performance and, ultimately, fairness considerations. However, the regulation sets up flexibility mechanisms to overcome the inherent inefficiency. Most importantly, there is the option to transfer Effort Sharing allowances between countries. Besides, the Effort Sharing regime allows for a certain temporal flexibility in meeting targets. Furthermore, abatement from measures regarding land use, land use change and forestry (LULUCF) as well as cancelled EU ETS allowances can be counted as credit for the Effort Sharing targets.[19]

[18] See CDU/CSU/SPD 2018

[19] German targets from the Climate Action Plan for the year 2030 are proportionally more ambitious in terms of emission reduction than European targets. This implies that Germany can more than proportionally reduce its emissions in the EU ETS sectors (which may be inefficient as outlined) or it can be more ambitious in non-EU ETS sectors.

Another topic regarding the potential for conflict with parallel climate targets is the question which country is held responsible for GHG emissions when emissions take place in one country but the produced good is consumed in another ("carbon liability"). Although carbon liability remains a pure question of accounting for global warming, it can determine whether a country meets its domestic climate targets or not. For instance, if Germany imports Chinese steel, the GHG emissions caused will – in the current regime – be allocated to China, although the steel was produced to satisfy German consumption. European and national carbon accounting based on national GHG inventories is using producer responsibility. The main reason lies in the fact that data on the emissions related to production processes is easier to obtain than the data for an assignment of emissions to final consumers. Basically, to achieve its national climate target, Germany has an incentive to import electricity from Polish coal-fired power plants as these emissions do not count for Germany.

The question of carbon liability also arises in the context of climate friendly synthetic methane and fuels from PtX technologies. An example is the currently much discussed option of importing synthetic fuels from Northern Africa where solar power could be produced at relatively low costs.[20] Carbon dioxide is used as input for the PtX-production; therefore, the process generates negative emissions. Under the principle of producer responsibility, consumers of synthetic methane and fuels will be held responsible for the same emissions as if they would have used fossil fuels. Burning synthetic energy carriers causes the same emissions than burning fossil fuels. In order to create an incentive for using PtX technologies, mechanisms should be established to enable trading of credits for negative emissions.

In summary, there are conflicts and inefficiencies caused by the interaction of parallel climate targets at different levels and for different sectors that need to be resolved. As climate change is a global challenge, emphasis should be on tackling total GHG emissions. This should be done as efficient as possible with abatement at the lowest cost. The best option to reduce conflict and increase efficiency is a high degree of flexibility, not in terms of total emission reduction but regarding the distribution of abatement, in order to enable cost efficiency. Institutionalized mechanisms should support the use of flexibility options. EU climate strategies and targets already reflect an awareness in this regard. Both EU ETS and effort sharing determine overall targets but enable flexibility. German targets should adopt this awareness and be embedded within this flexibility setup.

[20] For instance in Agora Verkehrswende, Agora Energiewende and Frontier Economics 2018.

3 KEY MECHANISMS FOR ACHIEVING CLIMATE TARGETS

This chapter features a discussion of key mechanisms for achieving the climate targets discussed in chapter 2. First, historical developments and, if available, specific targets are presented. Second, we analyse how major recent energy market studies approach the different mechanisms of tackling GHG emissions and how assumptions compare to historical development. Third, barriers that threaten the realization of the envisioned targets as well as scenarios are presented.

Key aspects of decreasing GHG emissions are illustrated in Figure 1. Given the historical final energy consumption in Germany (here illustrated for 2005 and 2017) and the generation of electricity from renewable energies (here for 2017) three basic mechanisms can be identified.[21] First, as the consumption of fossil fuels is directly related to emissions, energy consumption could be decreased. Second, electrification of the final energy consumption – either directly (e.g., e-mobility or heat pumps) or indirectly (synthetic fuels) – reduces the emission intensity of energy consumption if, third, emission intensity of electricity generation is low - usually proposed to be achieved by expanding the deployment of renewable energies.

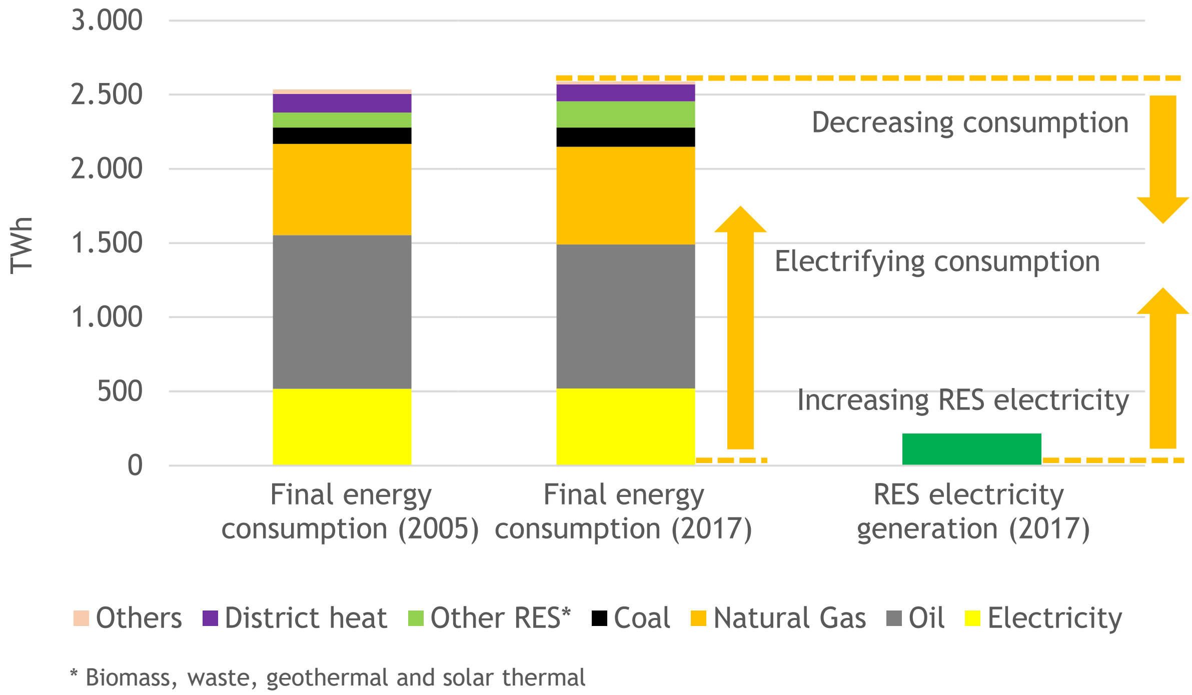


FIGURE 1: FINAL ENERGY CONSUMPTION AND PATHWAYS FOR ACHIEVING CLIMATE TARGETS
Source: AGEB 2018

[21] Other components like the expansion of the use of biomass and biofuels will not be discussed in detail, because the potential for the further expansion of the use of biomass and biofuels is considered limited. While some studies consider the current use of about 300 TWh (including imports) as constant (ewi ER&S 2017), others assume an increase up to 350 TWh (BCG & Prognos 2018) or 400 TWh (Fraunhofer ISI et al. 2017) until 2050.

We compare three major recent studies investigating integrated energy market scenarios. Thereby, we focus on how the aforementioned key mechanisms are taken into account. Particularly, we are interested in identifying critical assumptions and assessing their impact on study results. The studies were selected as they cover a broad spectrum of involved stakeholders[22] and, therefore, experienced broad public awareness. Studies considered are:

- Fraunhofer ISI et al. 2017 - Langfristszenarien für die Transformation des Energiesystems in Deutschland
- BCG & Prognos 2018 - Klimapfade für Deutschland
- dena/ewi ER&S 2018 - dena-Leitstudie Integrierte Energiewende[23]

All studies follow a similar approach: First of all, a reference scenario resembling a business-as-usual scenario based on current market conditions and climate protection measures is presented. These scenarios constitute exploratory scenarios as, e.g., GHG emissions, are not an input fixed a priory but are rather an outcome. Consequently, all reference scenarios differ with respect to GHG emissions: Whereas BCG & Prognos 2018 and dena/ewi ER&S 2018 project a similar reduction of around -60% (-44%) until 2050 (2030), Fraunhofer ISI et al. 2017 expect only -56% in 2050 (but also -43% in 2030). Extrapolating the historical trend from 2005 to 2015 reveals, that even the reference scenarios assume an acceleration of GHG mitigation as extrapolation results in a reduction level of only -47% (-36%) in 2050 (2030).

Following the reference scenarios all studies present various normative scenarios that describe how climate targets may be reached (usually in a cost-minimal way). In our analysis we focus on the main normative scenario in each study, featuring a reduction of GHG emissions by 80% until 2050 each. We are especially interested in how the scenarios incorporate mitigation options, what implicit and explicit assumptions are made, how these compare to the historical trend and what barriers concerning the implementation of mitigation pathways may exist. The comparison of all studies is based on the publicly available data which differs with respect to the level of detail as well as completeness. Nonetheless, key differences between the studies can well be identified.

As the two key mechanisms of reducing energy consumption and electrification of final energy demand are closely related (electrical applications are usually more efficient than using conventional fuel), they will be addressed at once in the following section. A discussion concerning increasing the deployment of renewable energies in the electricity sector follows subsequently.

[22] BCG & Prognos 2018 was commissioned by the BDI, the lobby group of the German industry; dena/ewi ER&S 2018 brought together more than 50 stakeholder ranging from individual companies to lobby groups; Fraunhofer ISI et al. 2017 was commissioned by the Federal Ministry for Economic Affairs and Energy (BMWi).

[23] ewi ER&S is lead consultant in this project. Parts of the analysis refer to dena 2017 which is based on the same assumptions and scenarios. The values in this study were taken from the Technology Mix scenario TM80.

3.1 Reducing energy consumption and increasing electrification

One major lever for reducing GHG emissions is decreasing energy consumption. This can be approached in two ways: sufficiency and efficiency.

Sufficiency focuses on consumers reducing their demand for resources. Sufficient consumption can be a result of ethical considerations or incentivized by an adequate policy framework. For instance, decreasing the demand for private transportation in favour of public transport - either via increasing private transportation costs or changing consumer preferences – can decrease energy demand. The concept of sufficiency is subject to controversial public discussion, because it may be in conflict with the political objective of continuous economic and welfare growth and interfere with the freedom of taking individual consumer choices. Supporters of the sufficiency argument state that without increasing frugality climate targets will not be met as rebound effects may offset any efforts to reduce energy consumption. Critics of the sufficiency argument, in contrast, argue that continuous growth based on increasing efficiency and renewable energy sources is compatible with achieving climate targets.[24]

The second approach to reduce energy consumption is to increase energy efficiency, i.e., decrease the amount of energy needed to provide a certain energy service.[25] Table 3 shows the German primary energy consumption target for 2050 and the current level of achievement.

TABLE 3: OVERVIEW OF GERMAN ENERGY EFFICIENCY TARGETS AND LEVEL OF ACHIEVEMENT

	Base year		Historical	Target 2050
Primary energy consumption	2008	Total reduction	-6% (2017)	-50%
		yearly avg.	-0.7% p.a. (2008-2017)	-1.9% p.a. (2018-2050)

Sources: BMWi 2015; AGEB 2017a; own calculation.

The envisioned target for consumption of primary energy amounts to a reduction of 50% until 2050 (compared to 2008). Until 2017 a reduction of only about 6% has been achieved (corresponding to an average annual reduction of 0.7%). To reach the target in 2050, the average annual reductions have to be increased to about 1.9% from now on. For the consumption of primary energy a target for 2020 - a reduction of 20% compared to 2008 - has also been announced. But given the current level an unrealistically high reduction of 5.3% p.a. would be necessary to reach that target.

[24] See Linz 2015

[25] The targets are based on the EU Energy Efficiency Directive (EED) published in 2012. The EED was issued to achieve the European energy efficiency target of reducing primary energy consumption by 20% until 2020 compared to 2005. One of the key elements is a requirement for member states to cut energy consumption by on average 1.5% p.a. from 2014 to 2020.

To better understand why the target is missed, we take a closer look at two examples: The transport and the buildings sector (see Table 4).

TABLE 4: GERMAN ENERGY EFFICIENCY TARGETS IN THE TRANSPORT AND BUILDINGS SECTOR

	Base year		Historical	Target 2050
Final energy consumption in the transport sector	2005	Total reduction	+6.5% (2017)	-40%
		yearly avg.	+0.5% p.a. (2005-2017)	-1.5% p.a. (2018-2050)
Primary energy consumption in the building sector	2008	Total reduction	-14.8% (2014)	-80%
		yearly avg.	-2.6% p.a. (2008-2014)	-3.9% p.a. (2015-2050)

Sources: BMWi 2015; AGEB 2018; own calculation.

For the transport sector, a final energy reduction target of -40% (-10%) until 2050 (2020) compared to 2005 was set. Yet so far, until 2017, final energy consumption actually increased by 6.5%. The target for 2020 - a reduction of 10% compared to 2005 is already out of reach. An annual reduction by 5.5% would be necessary to reach this target. Although energy efficiency (i.e., final energy consumption per transport kilometre) has been increased significantly by 10%, this was overcompensated by an increase in total transport distance by 16%. This stresses the importance of correctly assessing the future development of demand and that inadequate assumptions may compromise results.[26]

Another target focuses on the primary energy consumption of the building sector. The goal is to reduce consumption by 80% until 2050 in comparison to 2008 levels. Between 2008 and 2014 the consumption decreased by 2.6% on average per year. Given the current reduction level, a more ambitious reduction rate of 3.9% p.a. would be necessary to reach the target in 2050. Although in recent years (2008 until 2016) energy efficiency (i.e., final energy consumption per square meter) has been increasing significantly by 18%, this was partly compensated by an increase in total living space by 14% - triggered by an increase of single households.[27] One important factor for further decreasing energy consumption, in particular final energy consumption per square meter, is an increase in the building refurbishment rate. Refurbishment mainly refers to improvements of the building envelope as well as heating systems.[28] But despite various political attempts, the rate has been stagnating between 0.8% and 1% p.a. in recent years.

Since a reduction of GHG emissions may be cheaper to accomplish in the electricity sector than in other sectors, the second key mechanism to achieve climate targets is to electrify energy consumption. This can be done in two ways: First, by direct electrification using, e.g., heat pumps or electric vehicles.[29] Since electric vehicles and heat pumps are more efficient than fuel-based

[26] Own calculations based on AGEB 2017a.
[27] Own calculations based on AGEB 2017a.
[28] Oftentimes both types of measures are mutually dependent, e.g. the installation of heat pumps requires a high level of insulation of the building envelope in order to be cost efficient (dena 2017).
[29] See Fraunhofer ISI et al. 2017

combustion engines or heating, this also decreases energy consumption in the respective sectors.[30] Second, fossil energy can indirectly be replaced by synthetic fuels generated by PtX using electricity (for example power-to-gas or power-to-fuel).[31]

Reference studies

All studies introduced above stress the importance of decreasing energy consumption in the building sector. The main indicator for increasing energy efficiency is the building refurbishment rate. Due to variations in profoundness of the refurbishments, implemented heating technologies and other assumptions, available data only allows for a high level comparison of the studies. Table 5 gives an overview of the building refurbishment rates.

TABLE 5: OVERVIEW BUILDING REFURBISHMENT RATE

	dena/ewi ER&S 2018	BCG & Prognos 2018	Fraunhofer ISI et al. 2017[32]
Current rate		Approx. 1% per year	
80% scenario	1.4% p.a. (2015 - 2050)	1.7% p.a. (2015 - 2050)	1.1% p.a. (2015) linear increase to 2.5% p.a. (2050)

Sources: Fraunhofer ISI et al. 2017; dena/ewi ER&S 2018; BCG & Prognos 2018.

In its 80% scenario, dena/ewi ER&S 2018 assumes a constant refurbishment rate of 1.4% p.a. BCG & Prognos 2018 assumes a rate of 1.7%. Fraunhofer ISI et al. 2017, in contrast to the constant rates in the other studies, assumes a linear increasing rate until 2050: While the starting value in 2015 is close to the current rate, the annual building refurbishment rate increases to 2.5% until 2050 in the 80% scenario.

In addition to better insulation, all studies assume a significant increase in the diffusion of electrical heat pumps, driven by the underlying assumptions concerning technological progress and cost reductions (see Table 6). BCG & Prognos 2018 assume an increase to 14 million electrical heat pumps in 2050. Fraunhofer ISI et al. 2017 as well as dena/ewi ER&S 2018, although more modest, also assume a significant increase.

Concerning PtX fuels, only dena/ewi ER&S 2018 estimates them to be commercially feasible at some point after 2030. As a result of the significant deployment of PtX fuels (294 TWh in 2050), the importance of existing infrastructures for district heating and natural gas is stressed in this study.

[30] The effect on overall (primary) energy consumption and most importantly GHG reduction is determined by the source of electricity. While RES electricity generation is emission free and conversion efficiency is 100%, the use of coal-based electricity generation is ultimately a transfer of emissions as well as efficiency losses into the electricity sector.
[31] See ewi ER&S 2017 and dena/ewi ER&S 2018
[32] Own estimation of average value since rates are displayed individually for different types of buildings.

TABLE 6: OVERVIEW DEGREE OF ELECTRIFICATION

				dena/ewi ER&S 2018		BCG & Prognos 2018		Fraunhofer ISI et al. 2017	
			2017	2030	2050	2030	2050	2030	2050
Indirect electrification	PtX fuels	TWh	✗	✗	✓ 294 TWh	✗	✗	✗	✗
Direct electrification	Heat pumps	Million	0.8	3.4	6.5	na	14	na	na
		TWh	na	na	na	29 TWh	51 TWh	18 TWh	29 TWh
	E-Mobility (BEV+PHEV)*	Million	0.2	22	28	6	26	6	30
		TWh	na	72 TWh**	86 TWh**	30 TWh**	79 TWh**	12 TWh***	68 TWh***

* BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle
** Electricity consumption refers to the entire transport sector
*** Electricity consumption refers to electromobility in the entire transport sector

Sources: BWP 2017; KBA 2017b; Fraunhofer ISI et al. 2017; dena/ewi ER&S 2018; BCG & Prognos 2018.

In the transport sector, one of the main levers for reducing energy consumption and thereby greenhouse gas emissions is the deployment of electric vehicles. BCG & Prognos 2018 and Fraunhofer ISI et al. 2017 show a similar diffusion of e-mobility with up to 30 (6) million cars (battery electric vehicle and plug-in hybrids) in 2050 (2030). Given new registrations of 55 thousand electric cars in 2017 (a share of 1.6%), this requires a significant increase.[33] BCG & Prognos 2018 envision the share of electric cars on new registrations to increase to about 6% until 2020 to 42% by 2030. dena/ewi ER&S 2018 also stresses the importance of e-mobility, but at the same time points out the need for PtX-fuels.

Critical assumptions

Concerning the buildings sector, all studies assume a significant increase in refurbishment rates. Against the background of the historical development, this appears optimistic. Although there have been several attempts to increase the refurbishment rate in the past, all measures had only very limited effect.[34] Nevertheless, all studies assume significantly higher rates than the current value of 1% per year to achieve the national climate target of an 80% GHG reduction.

The refurbishment rate does not only depend on costs and economic incentives: Many building refurbishment measures are – already today – profitable in the long run. Increasing costs for gas and electricity might further reinforce this tendency. Still, high investment costs and long payback periods act as barriers for accelerated efforts.[35] There are also non-monetary factors such as the landlord-tenant dilemma[36] and acceptance issues due to increases in rent or construction noise.

[33] See KBA 2017a
[34] See dena 2017
[35] Especially for proprietors like pensioners and elderly people, this is often a major hurdle.
[36] While the cost of the refurbishment is paid by the landlord, the tenant benefits from low energy procurement costs. The incentive of the landlord to implement the economically efficient refurbishment is therefore dependent on the possibility of cost transfer to the tenant.

Another reason that might prevent decreasing overall energy consumption is the rebound effect.[37] It states that increases in energy efficiency often do not decrease energy consumption proportionally. Popular examples include observed increases in room temperatures after replacing inefficient heating systems as well as increasing annual mileage (or larger vehicles like Sports Utility Vehicles and limousines)[38] in response to greater vehicle fuel efficiency. The above cases describe direct changes in product use and are thus referred to as the direct rebound effect. Furthermore, decreasing fuel or heating cost enable consumers to spend more on energy intensive activities such as air travel or purchasing other goods and services that require energy to produce. This indirect increase in resource consumption is referred to as the indirect rebound effect. Although the consequences of the rebound effect are well known, they receive little attention in the political agenda and are typically not taken into account in energy scenarios.

Concerning the electrification of the transport sector, the prevalent scenarios envision a significant increase in electric vehicles. Even if cost-related barriers compared to conventional motors and possible raw materials shortages due to increased battery production are left aside, the diffusion of electric vehicles might be inhibited by non-monetary preferences: Factors like limited range, slow recharging and sparse service station infrastructure still favour conventional cars. Technological advances concerning battery technology may turn out to be crucial but are still uncertain.

The current structure of energy taxation might also turn out to impede an electrification of energy applications: Whereas taxes and levies not directly related to production and distribution amount to about one quarter of the gas price for households, the surcharge on the electricity price amounts to more than 50%.[39] Theses imbalances are typically not taken into account in energy market studies but significantly impact individual technology decisions. Given the complex system of taxes and levies for each energy carrier and type of customer and thus the complex distribution effects of a possible restructuring, the political barriers towards creating a level playing field for all energy carriers are manifold.

Electrification of final energy demand poses some challenges with respect to the electricity system: Depending on the charging behaviour for electric vehicles and heating profile for power-to-heat, demand peaks might occur that require sufficient back-up capacity to reliably balance demand and supply.

The electricity grid will face significant challenges with increasing electrification. Prevalent studies forecast a major demand for the refurbishment of the distribution grid for upcoming applications of electric vehicles and heat pumps. So far, the distribution grid is unfit to handle the anticipated demand peaks. The major financial requirements and associated costs for consumers

[37] See UBA 2014
[38] See Aral 2017
[39] See BDEW 2017a and BDEW 2017b

come along with significant grid construction efforts. Given the experiences with public resistance concerning infrastructure projects and experienced delays in the past, the electricity grid might turn out to be a bottleneck for a widespread electrification.

Using PtX fuels to some extent could reduce the need for enforcing the grid infrastructure as well as securing peak electricity supply: PtX fuels make use of the existing infrastructures and can be stored more easily. Also, existing industrial process routes and technologies based on fossil fuels could more easily be adapted to synthetic fuels. However, the PtX technology at present is not economically feasible and significant cost reductions have to be achieved. Furthermore, for synthetic fuels to reduce greenhouse gas emissions the required electricity has to stem from renewable sources. In Germany, due to space limitations for renewable energies, a significant production of PtX fuels may be unlikely. PtX generation is more likely to be cost effective in very sunny regions with low population density, for example Northern Africa or Saudi Arabia. In Europe there might be a business case for PtX close to offshore wind parks in Northern Europe.[40] Thus, using PtX would require significant energy imports.

[40] See ewi ER&S 2017

3.2 Expansion of RES electricity generation

For the electrification of energy demand (as discussed in the previous section) to be meaningful - in terms of reducing GHG emissions - the emission intensity of electricity generation has to be low. As using nuclear power plants is no longer an option in Germany due to an opposing public opinion, renewable energies are the preferred option.[41]

Since the introduction of the German Renewable Energy Act (EEG) in 2000 the share of renewables in electricity generation (mainly due to growth in wind and solar) has been increasing rapidly.[42] In 2017, it amounted to 36% of gross electricity consumption.[43] The overall goal is to reach a share of about 80% renewables of the gross electricity consumption in 2050 including an intermediate milestone of 65% in 2030, stated in the recent coalition agreement (provided that electricity grid expansion advances as planned).[44] For the share of RES electricity generation the interim target for 2020 is 35%. This was already exceeded in 2017.

Reference studies

Figure 2 illustrates the development of RES electricity generation of solar and wind in the reference studies. All three studies assume a strong increase in renewable energies.

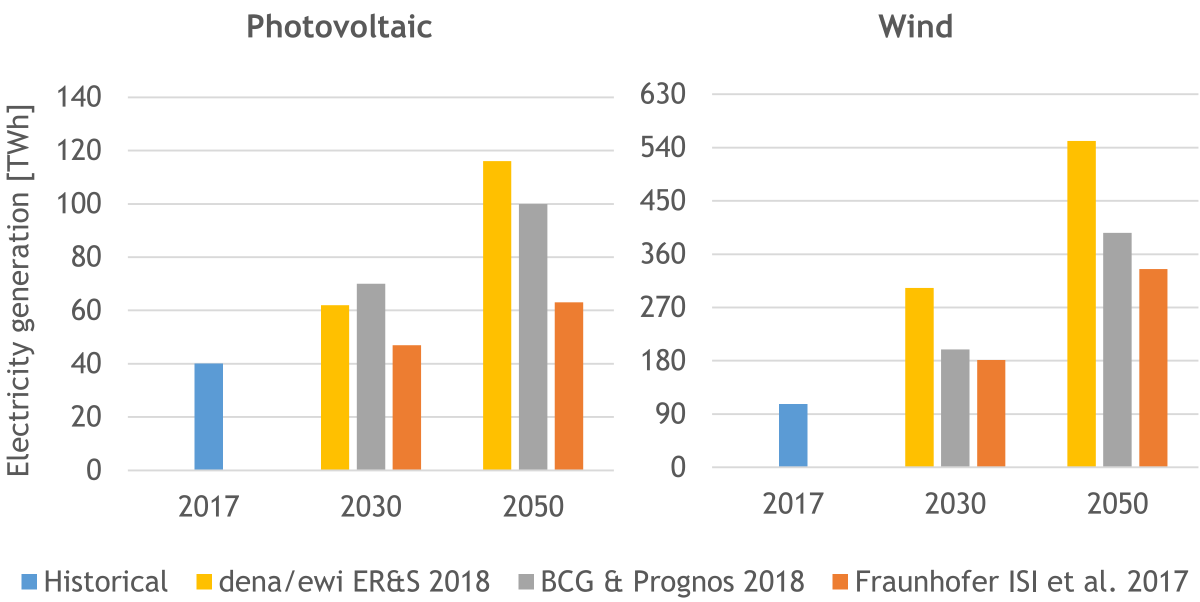


FIGURE 2: OVERVIEW RENEWABLE ELECTRICITY GENERATION

Source: BMWi 2018a; Fraunhofer ISI et al. 2017; Fraunhofer ISE 2018; dena/ewi ER&S 2018 and BCG & Prognos 2018.

[41] Replacing coal and lignite fired power plants by gas fired power plants additionally reduces the GHG intensity of electricity generation.
[42] See EEG 2017
[43] See BMWi 2018b
[44] The interim goal is part of the recently negotiated coalition agreement between SPD, CDU and CSU and there is no reference point for the % number defined yet (CDU/CSU/SPD 2018).

dena/ewi ER&S 2018 and BCG & Prognos 2018 both assume a strong increase in solar and wind based electricity generation. Solar energy generation is supposed to almost triple by 2050. The increase in wind power generation (including both onshore and offshore wind) is estimated to be even higher.

Fraunhofer ISI et al. 2017 assume a lower deployment of PV and wind. Net imports of 105 TWh compensate the missing generation in 2050. dena/ewi ER&S 2018 and BCG & Prognos 2018 on the other hand assume that Germany will have a rather even trade balance in the long run.

Critical assumptions

As discussed in the previous section, the increasing electrification of final energy consumption is associated with major challenges for the electricity grid: Grid congestion problems are likely to increase – in particular on the distribution grid level - due to the expected increase of heat pumps and e-mobility.

Grid congestions problems – in particular on the transmission grid level – are also one of the main challenges for a further expansion of decentralized and volatile RES generation capacities. In recent years, the expansion of the transmission grid has repeatedly been delayed which resulted in an increasing deficit in transmission capacities between the wind rich northern part of Germany and the high energy-consuming areas in the southern part.[45] The expansion of RES generation capacities may further increase grid congestion and require an accelerated electricity grid expansion. Given the experiences with public resistance concerning infrastructure projects and experienced delays in the past, the electricity grid might turn out to be a bottleneck for the expansion of RES generation capacity.

The studies do not consider a possible lack of acceptance of additional renewable capacities. In particular, the strong expansion of onshore wind turbines may encounter resistance in the population. Onshore wind farms, according to recent surveys, have the lowest level of acceptance among all RES alternatives, especially when in close proximity to residential areas.[46] This is mainly due to increasing concerns regarding acoustic emissions and visual appearance. These concerns are already transformed into legislative regulation increasing the minimum distances to residential areas or limiting the use of forest areas for example in Bavaria. Other states like North Rhine-Westphalia or Schleswig-Holstein are also planning more restrictive regulations.

Furthermore, a significant increase in flexible back up technologies such as open gas turbines and electricity storage such as batteries will be required to ensure security of supply in periods of low wind and solar radiation.

[45] See Löschel et al. 2016
[46] See Sonnberger & Ruddat 2016

4 EXPLORATORY APPROACH FOR DERIVING FUTURE ENERGY DEMAND – A THOUGHT EXPERIMENT

Given the sketched uncertainties regarding the realization of the prevailing normative scenarios and in light of the historical development of the energy system, we conduct a thought experiment. This experiment is used to illustrate, in a simplified framework, the consequences of failing to achieve key components in Germany's climate protection strategy. The experiment is constructed as an exploratory scenario: Based on historical data, we project the future development. Thus, in contrast to the prevailing normative scenarios (like the ones presented in the previous chapter), targets like CO_2-emission bounds are not regarded as inevitable with a system evolving around these targets, but are rather an outcome of the projected development.[47]

In the following, we focus our analysis on the development of energy consumption. More specifically, we focus on the development of primary energy consumption as it directly reflects GHG emissions. Figure 3 presents an overview of the historical development of primary energy consumption as well as scenarios for its development until 2050. The future composition of energy consumption with respect to energy sources is based on the 80% scenario of Fraunhofer ISIet al. 2017 - similar developments can be observed in BCG & Prognos 2018 and dena/ewi ER&S 2018. The extrapolation of the reduction rate for primary energy consumption between 2005 and 2015 (orange line) as well as the reference scenario from Fraunhofer ISI et al. 2017 (dark grey line) serve as additional reference points for the analysis.

The orange hatched area illustrates the potential shortfall of primary energy supply, calculated as the difference between primary energy sources in the 80% scenario and the alternative trajectories. The shortfall could, for instance, arise from additional (process) heating demand or fuel consumption in the transport sector. The resulting shortfall in primary energy between the 80% scenario and the extrapolation of the historic trend is about 730 TWh in 2030 and 1.000 TWh in 2050. This illustrates the large range of primary energy demand between the target achieving scenario and the historic trend: Assuming that the current rate of the decrease of primary energy consumption is extrapolated, the overall consumption is 52% higher in 2050 than the envisioned level in the 80% GHG reduction scenario.

[47] See Dieckhoff et al. 2014 for more on details on the design of energy market scenarios.

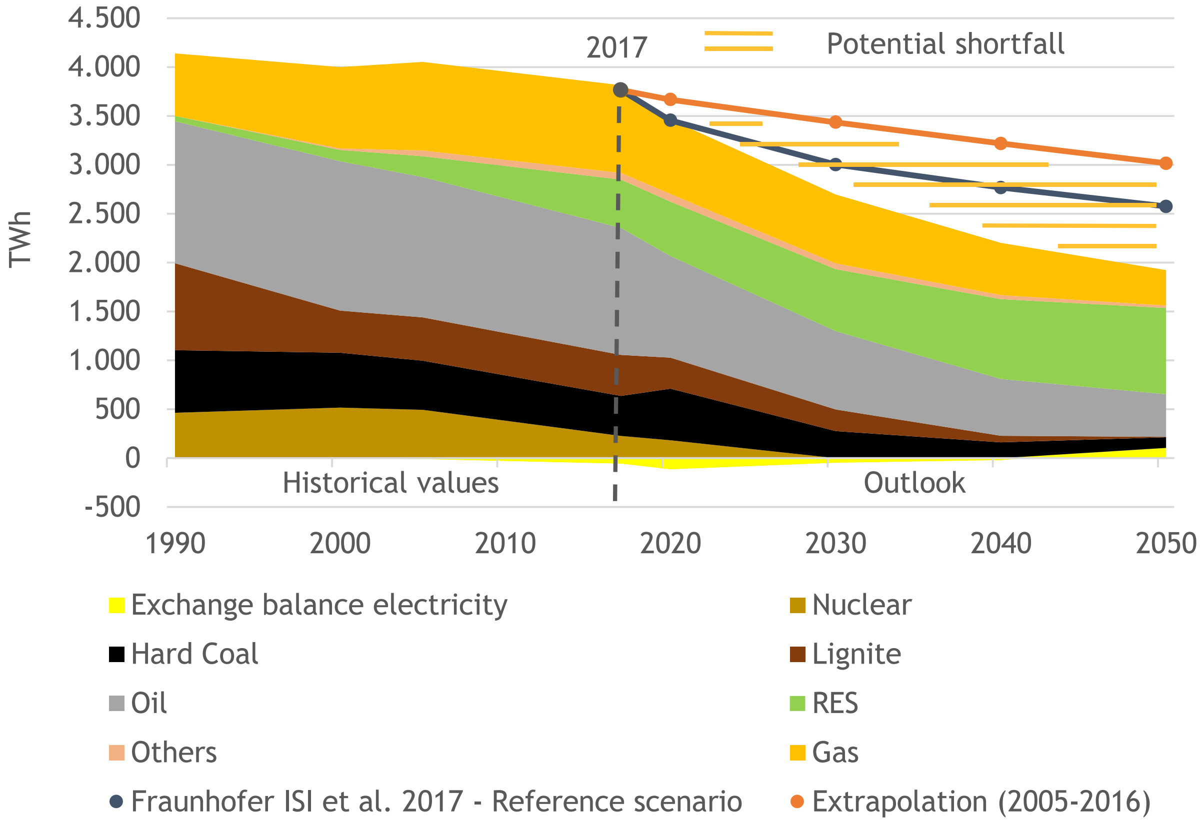


FIGURE 3: PRIMARY ENERGY CONSUMPTION – HISTORICAL DEVELOPMENT AND OUTLOOK

Source: AGEB 2017a; Fraunhofer ISI et al. 2017; own calculations.

Especially for the year 2030, given the historical development and the limited remaining time for regulatory interventions, the envisioned reduction in primary energy demand may be questionable. Thus, for the further analysis we focus on the developments in the medium term until 2030.

Assumptions of the thought experiment

We derive the potential primary energy demand until 2030 based on the following assumptions: First, we assume a total primary energy demand based on the extrapolation of the historical trend for the primary energy consumption between 2005 and 2015. Second, we assume that the gap in total demand is closed by a proportional increase of primary energy carriers in the reference scenario[48] – except, third, we assume lignite- and coal-fired electricity generation according to the more ambitious 80% scenario. The gap in electricity generation is compensated by low-emission gas-fired electricity generation. This scenario resembles a development where climate protection measures are not sufficiently implemented in all sectors to achieve postulated targets. However, the reduction of coal-fired power generation is being pursued.

Figure 4 illustrates the resulting primary energy demand based on the assumptions of the thought experiment. These imply that Germany will miss its national climate targets in 2030 of reducing

[48] The proportional increase is equivalent to +5.1% in 2020 and +12.5% in 2030.

GHG emissions by 55% in comparison to 1990 levels. The resulting path would instead correspond to a reduction of GHG emissions by approximately 40% in 2030, which is equivalent to the national reduction target for 2020.[49] This also implies that Germany does not achieve its effort sharing obligations on the European level, which might entail additional efforts to balance excess emissions (via the trade of emission rights) or penalties.

Given the assumption that the further expansion of RES capacities is limited due to restrictions concerning, e.g., available space, public acceptance, and limited expansion rates, the application of more gas-based technologies could help to reduce GHG emissions. Possible options include the promotion of gas-powered engines to replace petrol and diesel engines in the transport sector or a more accelerated phase-out of lignite-/coal-fired electricity generation.

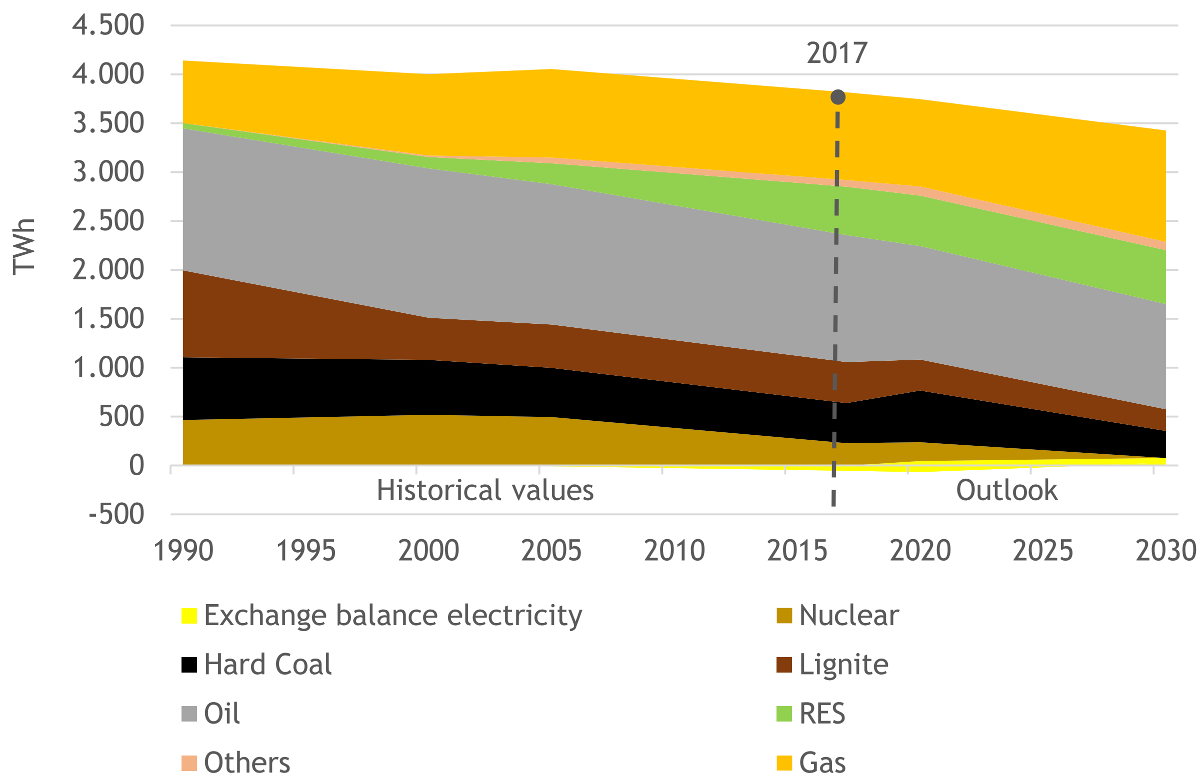


FIGURE 4: PRIMARY ENERGY CONSUMPTION - OUTLOOK THOUGHT EXPERIMENT

Source: AGEB 2017a; own calculations based on Fraunhofer ISI et al. 2017.

The results show that a scenario with a low increase in energy efficiency and limited RES expansion might cause a continued high demand for conventional energy sources. In particular the demand for gas could rise until 2030.

[49] This calculation is based on the assumption that there is no application of Carbon Capture and Storage (CCS) or emission neutral synthetic fuels.

Figure 5 gives an overview of the historical and estimated gas demand as well as the (projected) domestic production in Germany. On the left-hand side the estimated gas demand from the 80% scenario of Fraunhofer ISI et al. 2017 is illustrated; on the right-hand side the estimated gas demand based on the assumptions in the thought experiment is displayed. While the demand is decreasing from 843 TWh to 700 TWh by 2030 in the 80% scenario, the gas demand in the thought experiment would rise to 1105 TWh.

The national gas demand has to be covered by imports as well as domestic conventional, synthetic or unconventional gas production. The national production of gas has been declining since 2005 and is expected to further decrease until 2030 due to declining conventional resources.[50] Synthetic gas, produced via power-to-gas, is not expected to be economically feasible in the next decade.[51] Thus, the most relevant options to satisfy the residual demand (demand that is not covered by the domestic production of conventional gas) are imports and unconventional gas. In the following we discuss these options with special focus on gas procurement options and import dependency.

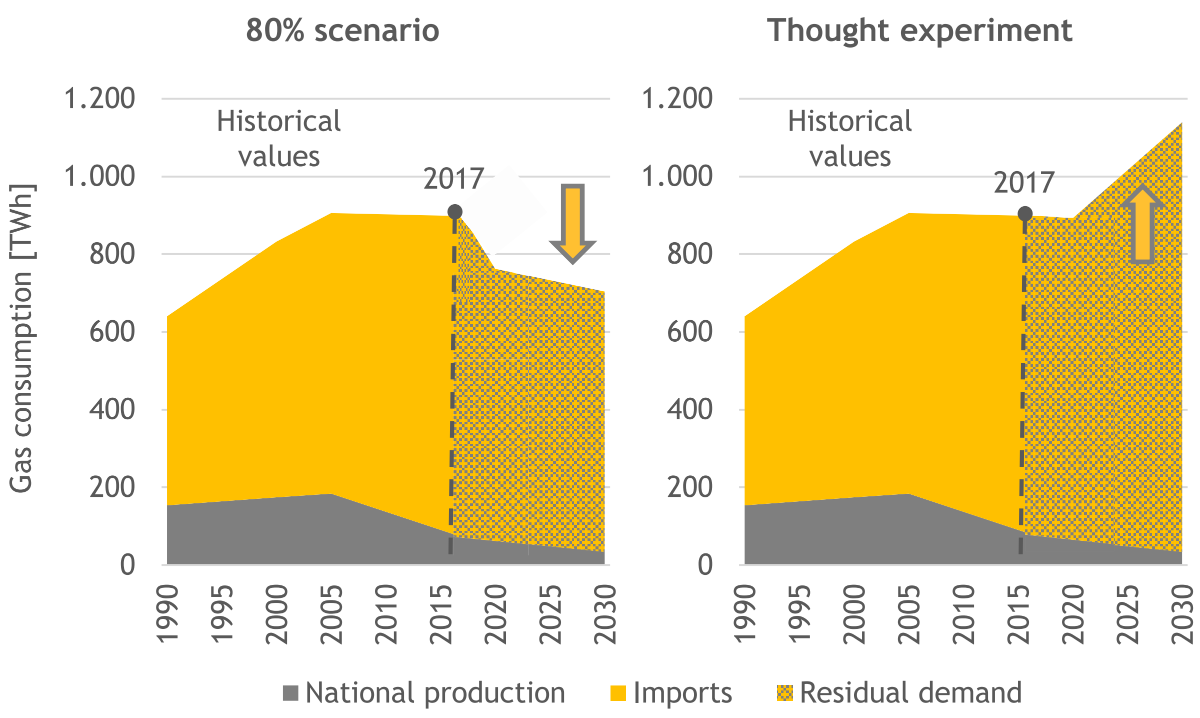


FIGURE 5: ESTIMATED GAS DEMAND AND NATIONAL PRODUCTION IN GERMANY

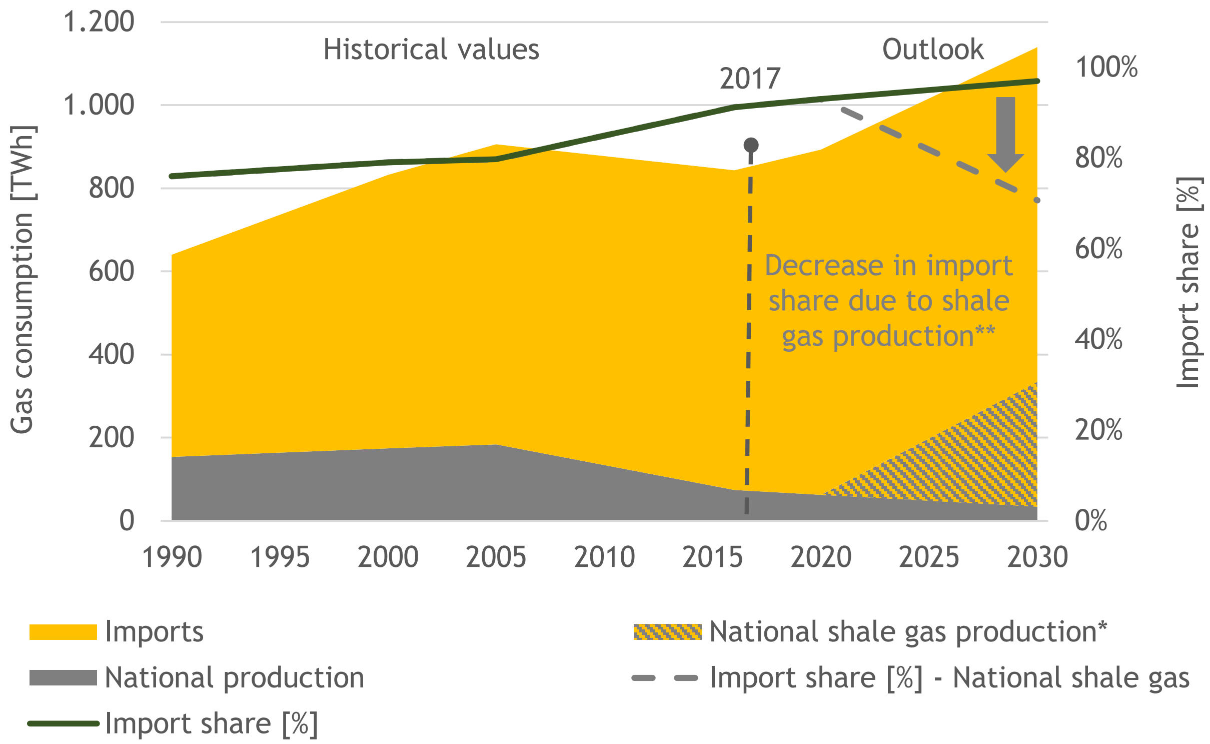
Source: AGEB 2017a; Fraunhofer ISI et al. 2017; own calculations based on Fraunhofer ISI et al. 2017.

[50] See ENTSOG 2017

[51] See dena/ewi ER&S 2018. Another option to produce synthetic gas is to use fossil fuels such as lignite, coal or bio fuels. Due to the high emissions of using fossil fuels and the very limited potential for bio fuels we refrain from discussing these options in the following.

Gas procurement options and import dependency

Figure 6 gives an overview of the historical and estimated gas demand in Germany based on the assumptions in the thought experiment described above. Historically, due to the decreasing national production and increasing demand, the import share has been constantly rising since 1990. As a result, in 2016 approximately 91% of the national gas demand was satisfied by imports.[52] The import share would, ceteris paribus, increase until 2030 to approximately 97% due to the further decreasing national production and increasing demand. In case that decreasing the import share and compensating for declining national production of natural gas is politically desired and/or economically feasible, the use of domestic unconventional/shale gas is an option.[53] Different studies estimate the technically recoverable potential of shale gas in Germany.[54] In the following we make a (conservative) estimate for the technically recoverable potential of 7.000 TWh in Germany based on BGR 2016. We further assume that approximately 1.500 TWh will be explored between 2020 and 2030; peak production of approximately 300 TWh domestic unconventional gas is reached in 2030. Given these assumptions, the import share would drop to about 71%.



* Economic viability, population acceptance and legal restrictions not considered
** Assumption: Technically recoverable potential of 7.000 TWh; 1.500 TWh explored by 2030

FIGURE 6: ESTIMATED GAS DEMAND AND NATIONAL PRODUCTION IN GERMANY

Source: AGEB 2017a, 2017b; BGR 2016; ENTSOG 2017; own calculations.

[52] The majority of imports stem from the Netherlands (23%), Norway (29%), Russia and others (42%). For data privacy issues only cumulated values for Russia and others (share of conventional gas imports from Russia in 2015: 39%). See AGEB 2017b.

[53] The terms unconventional gas and shale gas are used synonymously in this study as shale gas is the most known form of unconventional gas. Shale gas is released by fracturing deep rock formations. The so-called fracking process involves pumping large amounts of water, mixed with sand and chemicals, into the ground under high pressure in order to break open deep rock formations.

[54] See EIA 2015, BGR 2012 and BGR 2016

Especially the production of shale gas resources in the USA in recent years has triggered a public debate of the advantages and disadvantages of this technology – a debate usually controversially discussed. On the one hand critical voices emphasise negative environmental effects and a lack of economic efficiency. On the other hand proponents stress the reduction of import dependency and potentially decreasing gas prices hoping for a similar development like in the US, where the shale gas boom – in conjunction with substantial amounts of unconventional oil production - has triggered a substantial rejuvenation of the petrochemical and chemical industry.

ACER 2017 states that there is a low diversification for the German gas supply and that the rising market power of Russia could be regarded critical in this context. However, ewi ER&S 2016 concludes that during the next years, the European gas market has sufficient capacities for LNG imports and pipeline interconnections to ensure a high degree of upstream competition. The ewi ER&S study also states that in the case of a significantly rising gas demand in Europe and Asia, markets may tighten such that market power on the supply side may become an issue again. Riedel et al. 2017 point out that there might be strategic reasons for the production of unconventional gas: "On the one hand, this form of supply diversification could be beneficial with respect to supply security and on the other hand, it could weaken the bargaining power of suppliers in economical as well as political terms." But, from a political point of view and given the current state of the public debate – according to the authors - decreasing the bargaining power of suppliers by increasing LNG import capacities may be easier to implement than shale gas production.

While a considerable amount of academic literature deals with the estimation of the technically recoverable potentials or environmental impacts, estimates for the production cost of shale gas in Germany are rare. To the knowledge of the authors, the only available estimate is Riedel et al. 2017. They investigated the potential economic viability of shale gas resources in Europe. The results shown in Figure 7 indicate that shale gas in Europe is not competitive under current economic conditions with a wholesale gas price of around 20 €/MWh. As of today in Germany the total production costs are estimated to be in the range of 25 to 42 €/MWh. Additional price components like transport or profit margin are not taken into account and would result in even higher costs. However, strong price increases for conventional gas, as expected for instance by the World Energy Outlook 2016 (Scenario: New Policies) or the UK Department of business energy & industrial strategy (BEIS) (Scenario: High), might change the overall picture. Though, the forecast in the World Energy Outlook 2017 assumes wholesale prices below the estimated range of production cost for shale gas in Europe.

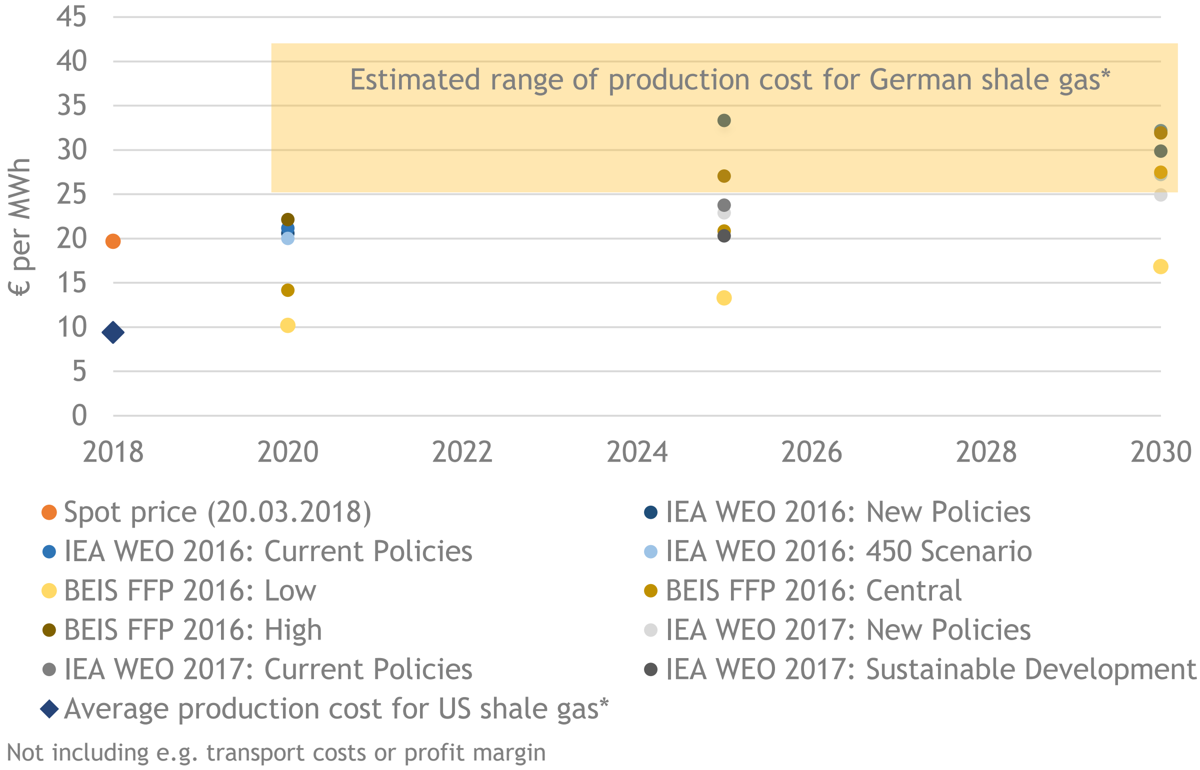


FIGURE 7: OUTLOOK NATURAL GAS PRICE AND ESTIMATED RANGE OF PRODUCTION COST FOR SHALE GAS

Source: Own illustration based on IEA 2016; IEA 2017; BEIS 2016; Mistré et al. 2018; Riedel et al. 2017.

Next to economic aspects, the potentially negative environmental impacts of hydraulic fracturing are controversially discussed. Reports of groundwater contamination and earthquakes in the USA caused by fracking and horizontal drilling have negatively affected the popular view on shale gas. Especially since in Germany most of the shale gas reservoirs are located in North Rhine-Westphalia and Lower Saxony, areas with high population density.[55] The high water consumption in the process is an additional argument for critics. However, the environmental effects of the shale gas production have been improved during the last decades. A study of BGR 2016 analysed the environmental impacts of shale gas fracking in Germany and found neither the probability of significant impacts to the groundwater pipelines/reservoirs nor seismic effects. Public perception in Germany is nonetheless shaped by the potential negative environmental impacts: The first unconventional shale gas fracking activities of ExxonMobil in Germany lead to massive political and social protest. Exxon decided to stop the project in 2011 and political regulation of hydraulic fracturing was intensified.[56]

Given the remaining uncertainties concerning the environmental impact of fracking the German Federal Government passed a regulation in February 2017. It legally fixed the ban of unconventional fracking actions. In Germany there are four sites where the production of shale gas/uncon-

[55] See EWI 2013
[56] See BGR 2012

ventional fracking for scientific purposes is permitted. The aim is to further explore the environmental impact and geographical conditions. Commercial unconventional fracking is banned till at least 2021.

5 CONCLUSIONS AND OUTLOOK

European and national climate regulations set ambitious greenhouse gas reduction targets. Currently, inconsistent target definitions and policy instruments make reaching these targets unnecessarily difficult. Aligning the targets could increase the efficiency of climate protection measures, reduce associated uncertainties and increase acceptance.

Prevalent energy market studies analysing possible scenarios for the decarbonisation of Germany typically ignore European targets – i.e., the mechanism of the EU ETS and the requirements of the Effort Sharing Regulations - and instead focus on national targets. Thereby, benefits of a common approach for climate protection are usually neglected.

Reaching climate protection targets requires significant efforts in all sectors. Extrapolating historical trends, i.e., assuming that more ambitious measures will not be implemented, would result in significantly higher greenhouse gas emissions than aspired. Given that targets in 2020 have already been abandoned by the new German government, it is unclear how to reach targets in the short and medium term, until 2030. Significant efforts have been made in existing studies on analysing technical and economic aspects of mitigation pathways concerning which technologies are needed when and how the cost efficient interaction of sectors may look like. However, questions on how barriers like rebound effects, slow adaption rates of technologies and acceptance problems - which have prevented reaching the 2020 goals – may be overcome are neglected. Given the sketched uncertainties with respect to the development of key components of the energy system, sensitivity scenarios with varying assumptions have to be taken into account. Especially regulatory and social factors set the framework for enabling or impeding a transformation of the energy system. Aspects of security of supply may turn out to be critical depending on certain developments and need to be anticipated. Security of supply has various facets ranging from sufficient availability of generation capacity to balance electricity supply and demand to securing long-term availability of energy sources like oil and gas.

With increasingly ambitious GHG reduction targets but at the same time a rocky road towards decreasing energy consumption, natural gas might play a key role in the energy system in the upcoming decades. However, domestic resources and therefore the production of natural gas are declining. This may result, ceteris paribus, in an increasing import share of gas. A theoretical alternative to conventional gas imports is the production of unconventional sources. Although considerable technical potential for fracking in Germany exists, concerns regarding potential environmental impact have resulted in a legal ban for commercial fracking until 2021. If these concerns can be removed, e.g., by technological progress, and the cost disadvantages compared to wholesale prices can be diminished, unconventional domestic gas sources might be a feasible option.

LIST OF ABBREVIATIONS

CCS	Carbon Capture and Storage
CDU	Christian Democratic Union
CSU	Christian Social Union
EEG	German Renewable Energy Act
ESD	Effort Sharing Decision
ESR	Effort Sharing Regulation
EU	European Union
EUA	European Emission Allowances
EU ETS	EU Emissions Trading System
GHG	Greenhouse gas
LULUCF	Land use, land use change and forestry
MSR	Market Stability Reserve
NDC	Nationally Determined Contributions
PtH	Power-to-Heat
PtX	Power-to-X
RES	Renewable energy sources
SPD	Social Democratic Party of Germany
UNFCCC	United Nations Framework Convention on Climate Change

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