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The underrated long-term relevance of gas in the decarbonizing German energy space

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EXECUTIVE SUMMARY

The long-term relevance of gas – for quite a while fossil natural gas and towards deeper decarbonization scenarios increasingly 'green gas' – is vastly underrated by many. This is partly due to the considerable complexity of a multitude of studies and reports where the acknowledged relevance of gas can easily be overlooked. But also because gas is frequently put in the 'dirty fossil corner' all too quickly. Therefore, the authors considered it useful to extract from various studies, but with a strong focus on the 'dena-Leitstudie' "Integrierte Energiewende", the considerations and arguments which emphasize the long-term relevance of gas in the decarbonizing German energy space.

In essence, we compare a scenario labelled "Electrons" - implying high electrification and lower use of gas – with a scenario labelled "Molecules", the latter implying a higher degree of direct gas use in all sectors.

The main findings are:

- Gaseous molecules as energy carrier will be indispensable in both the Electrons and the Molecules scenarios all the way towards 2050.

- (Fossil) natural gas demand can remain at current levels up to CO_2 reduction targets of 65% to 70%. For deeper decarbonization beyond 70%, gas has to become 'green', i.e. non-fossil. In the Molecules scenario, demand for green gas reaches ~800 TWh in 2050 in order to achieve a -95% CO_2 reduction.

- There are various options presently known for 'greening' gas. Bio-methane is the obvious first, but its growth potential is limited. Green hydrogen blending would be the next obvious step, but its use potential is limited due to gas quality constraints. This renders synthetic methane, produced by the power-to-methane process the most likely option for greening gas in large quantities. It is pivotal in either deep decarbonization scenario (e.g. -95%) towards 2050.

- Gas and the existing gas infrastructure will be pivotal for ensuring the security of electricity supply:

    - Peak electricity demand will increase significantly towards ~160 GW in the ambitious -95% Electrons scenario mainly due to the high use of electric heat pumps. Also gas-fired power generation capacity will have to increase strongly, namely towards 107 GW in the same -95% scenario. Gas is the main contributor to meet peak electricity demand. In the Molecules scenario particularly the higher direct use of gas for space heating alleviates the surge in peak electricity demand.

  - In the Electrons scenario, a tremendous rise in power demand is seen (towards ~930 TWh of final energy demand in 'EL95'). Since such (green) power is mostly furnished by intermittent wind and solar, gas performs a double role to ensure security of electricity supply: First, it acts as a 'permanent synchronizer' stabilizing the power grids. Moreover, it steps in the breach in the event of a protracted period of a "Kalte Dunkelflaute", where a prevailing cold-snap causes massive power and power peak demand but there is neither wind nor sun.

- With gas performing a crucial role in both the Electrons and the Molecules scenarios, we looked at the significant changes of gas demand patterns, also with a view to determine whether the existing gas infrastructure would suffice to live up to the task:

  - Peak gas demand will decline in both the Electrons and the Molecules scenario, so that existing gas infrastructure by and large suffices.

  - Seasonal demand patterns as we presently know them will largely vanish but volatility stemming from renewables intermittency will rise substantially. This implies less future need for seasonal storage and more need for short- and mid-term flexibility by line-pack and multiple-cycle peak storages.

- Gas-based decarbonization strategies are significantly less costly than electrification-based ones. The 'Molecules' scenario achieving 80% CO_2 reduction ('TM80') in 2050 causes additional costs of € 1.2 trillion, while the Electrons scenario achieving 95% CO_2 reduction ('EL95') causes costs of € 2.2 trillion:

  - A gas-based decarbonization strategy requires less investment needs in buildings, power-plants, industrial appliances and the infrastructure, an advantage that prevails even though costs for energy use are slightly higher.

  - It is far cheaper to transport energy in the form of gas than in the form of electricity due to its higher energy density.

  - Since the existing gas infrastructure is by and large 'up to the task' and can continue to be used, significant costs for expensive new-built power grid expansions can be saved.

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1. INTRODUCTION

After the COP[1] 21 summit in Paris 2015 Germany took a steep fall from ‘champion’ (of the Energiewende) to ‘fossil of the day’ at COP 22 in Marrakesh 2016 as well as COP 23 in Bonn 2017. Germany had not only failed to reach its CO_2 reduction targets[2], but featured increase instead. Hence, in a place where boasting multibillion subsidies for renewables was irrelevant whilst it was showtime for presenting actual CO_2 reductions, Germany experienced the doubtful honor of twice receiving the so-called ‘fossil of the day’ award[3] on a global stage.

FIGURE 1: GERMANY RECEIVING THE ‘FOSSIL OF THE DAY’ AWARD

Source: www.climatenetwork.org/fossil-of-the-day

What had happened? In a nutshell, Germany had confused the climate goal of CO_2 reductions with the proliferation of renewable generation capacity in the power sector only. While in the power sector, CO_2 emissions had indeed moderately decreased (at enormous cost in subsidies and levies imposed on the citizens), other sectors, e.g. industry, but particularly the transport sector, had either remained flat or even increased emissions.

Based on this inconvenient truth, amplified by the dawning insight that Germany would miss its own ambitious 2020 CO_2 reduction targets and – in all fairness – perhaps to a certain extent also due to the public embarrassment on a global scale, the necessity of emission reductions also in other sectors, namely the heat-, transport- and industry sectors, entered center stage. The initial silver bullet was ‘sector-coupling’, to this day a fashionable buzzword. In a nutshell, the early days sector-coupling concept thought to simply electrify the heat and transport sector with renewable electricity from the power sector.

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[1] Conference of Parties under the United Nations Framework Convention on Climate Change
[2] For the sake of simplification the term ‘CO_2’ stands for ‘CO_2 equivalent” throughout this paper.
[3] www.climatenetwork.org/fossil-of-the-day

This went down well with many, for a while. Gradually however, it transpired that fundamental issues had been overlooked or been ignored:

- The initial idea of sector-coupling commingled the *generation* of end use energy (e.g. power or heat) and the *consumption* of end use energy[4]. This sounds harmless but is not: on the demand side it omits assessment of the particularities of the specific demand in question (e.g. high temperature heat in industrial processes or high-temperature space heating) and the most sensible end use energy substitute (by already having decided that it is electricity) while on the supply side it was more or less taken ‘for granted’ that the respective additional quantities of renewable electricity needed for the resulting demand increase – and even more so the required peak capacity demand - would be available.

- The initial ‘all-electric hype’ led once more to a disproportionate focus on the power generation sector: If one only doubled (or tripled) the renewable generation capacity, essentially wind and solar, the ‘problem’ would be solved. A thorough look at the end-user energy demand structure where, not least due to their superior energy density, liquid or gaseous fuels prevail over electricity, was largely missing. The technical feasibility of electrification and its limits (e.g. airborne transport and certain industry processes) and the search for other sustainable sources of end use energy came into more prominent focus only recently.

- Also the issue of assured availability of renewable power from wind, solar and, to a lesser extent, hydro at all times[5] was only gradually coming into focus: Despite the exponential increase of interventions by grid operators to ensure grid stability, the inability of wind and solar to produce conform existing demand had largely been ignored or belittled. Moreover, the fact that, with increasing reliance on wind and solar in the face of nuclear being phased out and coal ever more declining, the need for residual load capacity (back-up) at times of ‘Kalte Dunkelflaute[6]’ was for a long time ignored.

- Conversely, the significant growth in both solar and wind capacity resulted in ever rising quantities of (over-) production exceeding actual demand. In consequence, exports at negative prices contributed to a further rise of the ‘EEG-Umlage’[7], towards € 26.5 billion in 2017. On top of that, re-dispatch measures and compensation for curtailment of renewable power ramped up further costs of € 1.4 billion in 2017 alone[8]. The discussion whether it might be meaningful to convert such otherwise ‘lost’ green power e.g. into

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[4] Bettzüge (2017).

[5] In electricity that means essentially ‚by the milli-second ‘, lest grid stability is imperilled.

[6] It is cold with rather low sun or wind generation for protracted periods of time.

[7] Renewables levy stemming from the difference between guaranteed feed-in tariffs and sales prices realized at the exchange by the TSOs, put on the bills of electricity end-users.

[8] These costs are ploughed into the grid costs and also paid by electricity end-users.

hydrogen or, one step further, into synthetic methane (the power-to-gas technology) and be able to store it in large quantities and over long periods of time in the gas infrastructure, is still ongoing: the implied admittance that wind and solar are not demand responsive appears sacrilege for many.

- Last but not least it has become ever more apparent that certain ‘expansion’ plans for further renewable power facilities might reach their limit by being denied the ‘social license to operate’. The delay in the North-South electricity link, supposed to transport wind power from North to South, blocked by never ending interventions and resistance of citizens, municipalities and certain NGOs, is a good example. Also the willingness of citizens to accept the further proliferation of onshore windparks has reached a critical point. All this has helped to pave the way for a more technology-open discussion of the way forward.

- Finally the costs: whilst thus far Germany’s Energiewende certainly created the impression that ‘costs do not matter when you are rich’[9], serious decarbonization scenarios range from € 1.2 trillion to € 2.2 trillion. Eye-watering numbers in any event but with up to a € 1 trillion[10] difference perhaps worth a look.

A meta-study by enervis[11] (for good reason sub-titled ‘*analysis of a complex discussion*’) has reviewed 10 of the most relevant studies and reports in the last 2 years. It observes that almost all studies come to the conclusion that gas will play an important role in reaching an 80% CO_2 reduction target. Also for deeper decarbonisation goals (e.g. 95%) gas, mostly in the form of synthetic gas derived by the power-to-methane process, plays an important role.

The recently published ‘dena[12] Leitstudie’ (dena 2018)[13], for which ewi ER&S conducted the entire quantitative scenario modelling (ewi ER&S 2018a)[14], was published after the enervis meta study. It is perhaps the most comprehensive analysis by both approach and content. Whilst it claims not to provide a ‘roadmap’ but ‘only offering scenarios’, many regard it as such. Unlike other studies, the dena Leitstudie collected input from some 60 stakeholders/participants, e.g. academia, companies, industry associations and others active in the energy, building, industry and transport sectors and hence familiar with their respective consumer needs and demand structures. The wide range of differing positions and interests among the participants, but also their intricate knowledge of what might be feasible or not, greatly assisted in making the ‘dena Leitstudie’ as unbiased as possible. Importantly, the ‘dena Leitstudie’ approaches the demand

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[9] Peters (2016).
[10] Admittedly the difference between TM80 (least cost) and EL95 (most expensive).
[11] enervis (2018).
[12] Deutsche Energie-Agentur.
[13] dena (2018).
[14] ewi ER&S (2018a).

side of each sector first and only then draws conclusions about the suitable sustainable substitute supply options capable of achieving various levels of climate targets.

Perhaps the most important message of the dena Leitstudie is that sector-coupling as initially understood, i.e. an all-out electrification, is not the ‘silver bullet’. Instead, the integration (‘coupling’) of the various existing infrastructures, i.e. the power grids, gas grids and heat grids, combined with a technology-open attitude, is the most cost efficient and thus reasonable approach. While also electrification scenarios are modelled (‘EL’), it becomes blatantly clear that the scenarios featuring ‘technology-openness’ (‘TM’[15]) are the more robust and convincing ones not least since they give credence to the fact that nobody knows which technologies will prevail in the future and ‘picking winners’ is not only arrogant, but a potentially very costly fallacy.

Given the sheer volume and complexity of the various scenarios, it may easily be overlooked how important the long-term relevance of gas is in all scenarios. Moreover, gas is still frequently dismissed by putting it all too quickly in the ‘dirty fossil corner’. Therefore, the authors considered it useful to discuss the role of gas for the German energy transition in this paper in somewhat more detail. The approach chosen is to compare two completely different end use energy carriers and hence vastly different worlds, namely the ‘Electrons’ and the ‘Molecules’ scenarios (Chapter 3). ‘Electrons’ means a high degree of electrification and, thus, a rather low demand for gas as end use energy. In contrast, ‘Molecules’ implies a high degree of gas use as end use energy. The role of gas is then discussed from three perspectives: First, the future demand for and the relevance of gas (Chapter 4). Second, the necessity of deploying gas to ensure security of electricity supply and its ability to ‘live up to the task’ (Chapter 5). And third, gas and gas infrastructure supporting the most cost-effective solution to reach climate targets (Chapter 6).

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[15] ‚Technical Mix‘, in more detail explained later.

2. THE CHALLENGE: INCREASING CO_2 REDUCTIONS BY A FACTOR OF 3 FOR THE NEXT 30 YEARS

For the avoidance of doubt, the authors accept global scientific consensus of anthropogenic (man-made) climate change contributions and the subsequent international, European and national CO_2 reduction targets envisioned, agreed or regulated. The authors further acknowledge that battling climate change is a truly global issue where an individual country like e.g. Germany is of limited relevance. Nonetheless, we considered it useful to take a closer look at Germany because it is the largest gas market in Europe and, at the same time, never mind the draw-backs mentioned earlier, still aspires to be a frontrunner of the energy transition. Hence, German climate targets[16] are not questioned but rather, in the same spirit as the dena Leitstudie, the most feasible pathways to reach them – with emphasis on the role of gas therein - are analysed.

Energy transition in Germany towards a -95% target by 2050 means nothing else than tripling the current speed of CO_2 reduction year-on-year and keep it at such rate for the next 30 years. German CO_2 emissions amounted to 905 million tons of CO_2 in 2017. This equals a reduction of 27% from 1990s levels. However, most of this reduction was achieved in the course of the 1990s when, as a consequence of the German re-unification, inefficient (and highly pollutant) East-German power plants and industrial complexes had been decommissioned. Since 2000, the year of inception of the so-called 'EEG[17]', CO_2 reductions have only declined by an average of 8 million tons per year. In order to reach a -95% CO_2 reduction target, this value has to increase to an average reduction of 26 million tons per year.

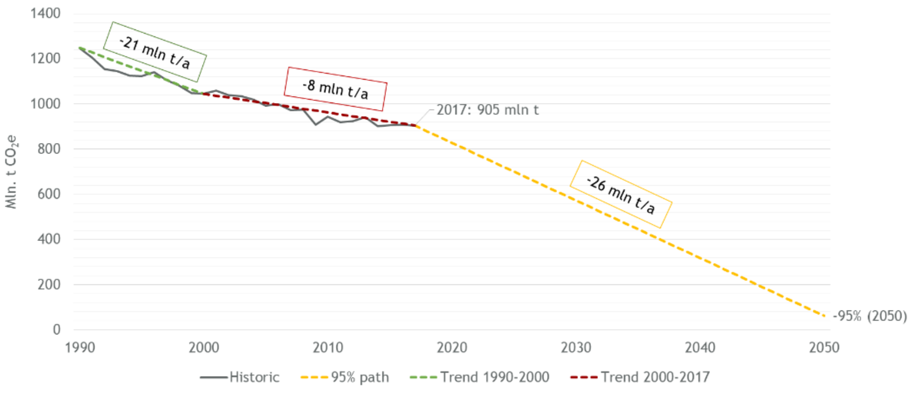

FIGURE 2: CO_2 EMISSIONS IN GERMANY AND 95% REDUCTION TARGET

These numbers illustrate the order of magnitude of ambition and challenge for the German energy transition. They also underpin the need for sober policy decisions.

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[16] E.g. German Climate Protection Plan (Klimaschutzplan), BMUB (2016).

[17] The German ‚Erneuerbare Energien Gesetz', i.e. ‚Renewable Energy Law'.

3. ELECTRONS AND MOLECULES – COMPLETELY DIFFERENT STEP-SISTERS BUT BOTH ACHIEVING GERMANY'S 2050 CLIMATE TARGETS

Most of the recent studies assessing potential pathways to reach German climate targets towards 2050 feature two completely different energy carriers and in consequence completely different scenarios for decarbonization: electrons and molecules. We call them 'step-sisters' because on the one hand they both constitute end use energy but on the other hand they differ significantly.

The main differences between electrons and molecules

The first obvious difference is that electrons are a 'secondary' source of end use energy while molecules are a primary source of end use energy. In other words, before you can use electrons, you must first generate (produce) them. We will come back to this aspect below.

The second, and perhaps the most relevant difference is their energy density: molecules feature a by far higher energy density than electrons. The point is best made by comparing the cost for transport of electricity and gas as illustrated in Figure 3.

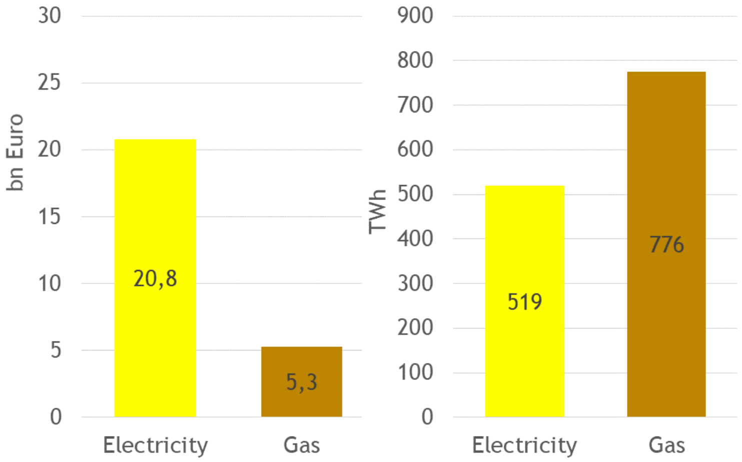

FIGURE 3: ANNUAL TRANSPORT COSTS (LEFT) AND FINAL ENERGY CONSUMPTION (RIGHT) IN GERMANY, 2015

The costs to transport and distribute the 2015 German gas consumption of some 800 TWh amounted to ~€ 5 billion. In the same year, the costs for transport and distribution of some 500 TWh of electricity consumption amounted to ~€ 21 billion. This implies a cost factor of greater than 6 in terms of €/kWh for electricity versus gas. We will get back to this important aspect in Chapter 6 below.

Why wind- and solar-based electrification is not the 'silver bullet'

The differences between the two stepsisters are compounded if you set out to generate the secondary end use energy electrons by predominantly wind and solar[18]:

- For the stability of the electricity grid synchronology between demand and supply is required essentially by the milli-second. Neither solar nor wind do have such demand responsiveness and hence require other means of synchronization. As we shall see, gas-fired power plants will, to a large extent, assume the role of 'permanent synchronizer'.
- At times of 'Kalte Dunkelflaute', illustrated in Figure 4, i.e. an extended period where it is cold and there is neither sun nor wind, instant availability of so-called 'residual load' is required: back-up e.g. from gas-fired power plants.

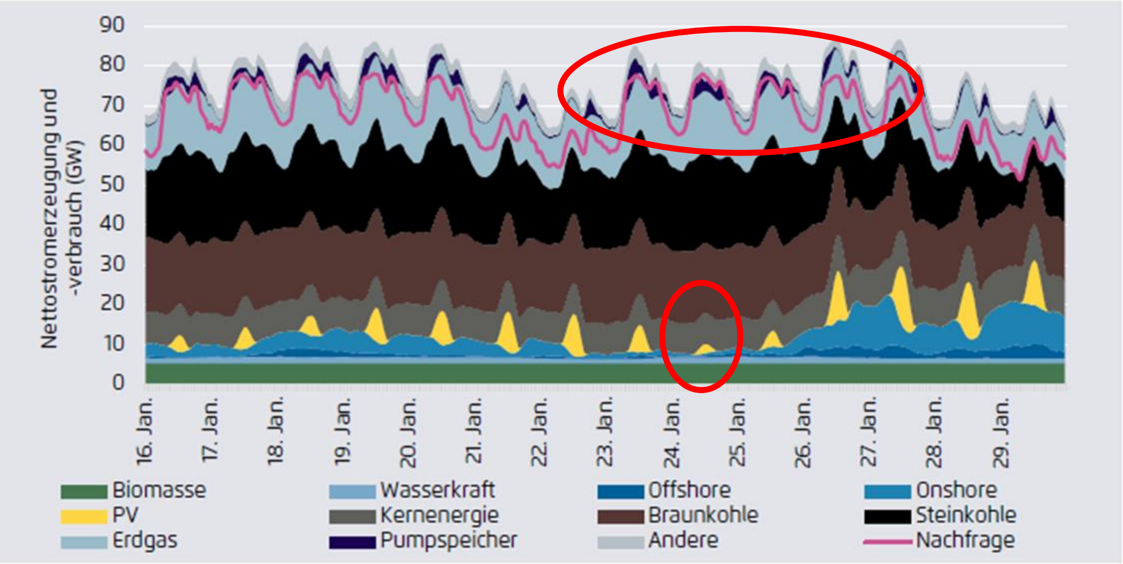

FIGURE 4: GERMAN POWER GENERATION BY SOURCE AND DEMAND, JANUARY 2017

Source: Agora Energiewende (2018)

- Conversely, the significant growth in both solar and wind capacity has, at times of strong sun radiation and lots of wind, resulted in ever rising quantities of (over-) production exceeding actual demand, causing ever rising costs through exports at negative prices, re-dispatch measures and finally compensation for curtailment of renewable generation. This phenomenon cannot entirely be attributed to an inferior quality of electrons vs. molecules, but has much to do with the regulatory system of priority feed-in rights for renewables which, when denied, trigger compensation. However, in the context of

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[18] At present the only renewable sources with significant further growth potential in Germany.

generating electrons a greatly compounding factor for this phenomenon are the low full-load hours for both solar and wind based power generation: on average, PV panels in Germany achieve below 1,000 (of the possible 8,760) full load hours, onshore wind below 2,000 and offshore wind some 4,000 full load hours. This means that the capacity required to reach sizeable volume contributions (as annual average share[19]) is exponentially higher than would be necessary for conventional generation capacity. In consequence, if such inflated renewables capacity is indeed at times fully productive, the respective overproduction impact is an unavoidable consequence.

- The aforementioned absence of production at times of ‘Kalte Dunkelflaute’ as well the over-production above actual demand at times of high radiation and strong wind lead to another conundrum with electrons: they can well be stored in small quantities over short periods of time in different kinds of batteries. They cannot, however, be stored in large quantities over long (e.g. seasonal) periods of time. This is where the debate over the ‘power-to-gas’ (‘P2G’) technology chimes in: Instead of paying ever rising compensation for renewable power curtailment, might it not be the better idea to use such green electricity in an electrolyzer and convert it to ‘green’ hydrogen which can be blended with natural gas, i.e. ‘stored’ in the gas infrastructure? Or go one step further and convert such green hydrogen into synthetic methane?

- As shall be discussed in more detail below, the aforementioned conundrum of over- and underproduction will not be alleviated by further expansion of wind and solar capacities. On the contrary, since the hourly and spatial generation profiles of wind and solar are highly correlated across Germany[20], each additional unit of wind and solar capacities will alleviate renewable undersupply only modestly, while oversupply strongly increases. This underpins the urgency to develop the power-to-gas technology to industry scale with respective cost degression rather sooner than later.

As indicated before, many of these aspects have only lately become part of the debate. The recent studies mentioned, including the dena Leitstudie, deal with these questions. In departure from the previous all-electric dominance, they well continue to analyse electrification scenarios, but put them in contrast to more molecules-based and technology-open scenarios, particularly the latter with a prominent role for gas.

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[19] The periodically reported ‘rising share’ of renewable power compares annual average quantities, which tells nothing about ‘supply meeting demand’.

[20] And, by the way, also beyond Germany’s territorial borders.

Electrons and Molecules scenarios: strong variances of gas demand per sector but pivotal in either scenario

As the reader might expect, we label the electrons-based scenarios '*Electrons*' in this paper. These scenarios assume a deep electrification of end-use sectors. This means e.g. a strong penetration of heat pumps, electric vehicles and industry-scale power-to-heat applications.[21] Importantly, none of the 'Electrons' scenarios assumes a full electrification of all sectors, since it appears unrealistic from today's technical perspective: E.g. FNB Gas (2017)[22] presents an over-the-thumb calculation where the batteries needed to realize a full electrification of all end-use sectors would require 18 million container-size batteries. This was considered prohibitively costly and hence unrealistic.

Unsurprisingly, we label the molecules-based scenarios '*Molecules*'. These assume a much stronger presence of end-use appliances directly burning molecule-based final energy, e.g. gas.[23] It should be noted that also most of the 'Molecules' scenarios assume a certain degree of electrification, however, to a much lesser extent than the 'Electrons' scenarios.

In the following chapters, we shall compare the 'Electrons' and 'Molecules' scenarios, for which we use two scenarios from the dena Leitstudie: On Electrons the electrification scenario (EL) and on Molecules the Technology Mix scenario (TM). Table 1 illustrates, in a rather high level of detail, the main differences between both scenarios (calculated for 95% CO_2 reduction), labelled as EL95 and TM95. The main differences for the year 2050 are:

- Final electricity demand in the three end-use sectors buildings, industry and transport is a massive 928 TWh for EL95, whereas it is 565 TWh for TM95.

- Final gas consumption[24] in those sectors is 341 TWh for EL95, whereas it is 771 TWh for TM95.

- Stronger electrification in EL95 does not only increase power demand on an annual basis but even more so peak load requirements in the power sector: In EL95, peak load reaches 160 GW whereas it increases to only 101 GW in TM95. In either scenario most of the peak load is provided by gas-fired power plants.

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[21] The 'Electrons' approach comprises scenarios such as 'EL80' and 'EL95' (dena, 2018)/(ewi ER&S 2018a), 'EEV' (ewi ER&S, 2018b), 'Revolution' (ewi ER&S, 2017), 'Strom und Gasspeicher' (FNB Gas, 2017) or 'Maximale Elektrifizierung' (enervis, 2017).

[22] FNB Gas (2017).

[23] The 'Molecules' approach comprises scenarios such as 'TM80' and 'TM95' (dena, 2018)/ewi ER&S (2018a), 'TO' (ewi ER&S, 2018b), 'Evolution" (ewi ER&S, 2017), 'Strom und grünes Gas' (FNB Gas, 2017) or 'Optimiertes System' (enervis, 2017).

[24] In this figure, non-energetic use of gas in industry and hydrogen use in transport is included.

- In other words, gas is indispensable in both scenarios. Either for intensified use in the end-use sectors (TM95) with a capacity increase towards 55 GW or for ensuring the security of power supply (EL95) with a capacity increase towards 107 GW.

TABLE 1: OVERVIEW OF DIFFERENCES BETWEEN SCENARIOS EL AND TM

	2015		2050 EL95	2050 TM95
Buildings				
Final energy consumption for heating (TWh)	998		362	523
Gas	396		18	141
Electricity	213		280	240
Number of heat pumps (million)	0,5		17	7,4
Number of gas-boilers (million)	10,3		1,2	6,4
Industry				
Energy/non-energy use (TWh)	823		837	673
Gas	231		187	445
Electricity	286		539	239
Transport				
Final energy consumption (TWh)	698		331	401
CNG/LNG/H_2	3,5		136	185
Electricity	11		109	86
Number of cars (million)	44,7		42,5	42,5
CNG/LNG/H_2	0,3		6,6	14,5
Electric (BEV/PHEV)	0,1		35,7	28,1
Number of trucks (million)	2,8		3,3	3,3
CNG/LNG/H_2	0,0		1,2	1,7
Electric (BEV/PHEV)	0,0		2,0	1,4
Power				
Total final consumption (TWh$_{el}$)	510		928	565
Generation (TWh$_{el}$)	604		1,008	847
Gas	60		122	74
Renewables	179		879	769
Peak load (GW)	84		160	101
Capacities (GW)	192		556	424
Gas	30		107	55
Wind/PV	81		377	310

Source: dena (2018), ewi ER&S (2018a)

In order to illustrate the significant differences of the Electrons and Molecules scenarios in somewhat more detail, we shall briefly look at the individual sectors.

Building sector: gas demand will decline, but gas-fired appliances keep a significant market share in the TM scenario

In the building[25] sector, gas demand declines in the EL scenario from 2015 levels of 400 TWh by roughly 50% until 2030 and almost vanishes completely towards 2050. This development is driven by a high degree of building insulation and the proliferation of electric heat pumps, which supply 80% of all buildings in 2050.

The TM scenario is different. Gas demand is in decline as well, due to improved energy efficiency (by more efficient gas fired boilers and improved building insulation). However, gas-fired appliances still keep a significant market share. Gas demand declines by one quarter till 2030 and reaches 141 TWh by 2050.

Industry sector: gas will continue to play a major role and has significant growth potential in the TM scenario

In the industry sector, gas demand is doubling until 2050 in the TM scenario and declines slightly in the EL scenario. Since the industry sector is expected to grow by some 1% per year, even ambitious assumptions on energy efficiency improvements do not result in a significant decrease of overall final energy demand. In the EL scenario, strongly increased use of power-to-heat appliances cause gas to lose market share. However, gas is able to compensate for those losses since it displaces coal and oil due to its lesser CO_2 intensity. Overall, gas demand decreases slightly from 200 TWh in 2015 to 187 TWh in 2050 in the EL scenario.

In the TM scenario power-to-heat appliances play a less important role compared to EL. However, since industrial output grows and gas displaces coal and oil, gas demand from the industry sector almost doubles reaching over 440 TWh by 2050.

Power sector: gas use grows as dispatchable gas-fired units support intermittent wind and solar and also fill any supply gap

In the power and CHP sector, gas demand increases in both scenarios. In EL95, gas demand increases from 190 TWh_{th} in 2015 to 290 TWh_{th} in 2050 as a consequence of higher electricity demand. In TM95, demand increases to 240 TWh_{th}. Hence, gas plays a substantial role in the power sector in both scenarios even in 2050. Since it is assumed that there will be no dispatchable coal

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[25] According to the definition in dena (2018) and ewi ER&S (2018a), the building sector includes residential and commercial buildings and energy used for space heating and warm water from the industry sector.

and nuclear plants in 2050, gas steps in the breach to balance intermittent solar and wind power generation as a ‘permanent synchronizer’. Moreover, as already discussed, large amounts of installed wind and PV capacities will at times cause highly overshooting power supply but at other times not enough to satisfy demand. Power storage or smart algorithms are assumed to partially alleviate this issue by 2050, but by far not solve it. Hence, also here gas steps in the breach to cover the supply gap. The role of gas-fired power generation will be discussed in more detail in Chapter 5.

Importantly, the need for further gas-fired power generation will increase with the further expansion of wind and solar capacities. As already indicated, the hourly and spatial generation profiles of wind and solar are highly correlated across Germany. Hence, each additional unit of wind and solar capacity will alleviate renewable undersupply only moderately, while oversupply strongly increases. Thus, dispatchable gas-fired power plants are ever more required to fill the gap in the face of rising electricity demand. As shall be demonstrated below, in the deep decarbonization scenarios towards 2050, these gas-fired power plants would have to be fed by carbon-neutral gas.

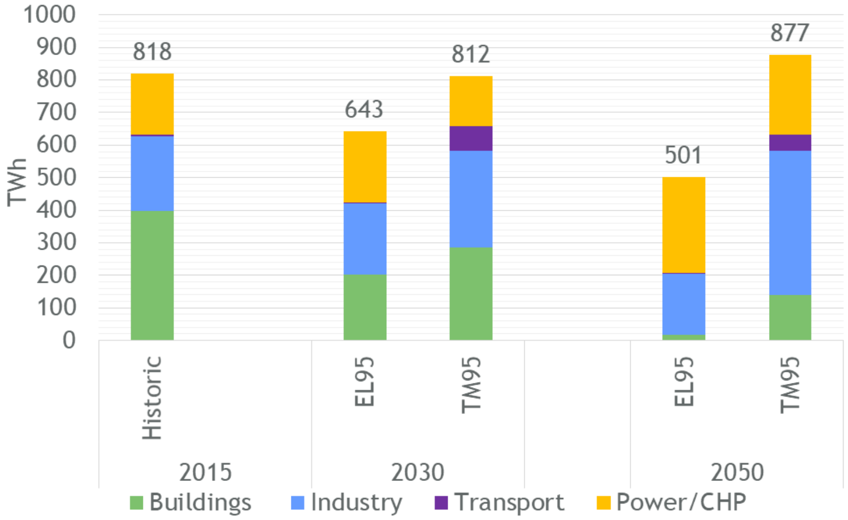

FIGURE 5: GERMAN GAS DEMAND BY SECTOR, 2015-2050

Source: own illustration based on dena (2018), ewi ER&S (2018a)

Transport sector: Some additional demand in the TM scenario, however no game-changing volumes expected

Finally, the TM scenario sees additional gas demand in the transport sector, especially regarding heavy-duty trucks[26]. All-in-all however, quantities are modest, reaching 50 TWh by 2050. In the EL scenario, gas only plays a marginal role.

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[26] Further potential demand from e.g. marine transportation is not considered since the dena Leitstudie did, due to international monitoring standards, not consider international air- and waterborne traffic.

Both the Electrons and the Molecules scenarios achieve the German climate targets

Even though the two pathways outline completely different worlds, they both reach the German climate targets for the years 2030 (-55% reduction compared to 1990), 2040 (-70%) and 2050 (-80% to -95%), as illustrated in Table 2. However, emissions by sector vary significantly between the two approaches. Given an 80% reduction target, in “Molecules”, the highest CO_2 reduction occurs in the power sector. In contrast, in ‘Electrons’ the final energy sectors buildings, transport and industry feature high CO_2 reductions. For a 95% reduction target, the power sector, the building sector and the transport sector need to become climate neutral in either scenario.

TABLE 2: CO_2 EMISSIONS IN GERMANY BY SECTOR AND SCENARIO

	2015		EL80 2050	TM80 2050	EL95 2050	TM95 2050
CO_2 emissions						
Total (Mln t CO_2e)	908		250	250	64	64
Buildings	124		5	40	0	0
Industry	182		98	134	27	27
Transport	164		20	21	0	0
Energy	355		76	3	0	0
Others	83		51	51	37	37

Source: own illustration based on dena (2018), ewi ER&S (2018a)

It is important to understand that the variance in CO_2 reductions per sector in the Electrons (EL80/EL95) and Molecules (TM80/TM95) scenarios is by no means the outcome of a random exercise. Rather, the variances hinge on measures (and the respective costs thereof) necessary to ‘make-it-so’. An illustrative example is the buildings sector: If I ‘make-it-so’ and electrify also the heating of existing buildings with poor insulation (i.e. buildings requiring ‘high temperature heating’) by installing electric heat pumps, I will indeed achieve impressively low emissions in the building sector, but at a massive cost for insulation and higher peak capacity requirements with the respective need to abate emissions in the power sector nonetheless. A similar picture applies to the industry sector: driving electrification beyond economic feasibility will achieve lower emissions in the industrial sector but at tremendous costs and a respective knock-on effect in the power sector. We shall compare the costs of the Molecules and Electrons scenarios in somewhat more detail in Chapter 6.

4. GAS WILL BE PART OF THE SOLUTION IN BOTH WORLDS, BUT IT WILL HAVE TO TURN GREEN IN THE LONG RUN

Gas molecules are pivotal in any scenario

Gas as a molecular energy carrier with its respective in-place infrastructure is not only compatible with a climate neutral German energy system, but becomes indispensible in both the “Molecules” and the “Electrons” scenarios. As Figure 6 illustrates, gas demand in Germany will be in excess of 500 TWh per year in any scenario, even in the most ‘electrons-heavy’ EL95. However, there are big differences between them:

- In the Electrons scenarios, gas demand decreases by one quarter until 2030 and declines further towards roughly 500 TWh in 2050 in the EL95 scenario.[27]

- In the ‘Molecules’ scenarios (TM80/TM95) gas demand stays roughly on today’s level of some 800 TWh until 2050.

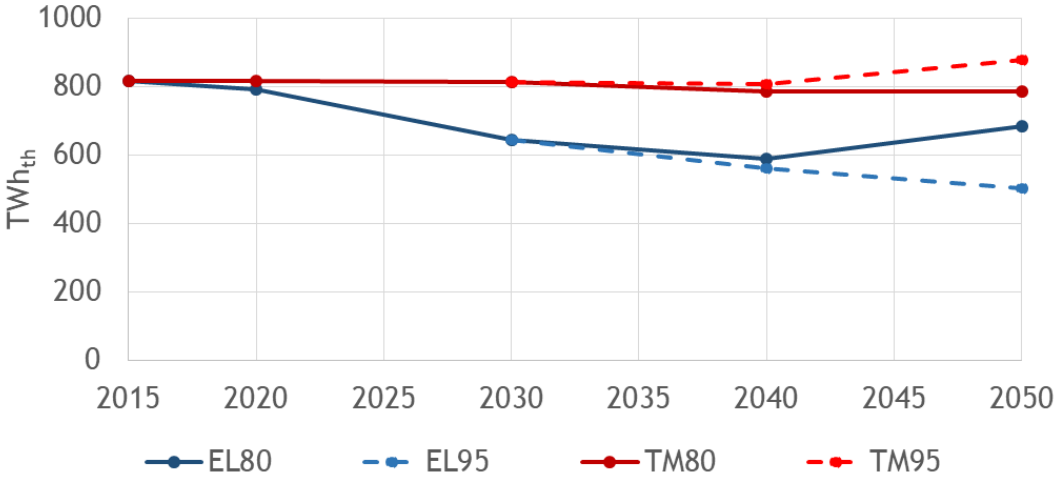

FIGURE 6: GAS DEMAND IN GERMANY, 2015-2050 IN DIFFERENT SCENARIOS

Source: own illustration based on ewi ER&S (2018a)

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[27] In the EL80 scenario gas demand surprisingly increases between 2030 and 2050, which is driven by the power sector. Since the end use sectors are highly electrified, a lot of power demand needs to be served and a substantial part of the German CO_2 budget is available to the power sector. Both circumstances favour gas in the German power sector leading to a demand increase.

Total gas demand stays high – but the ratio of natural gas and green gas shifts towards green with deeper decarbonization

Figure 7 illustrates the correlation between (both natural- and green-) gas demand and CO_2 reduction (compared to the year 1990). As we can see, especially the TM scenarios show high gas demand even in deep decarbonisation scenarios such as -95%. However, as we will see in the following, the ratio between natural gas and green gas will shift towards green gas with deeper decarbonisation.

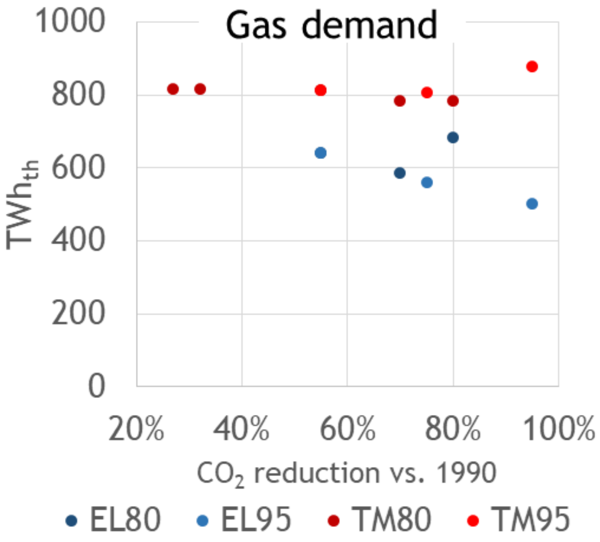

FIGURE 7: GERMAN DEMAND FOR GAS IN RELATION TO CO_2 TARGETS

Source: own illustration based on ewi ER&S (2018a)

Natural gas demand remains at its current level up to CO_2 reduction targets of 65% to 70%

When focusing on (fossil) natural gas only, Figure 8 illustrates that it can stay almost on today's level and perfectly fit CO_2 reduction targets up to minus 65% to 70% CO_2 reduction levels. This changes drastically towards higher degrees of decarbonization beyond -70%: E.g. at a -95% reduction level its usage has to vanish almost completely, except for some minor volumes as industrial feedstock.

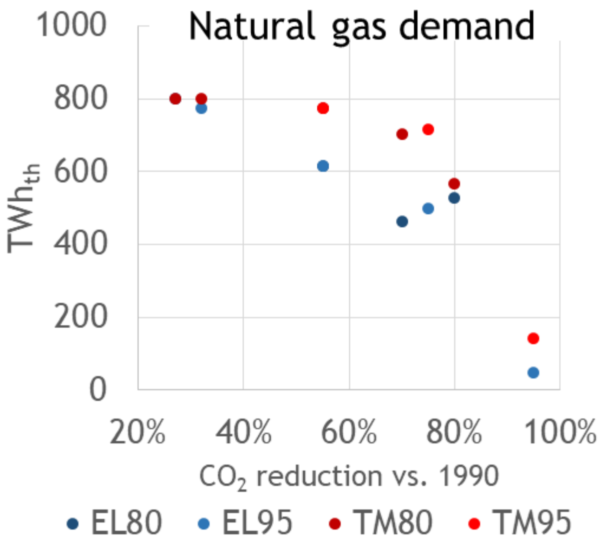

FIGURE 8: GERMAN DEMAND FOR NATURAL GAS IN RELATION TO CO$_2$ TARGETS

Source: own illustration based on ewi ER&S (2018a)

For deep decarbonization, natural gas has to be replaced by green gases

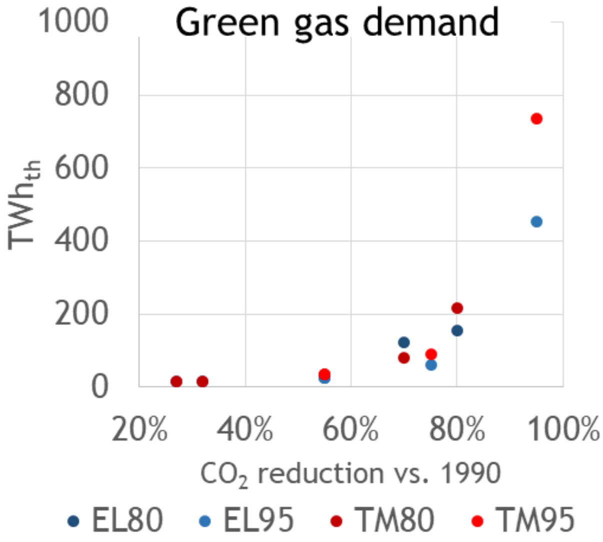

FIGURE 9: GERMAN DEMAND FOR GREEN GAS IN RELATION TO CO$_2$ TARGETS

Source: own illustration based on ewi ER&S (2018a)

If we now look at ‘green’, i.e. CO$_2$ neutral, gas only, we see the converse effect we just saw for natural gas: As Figure 9 illustrates, its use rises exponentially in the deep decarbonization scenarios. In the TM95 scenario almost 800 TWh have to be green gases and even in the electrification scenario EL95, almost 500 TWh of green gases are required. Hence, green gas is indispensable to reach a German climate target of minus 95% CO_2 reduction.

What are technological options for greening gas?

Biomethane, i.e. biogas converted to natural gas quality, is perhaps the best-known option. Less technically mature at least in large-scale applications is the so-called ‘power-to-gas’ (‘P2G’) process, which is a two-step process. The first is the production of climate neutral hydrogen[28], produced via electrolysis fed with climate-neutral power. It can – within certain limits due to gas quality constraints – be blended with natural gas in the gas grids. In a second step such green hydrogen can be methanized rendering synthetic methane, i.e. green gas (‘power-to-methane’). All of the three options, and maybe other innovations, e.g. methane cracking, will be needed to supply the vast amount of up to 800 TWh to the German market. We shall elaborate somewhat on the mentioned options below.

Figure 10 illustrates the types of green gases serving gas demand in 2050.

Biomethane is the first option for greening gas, but its potential is limited

In each scenario, biomethane is the first, since cheapest, option for greening gas. In the EL80 scenario some 130 TWh of biomethane are required, i.e. biogas blended to gas quality. However, the supply of bioenergy (including biomethane, biofuels and solid biomass) is assumed to be limited to 300 TWh per year for Germany (including imports) since agricultural space is limited. This is why in TM80, the use of biomethane is even lower than in EL80: Due to lower electrification of the end use sectors, more bioenergy is needed in the form of bioliquids and biosolids, limiting the amount of biomethane in that scenario.

Hydrogen blending is limited due to gas quality constraints

Hydrogen fed into the gas grid is below 20 TWh, limited by the assumed 10% (volume) restriction in the gas grid in both scenarios. A higher threshold for H_2 injection into the gas grid than 10%, hinging on the ability to adapt end-use appliances accordingly, would create upside potential for this method of ‘greening’ gas.

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[28] Both scenarios, EL and TM, see significant use of pure hydrogen as an energy carrier especially in the transport and the industry sector. Both are served via specific pure-hydrogen infrastructure. This paper focuses on gas and gas infrastructure, hence only hydrogen which is fed into the gas infrastructure is analysed

Power-to-methane is pivotal in either deep decarbonization scenario

While power-to-methane only plays a marginal role in EL80, TM80 requires some 150 TWh of it by 2050. TM80 has somewhat higher final energy needs for gas than EL80, of which a major part has to be climate neutral. Expanding CO_2 reduction towards 95% basically leads to a replacement of fossil natural gas by power-to-methane in both scenarios. In 2050, natural gas is solely used as feedstock and cannot be used energetically. A major part of such climate neutral gas demand is supplied by power-to-methane. It would mainly be imported from abroad, where it can be produced at lower cost. Notably, power-to-methane needs are substantially higher in the TM95 scenario (630 TWh) than in the EL95 scenario (320 TWh) because of its higher gas demand. However, neither of the 95% scenarios is able to work without power-to-methane. This underpins the urgency of progressing this technology to industry scale and the respective cost degression as soon as possible.

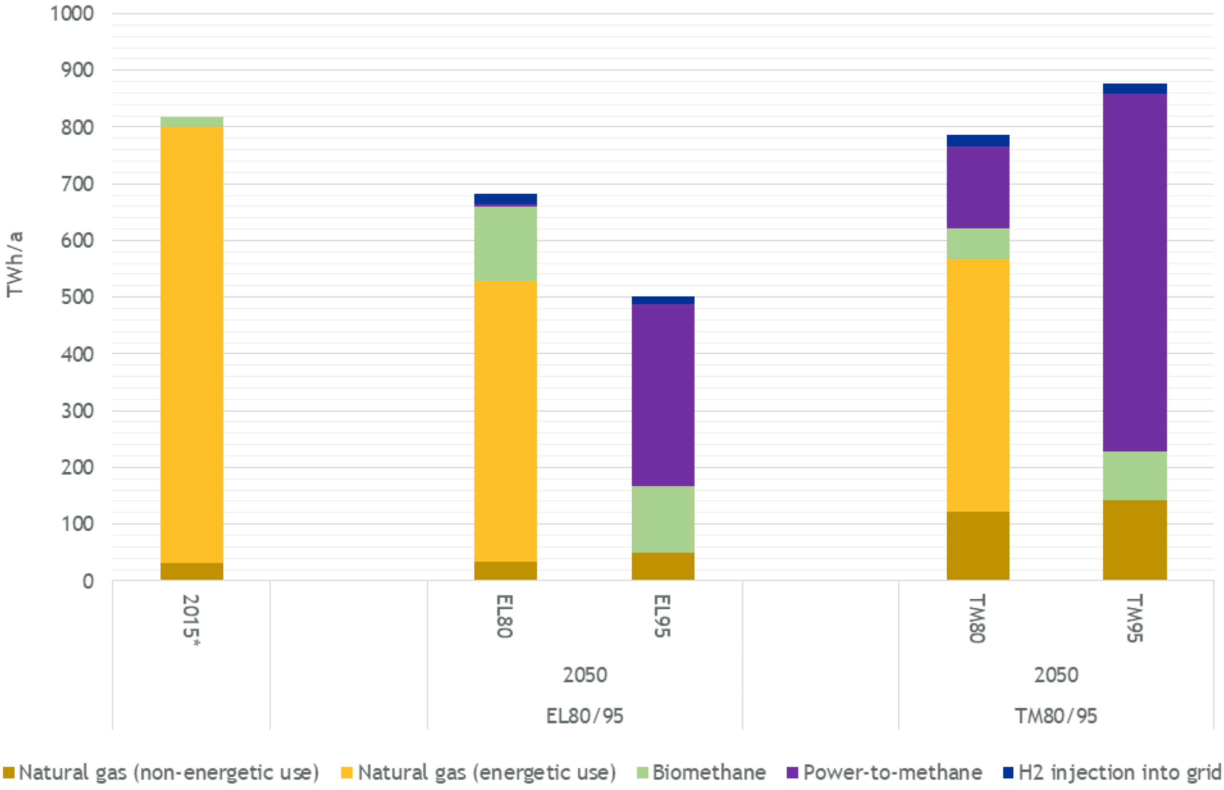

FIGURE 10: GAS DEMAND IN GERMANY BY TYPE AND SCENARIO, 2050

Source: own illustration based on ewi ER&S (2018a)

5. GAS AND ITS EXISTING INFRASTRUCTURE WILL ENSURE SECURITY OF POWER SUPPLY

The energy transition to reach the 2050 climate targets does not only drastically change the fuel mix, it also implies new challenges for the security of power supply. In the face of rising electricity demand in both scenarios, largely supplied by intermittent solar and wind power generation, the need to ensure security of power supply is obvious. Gas will be one of the major contributors for secure power supply irrespective of the scenario. Gas-fired turbines or rather decentral gas-engines are well suited to serve as ‘permanent synchronizer’, supplement power supply during residual peak hours (i.e. when load is high and renewable generation is low) and supply significant quantities of electricity during a ‘Kalte Dunkelflaute’, i.e. a two-week period of low renewable generation coinciding with cold weather, i.e. high electricity demand.

In the following, we will discuss specific aspects of the role of gas in the decarbonizing German energy space, including a critical look as to whether the existing gas infrastructure is up to the task.

Peak electricity demand will rise but gas use alleviates the increase

Figure 11 shows the development of peak electricity demand until 2050 (red dots). Here, a fundamental difference between the EL scenario and the TM scenario arises. Until 2050, peak electricity demand will almost double in the EL scenario (towards 160 GW), whereas it increases more moderately in the TM scenario (towards 101 GW). High penetration of heat pumps, electric vehicles and electrification of industrial processes cause these differences, even though the analysis assumes a high level of ‘smartness’ (e.g. technologies avoiding simultaneous peak demand). The TM scenario has a lower peak electricity demand since the direct use of ‘molecules’, e.g. gas in gas-fired appliances, serves peak *energy* needs outside the power space.

Gas-fired power generation capacities will strongly increase and furnish more than 50% of the electricity peak load

Figure 11 demonstrates further that gas-fired units furnish more than half of the electricity peak load requirements. Since Germany will phase out nuclear power by the end of 2022 and coal-fired capacity will decline by 50% driven by the -55% reduction CO_2 target in 2030, there will, already in 2030, be a significant need for additional gas-fired power generation. We see that in the EL-scenario some 71 GW of gas-fired capacity is needed by 2030, increasing to 107 GW by 2050. In the TM-scenario, capacity needs rise more moderately, namely towards 51 GW by 2030 and 58 GW by 2050.

Besides gas, a variety of technologies contribute to peak electricity supply such as batteries and pump storages, biomass, hydro power and demand side management processes. However, gas-fired generation is more attractive for a variety of reasons: Capital costs are comparatively low, the use of the technique is almost universally possible while other alternatives (e.g. hydro in the form of pump storages) have limitations. Importantly, gas-fired units serve a dual purpose: besides providing peak capacity they are also capable of supplying significant quantities of power during a so called ‘Kalte Dunkelflaute’, which e.g. battery storages cannot deliver.

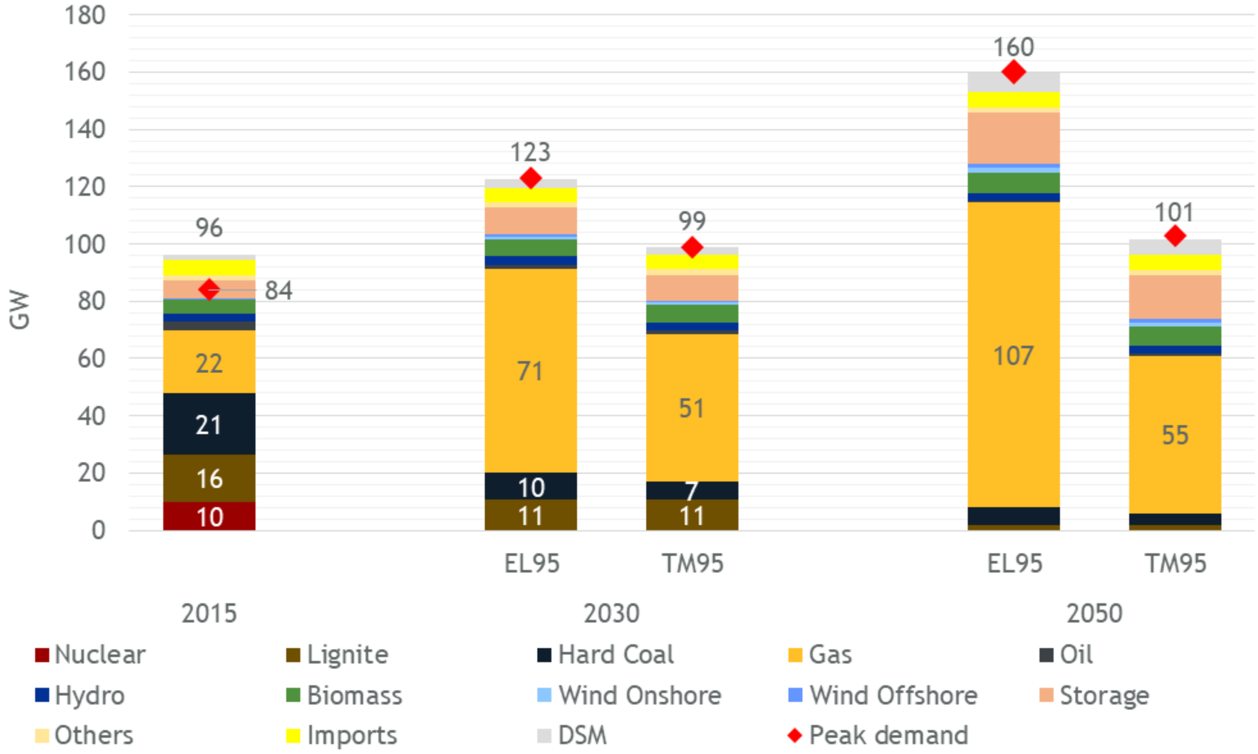

FIGURE 11: CONTRIBUTION OF GAS-FIRED CAPACITIES TO PEAK POWER SUPPLY

Source: own illustration based on ewi ER&S (2018a)

Electric heating causes a tremendous rise in power demand during a cold-spell - gas steps in the breach during a two-week ‘Kalte Dunkelflaute’

Figure 12 illustrates the electricity demand/supply balance during a two-week period of low temperatures (-3° Celsius on average). The comparison of EL and TM demonstrates that electricity demand is some 50% higher in the EL scenario during such period. This difference is mainly driven by the building sector: In EL, the penetration of electric heat pumps is very high, while only moderate in TM.[29] Hence in a cold weather period, electricity demand is substantially higher in EL.

If such demand surge coincides with low wind and PV generation, i.e. wind only at an average utilization of 10% and PV only at 3% during such two-week period[30], we speak of the so-called 'Kalte Dunkelflaute': Gas steps in the breach to fill the arising supply gap. In the TM scenario, gas-fired boilers supply substantially more households with heat than in EL. Hence, gas being used directly in gas boilers reduces electricity demand for heating with heat pumps.

Power needs during a 'Kalte Dunkelflaute' are mainly supplied by gas-fired units

Figure 12 also illustrates which quantities of the electricity demand during a two-week 'Kalte Dunkelflaute' not supplied by wind and solar are furnished by gas-fired power plants: of the 45 TWh required in EL95 in 2050 two-thirds, i.e. 30 TWh, are supplied by gas-fired power plants. This underpins the point made earlier that gas performs a twofold role in ensuring security of power supply: gas-fired power plants are not only needed for peak electricity supply, but they also secure electricity supply during a 'Kalte Dunkelflaute'. Intermittent solar PV and wind supply only 9 TWh during such two-week period. In the TM95 scenario only 29 TWh of electricity are required during the two-week period, with gas-fired power plants supplying roughly 15 TWh.

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[29] For industry and transport, we assume an average demand for the two-week period, which is identical to the annual average.

[30] Whereas wind onshore is assumed to have an average utilization of 32% over the course of a year in 2050, it is only 10% during the two-week period. Wind offshore is assumed to have an average annual utilization of 49%, solar PV of 12%. Utilization rates of PV and wind are assumed to increase compared to today because of technological progress.

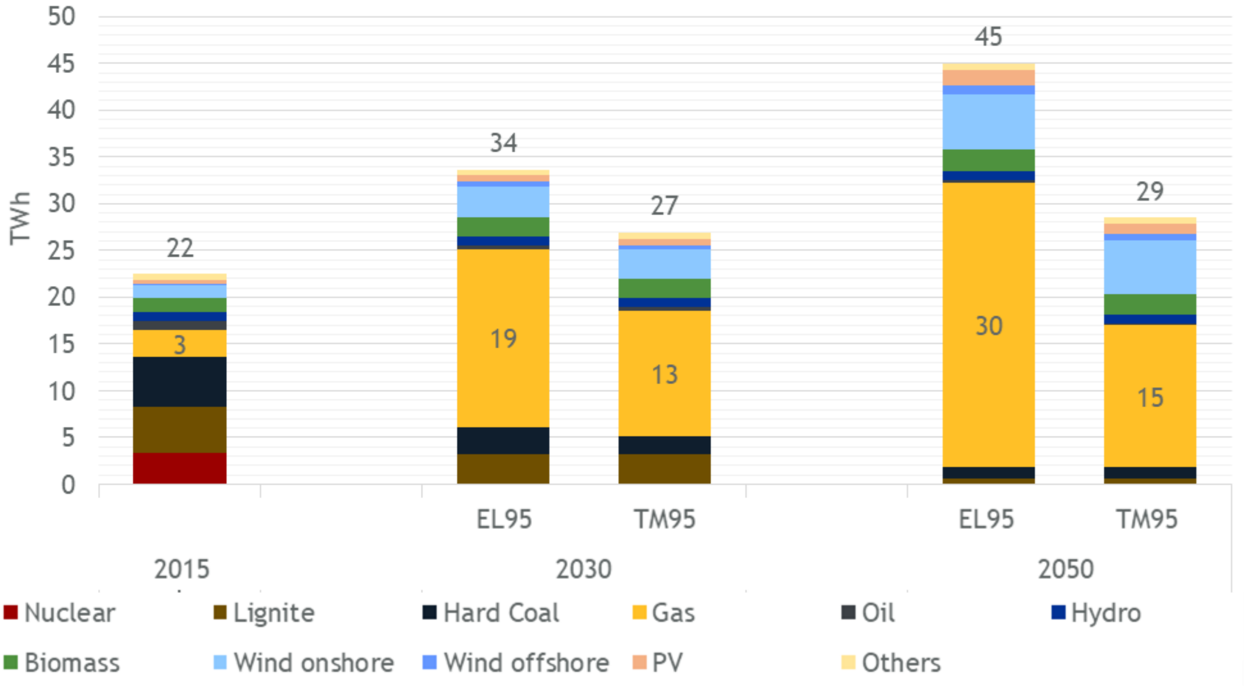

FIGURE 12: CONTRIBUTION OF GAS-FIRED CAPACITIES DURING A TWO-WEEK ‘KALTE DUNKELFLAUTE’

Source: own illustration based on ewi ER&S (2018a)

Interim Conclusion

Any which way you look at it, gas is a pivotal source to ensure the security of power supply, either by gas-fired power generation stepping in the breach in the EL scenario or, in the TM scenario, by the direct use of gas appliances alleviating peak power demand during cold spells.

Peak gas demand will decrease as a consequence of higher energy efficiency especially in the building sector

Having addressed the crucial role of gas for peak electricity demand it appears useful to also look at the impact of the changing energy landscape on peak gas demand itself. Figure 13 compares gas demand on a peak day in 2050 in both the EL95 and TM95 scenarios with the 2015 demand structure. As we see, peak gas demand will decrease in both scenarios. In 2015, peak gas demand[31] was about 6,100 GWh per day, with the building sector accounting for two-thirds. In the EL95 scenario, peak gas demand will decrease to ~5,550 GWh per day and in the TM95 scenario to ~5,300 GWh per day. The decrease in peak gas demand is an important insight when it comes to assess the continued use of the gas infrastructure (and the respective cost benefits) in Chapter 6.

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[31] Peak gas demand refers to the potential peak demand, not the peak that has been the actual maximal demand in 2015.

Peak gas demand shifts from the building sector to the power sector

Even though peak gas demand in total is relatively similar in both scenarios, the sectoral split is very different. In the building sector, peak gas demand vanishes almost completely in the EL95 scenario since most gas boilers are replaced by heat pumps.

In the TM95 scenario, peak gas demand decreases by 50%. Besides losing market share to heat pumps in new-built, energy efficient buildings, improved energy efficiency through insulation and heaters drive down peak gas demand also in this scenario. Since demand from the industry remains at a rather flat profile, industry does not substantially influence peak gas demand in either scenario.

The major driver of peak gas demand in the Electrons scenario is the power sector, where gas-fired power plants require roughly 5,000 GWh of gas per day in 2050 to ensure security of power supply. As already discussed, on a cold winter day electricity demand would peak enormously due to electric heating needs.

Peak gas demand stemming from the power sector increases also in the Molecules scenarios, but less drastically: it rises towards 2,700 GWh per day from the 1,500 GWh per day required in 2015. Even though the heat pump penetration is lower in TM than in EL, the increasing share of renewables and very minor remaining capacities of coal and nuclear make gas crucial in the power sector and see its respective sectoral peak gas demand soar in either scenario.

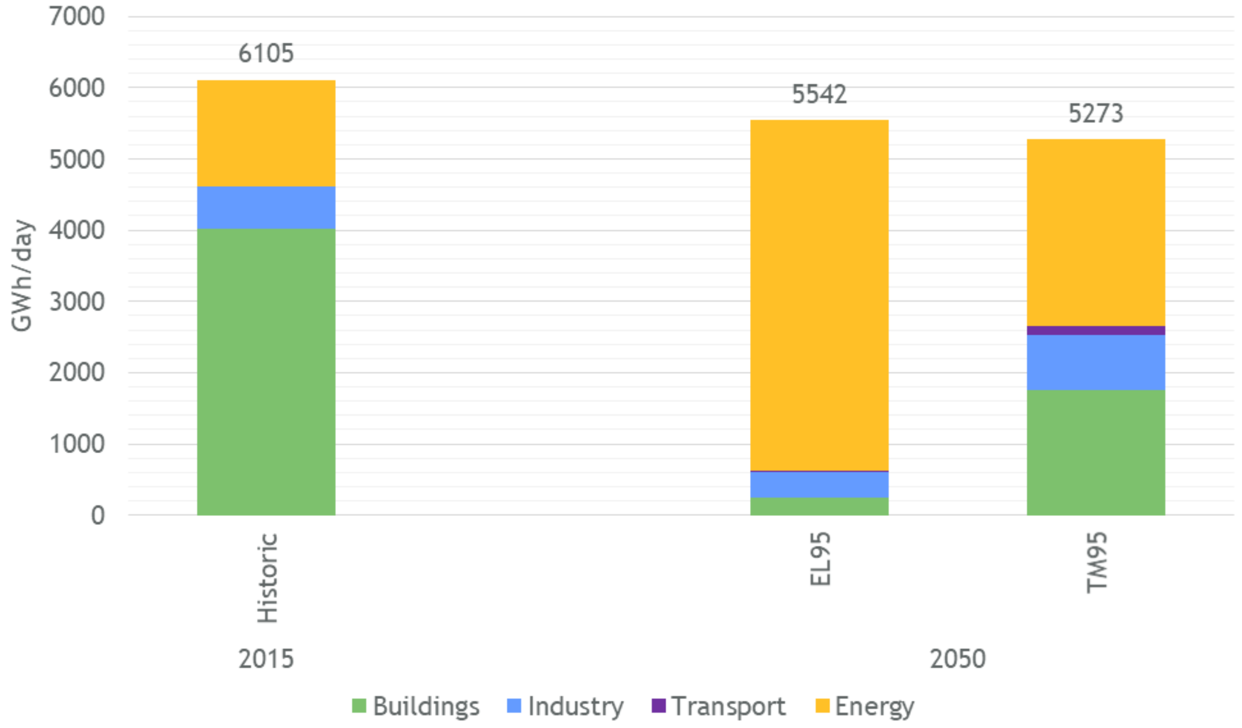

FIGURE 13: PEAK DAY GAS DEMAND IN GERMANY BY SCENARIO.

Source: own illustration based on ewi ER&S (2018a)

Interim Conclusion

Gas will be pivotal to address power peaks with respective increases in gas-fired power generation capacity required. Peak gas demand however will decline in both the Electrons and Molecules scenarios. This indicates that the existing gas infrastructure is by and large calibrated satisfactorily to perform the task. It should be noted however that, with an increase of gas-fired power generation capacity from 30 GW in 2015 towards 55 GW in TM95 and even 107 GW in EL95[32], certain adjustments and re-enforcements may be necessary towards 2050 in more regional granularity.

Demand patterns will change substantially with less need for seasonal storage and more need for short- and mid-term flexibility

Having assessed both the ability of gas to support peak electricity demand and the peak gas demand itself – always also with a view towards the suitability of the gas infrastructure to enable such - it appears useful by the same token to take a look at the demand profile (demand per day

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[32] See Table 1 (second-last row).

throughout the gas-year) for gas, again with a view towards the suitability of the respective elements of the gas infrastructure. As one would expect, profound changes will transpire.

The changed energy landscape clearly affects the daily and seasonal gas demand profile. Figure 14 and Figure 15 illustrate three patterns of daily German gas demand throughout a gas-year. Figure 14 shows the current situation in stylized fashion: heat demand in dwellings causes a strongly temperature-driven seasonal pattern.

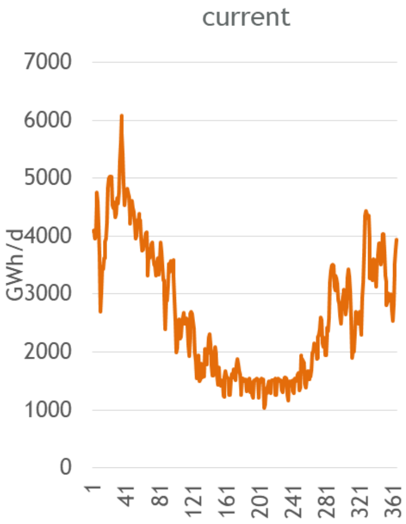

FIGURE 14: CURRENT DAILY GAS DEMAND STRUCTURE FOR GERMANY

Figure 15 illustrates gas demand patterns in both the TM95 scenario (left chart) and the EL95 scenario (right chart) in 2050.

The comparison of these patterns reveals three insights:

- First, the higher gas demand in the building sector (current situation), the more 'seasonal' the profile. Thus, TM95 is less seasonal than the current profile. Unsurprisingly, the gas demand profile is even less seasonal in EL95.
- Second, the more gas-fired plants are needed to synchronize and secure wind- and solar-based power supply, the more volatile the profile becomes. This renders the EL95 scenario the most volatile profile while TM95 is less volatile due to lesser electric heat pumps and instead the direct use of gas appliances.
- Third, the base load demand quantities - relative to heating dwellings - are higher due to a larger proportional share of industrial demand, which is rather flat throughout the year. In consequence, the TM95 scenario, which assumes a much higher direct use of gas, has a considerably higher baseload than EL95.

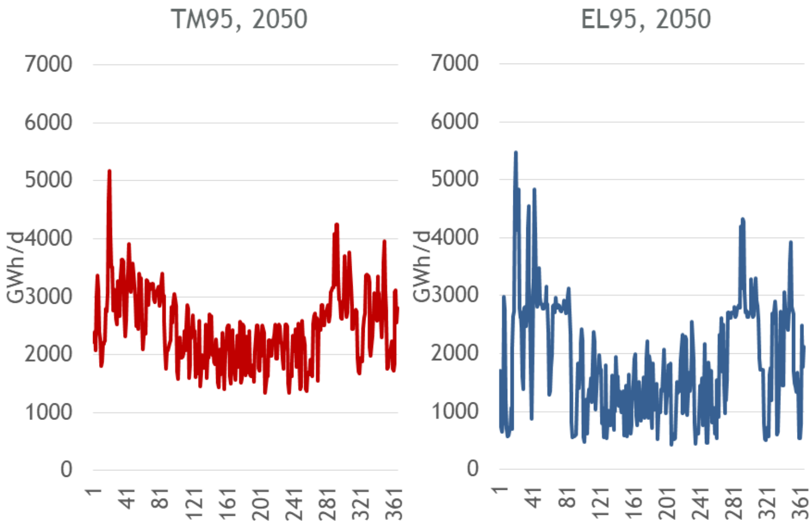

FIGURE 15: DAILY GAS DEMAND STRUCTURE FOR GERMANY IN SCENARIOS TM95 AND EL95

Interim conclusion for gas transport and storage infrastructure

The above analysis has demonstrated that gas will be pivotal in either scenario for

- acting as a permanent synchronizer of intermittent wind and solar-based power generation
- furnishing peak electricity supply at times of high demand during cold spells
- filling the renewables supply gap during ‘Kalte Dunkelflaute’,

thereby ensuring security of power supply in more than one way.

The analysis has further demonstrated that the existing gas infrastructure is capable of coping with the drastically changing gas demand patterns. However, the aforementioned ‘flattening’ of the seasonal demand pattern and, at the same time, a substantial increase in volatility bodes well for short-term flexibility via line-pack[33] and multiple-cycle peak storages, but not so well for seasonal storages.

This clearly qualifies the gas infrastructure to become part of an integrated (‘holistic’) energy system in a decarbonized world. Irrespective of the scenario, gas transport and storage infrastructure remain indispensable assets for securing Germany’s energy needs throughout the year. The respective cost benefits shall be addressed in the following chapter.

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[33] Line pack is the ‘buffer’ of gas in pipelines due to various degrees of compression and hence the most immediate source of flexibility on a moment’s notice.

6. GAS AND THE CONTINUED USE OF ITS INFRASTRUCTURE RENDERS THE MOST ECONOMICAL SOLUTION

As demonstrated, Germany needs to drastically accelerate the reduction of CO_2 in order to reach its climate targets. Clearly, it is imperative to take a sober look at the most cost efficient way. Several studies have come to the conclusion that ‘Molecules’ scenarios are less costly than ‘Electrons’ based scenarios.[34] In all ‘Molecules’ based scenarios, gas plays a crucial role. In the following, we shall briefly demonstrate that the intensive use of gas, gas infrastructure and gas technologies is instrumental for achieving the climate targets but at the same time in a vastly more cost efficient way. We shall use the results from dena (2018) and ewi ER&S (2018a).

Gas-based decarbonization strategies are significantly cheaper than electrification-based ones

‘Molecules’ is economically advantageous because it features significantly lower costs of capital for power plants, renewables, heating appliances, building insulation, cars and energy infrastructure.

In contrast, ‘Electrons’ achieve a somewhat lower consumption of end use energy, which results in cost savings for respective conventional and synthetic fuels. This perceived advantage over ‘Molecules’ is erased however by the enormous rise in power and peak power demand including the required electricity infrastructure, but also buildings insulation, appliances etc.

In other words: ‘Molecules’ allows a less drastic transition of the energy system with less needs for newly built appliances and infrastructure. While the cumulative additional costs for the energy transition between 2018 and 2050 amount to € 1.2 trillion in TM80, it has a cost advantage of almost € 600 billion over EL80. Also for the 95% CO_2 reduction target, EL95 (with total additional costs of € 2.2 trillion) is more than € 500 billion more expensive than TM95.

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[34] See for example enervis (2017), FNB Gas (2017), ewi ER&S (2017) or ewi ER&S (2018b).

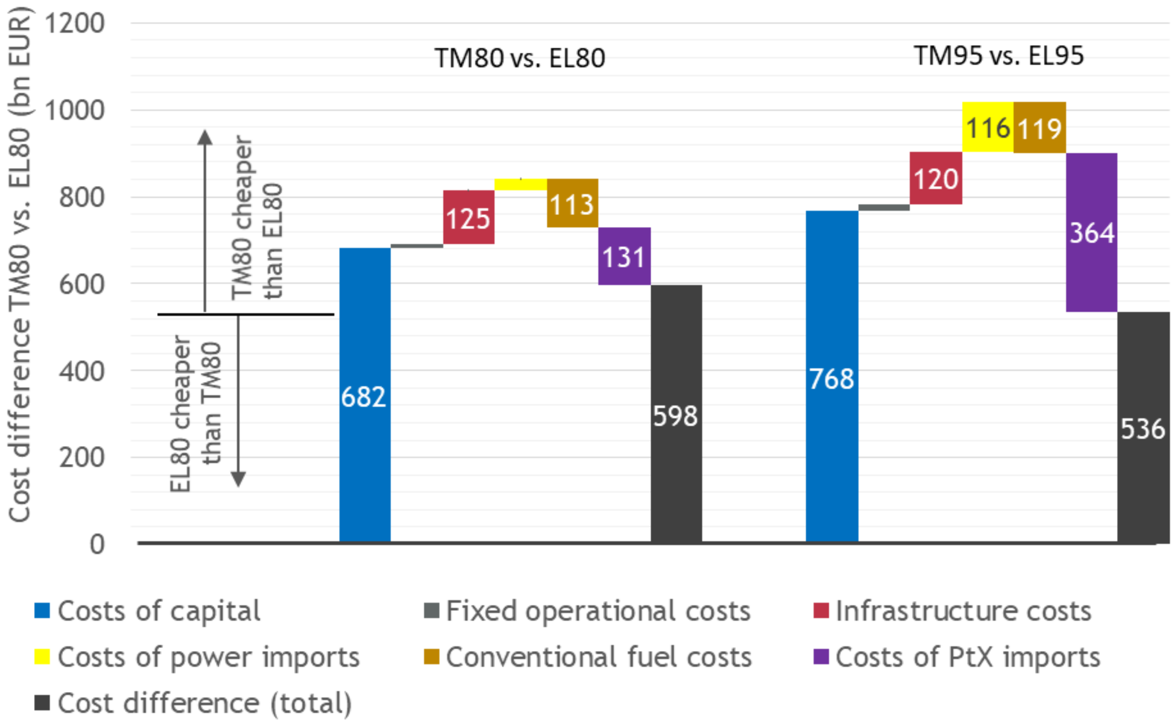

FIGURE 16: CUMULATED TOTAL ADDITIONAL COSTS OF THE GERMAN ENERGY SYSTEM 2018-2050 BY CATEGORY.

Source: own illustration based on ewi ER&S (2018a)

It is far cheaper to transport gas (molecules) than electricity (electrons)

As discussed earlier, one of the major advantages of molecules over electrons is its higher energy density. We demonstrated that by comparing the 2015 cost for electricity and gas transportation and distribution and computed a factor of greater than 6 on a €/kWh basis (see Chapter 3). This cost advantage/disadvantage is compounded when you set out to extensively electrify most of the end use energy demand, as Figure 17 illustrates.

Costs for using existing gas infrastructure remain flat while costs for electricity infrastructure rise substantially

We already established that the existing gas infrastructure is essentially suitable to perform the tasks falling on gas in a decarbonized energy space. This proves hugely advantageous for the costs of the energy transition.

According to Figure 17, gas transport and distribution costs will rise only modestly from € 5.3 billion in 2015 to € 5.5 billion in TM95 in 2050 and even decrease slightly in EL95 towards € 4.6 billion in 2050.

In contrast, the Electrons path results in exponentially rising costs for transport and distribution of electricity. In the EL95 scenario, these costs will rise from ~€ 21 billion in 2015 towards a staggering € 41.5 billion in 2050. Also in the Molecules (TM95) scenario, the costs for transport and distribution of electricity rise, but significantly less than in the Electrons scenario: namely from ~€ 21 billion in 2015 towards ~€ 32.4 billion in 2050, credit for which clearly falls to gas: the higher direct end use of molecular gas and its existing infrastructure alleviates the need for even more expensive new-built electricity grids.

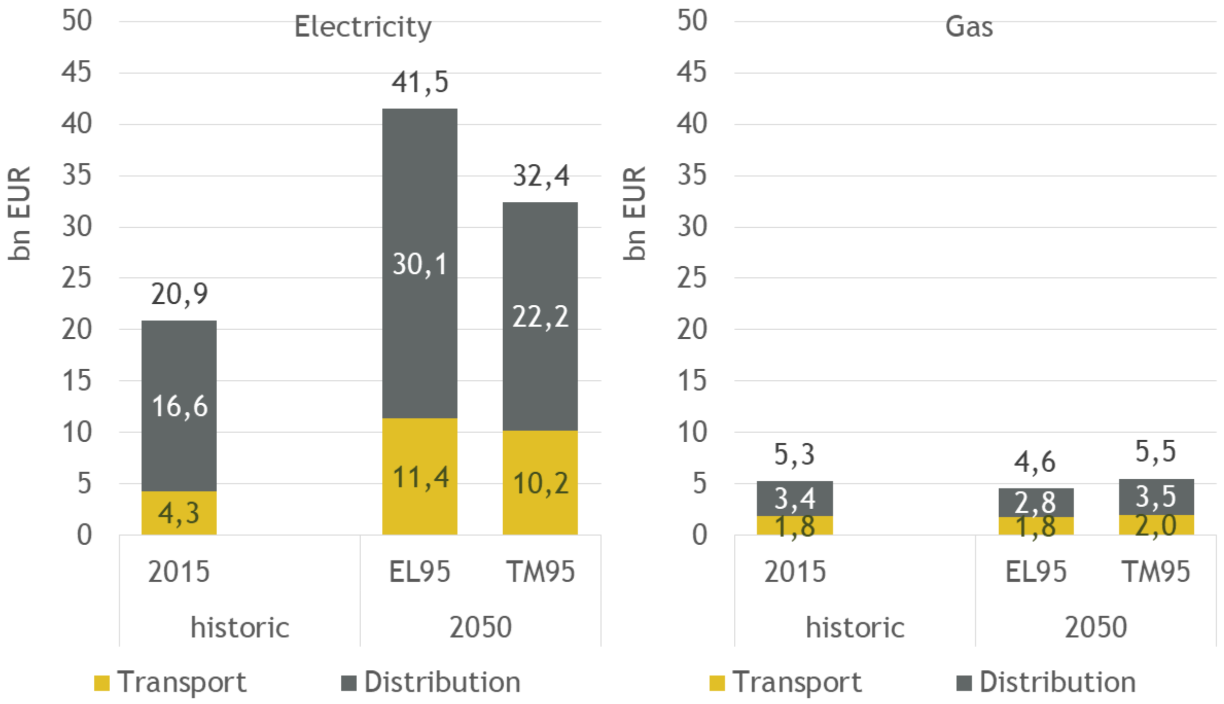

FIGURE 17: ANNUAL COSTS FOR ELECTRICITY (LEFT) AND GAS (RIGHT) TRANSPORT AND DISTRIBUTION INFRASTRUCTURE.

Source: own illustration based on ewi ER&S (2018a)

7. CONCLUSION AND OUTLOOK

Gas is instrumental in meeting climate targets in its own right and further ensures security of electricity supply

The analysis and comparison of Electrons and Molecules scenarios has clearly demonstrated that it would be wrong to dismiss gas into the ‘dirty fossil corner’. On the contrary, its long-term relevance – for quite a while as fossil natural gas and towards deeper degrees of decarbonization increasingly green – renders it indispensable: not only does it contribute to meet climate targets in its own right, it also ensures security of electricity supply.

We saw the benefits of its higher direct end use in the TM scenarios predominantly on the cost side. It is important to remember though that TM stands for ‘technical mix’, i.e. a technology openness which was largely missing in the early days of sector-coupling discussions.

Technology openness clearly goes beyond gas and there could well be ‘disruptive’ developments with a profound impact on the role of gas as described in this paper. E.g. its crucial role to ensure security of electricity supply would be diminished if there were a break-through with regards to storing electricity or heat in large quantities over long periods of time. At the same time, it is hard to imagine how the beneficial role of gas in direct use for heating of existing buildings, alleviating the massive costs for insulation and avoiding the exponential surge in power and peak power demand could easily become obsolete.

But there is ‘room for improvement’ as to technology openness also in the gas space itself. We saw for example that the removal or relaxation of the current limitations for blending green hydrogen with natural gas constitute significant upside potential for ‘greening’ gas.

The perhaps most important insight is that nobody knows which superior future technologies will evolve. Technology openness – as opposed to picking winners – is therefore the best guarantor to put ingenuity to work and possibly develop solutions presently unimaginable.

In the meanwhile, there is a (carbon-) budget to manage which will get ever harder (and more costly) to do the longer there is no immediate progress. The decisive deployment of gas would greatly contribute to achieve significant CO_2 reductions now as opposed to ‘wait for a better day’.

Will Germany become ‘champion’ again?

In 2008, Germany ranked second on the ‚Climate Change Performance Index‘ of ‘Germanwatch’. In 2018, Germany ranks 22nd, only slightly ahead of Belarus and below EU-28 average[35].

The currently ongoing discussions do not bode well for decisive steps forward, not least because Germany has deprived itself of several options which may be unpopular with many in Germany but could have greatly assisted in battling climate change[36].

While ‘coal-exit’ is heavily discussed, there is barely a word on the deployment of gas. We recall that the decommissioning of say 7 GW of lignite-fired power generation would require more than 4 times the capacity of onshore wind (i.e. >28 GW) to generate the same annual average power production, and requiring back-up on top as extensively discussed. In contrast, the permanent replacement of 7 GW of lignite plants by gas-fired power plants could be done by the very same 7 GW of capacity.

Neither insight nor aspiration are visible to bring this ‘coal-to-gas’ switching about. While the carbon price has recently risen by an impressive 400% towards ~ 20 €/t, the gas price has risen as well and annihilated a market driven coal-to-gas switching. The introduction of e.g. a carbon floor price at a level which would materially affect the power generation merit order in favour of gas on national level (like seen in the U.K.) is not on the radar screen.

Perhaps further ‘fossil of the day awards’ are necessary to mobilize effective measures to reduce German CO_2 emissions and start to battle climate change in earnest. Gas stands ready to join.

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[35] https://www.climate-change-performance-index.org/sites/default/files/documents/the_climate_change_performance_index_2018_a4.pdf

[36] The ‚dismissal’by law of e.g. ‘CCS’ (carbon-capture-storage), by the same token creating barriers for ‘CCU’ (carbon-capture-utilization) is an example of such.

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