Focusing expertise, shaping policy – energy transition now!

Essential findings of the three baseline studies into the feasibility of the energy transition by 2050 in Germany

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A comparison of three baseline studies

Energy Systems of the Future	Coupling the different energy sectors – options for the next phase of the energy transition https://energiesysteme-zukunft.de/en/topics/coupling-different-energy-sectors/
Federation of German Industries	Climate Paths for Germany https://www.bcg.com/de-de/publications/2018/climate-paths-for-germany-english.aspx
Deutsche Energie-Agentur	dena Study Integrated Energy Transition https://www.dena.de/en/topics-projects/projects/energy-systems/dena-study-integrated-energy-transition/

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Essential findings of the three baseline studies into the feasibility of the energy transition by 2050 in Germany

What will the energy supply of the future look like? How can Germany reshape its energy system to make it climate-friendly while maintaining security of supply at the lowest possible cost? Or in a nutshell: how can Germany's energy transition succeed? The German Academies of Sciences' joint "Energy Systems of the Future" (ESYS) initiative, the Federation of German Industries (BDI) and the German Energy Agency (dena) have independently addressed these questions and published their results in three studies.

ESYS, BDI and dena have got together around one table with their studies and have jointly concluded that, although feasible, an energy transition can only be achieved if policymakers take immediate decisive action. A "business as usual" approach will result in Germany comprehensively failing to meet its climate targets. Time is pressing and delays to major decisions and investment will ultimately result not only in distinctly higher costs but also in the windows of opportunity for the necessary restructuring being missed and the technology and infrastructure not being available in good time.

Successful energy system policy establishes a clear, long-term regulatory framework, provides technology-neutral incentives for energy-efficient technologies with low climate impact, uses cross-sectoral instruments taking account of the entire energy system and strengthens local, European and international partnerships. The sector targets set in the Climate Action Plan are a clear signal that the energy transition can only succeed if all sectors reliably make an ambitious contribution. The three studies have revealed, however, that the best possible paths for 2050 do not necessarily pass via rigid sector targets for 2030. Taking an open and flexible approach to this inconsistency is one of the tasks faced in the design of Germany's Climate Protection Act.

Citizens, businesses and the public sector will have to make major investment to achieve this transformation. This requires long-term incentives for investment in low-impact technologies and a regulatory framework which puts a price on CO_2 emissions, including for sectors outside the scope of the EU emissions trading.

At the same time, there is a need for an ongoing debate within society as a whole about how Germany intends to meet its climate targets. The energy transition and climate protection may spur progress in Germany as a centre of industry. On the one hand, they offer opportunities for innovation, jobs, export and quality of life while on the other hand they entail major changes and challenges for business, regions and individuals. Transformation will not succeed in the absence of a high level of consent in society.

The present legislative period is when policymakers will have to take decisions which will point the way forward. More courage and commitment will be essential if Germany is to be able to meet its climate policy promises, maintain its credibility and draw full benefit from its potential.

Priority action areas for a successful energy transition

The key findings from the comparison of the three studies can be summarized in seven points:

1. Expand renewable energies more quickly
2. Secure supply: make consumption more flexible and provide dispatchable power plants
3. Develop market and technologies for renewable synthetic energy carriers
4. Shift to a new technology mix in the transport sector
5. Increase the extent and speed of energy refurbishment for buildings
6. Avoid industrial emissions by efficiency, renewable energy sources and new processes
7. Take an integrated approach to managing the energy transition to enable investment

Overview of the baseline studies

Study	**ESYS** **Coupling the different energy sectors – options for the next phase of the energy transition**	**BDI** **Climate Paths for Germany**	**dena** **Study Integrated Energy Transition**
Project	Timeframe: 06/2015 – 11/2017 Participants: approx. 20 working group members, approx. 10 additional authors on individual topics Heads of working group: Prof. Dr. E. Umbach (acatech), Prof. Dr. H.-M. Henning (Fraunhofer ISE) Scope: Germany	Timeframe: 01/2017 – 01/2018 Partners: 70 study partners Consultants: Boston Consulting Group and Prognos AG Scope: Germany	Timeframe: 01/2017 – 06/2018 Partners: 60 study partners from business and science Expert opinion: ewi Energy Research & Scenarios gGmbH Scope: Germany
Content & aim	**Options for achieving a climate-friendly energy supply in 2050 which meets long-term climate protection targets.** The major steps involved were: **Quantitative and qualitative evaluation** of the technical options Bringing technical, economic and societal **limitations and challenges** to the fore Identifying important **system parameters and interrelationships** on the basis of own model calculations This reveals possible **development paths, key technologies and system costs** Deriving **central areas of activity** and **possible political courses of action**	**Identifying shortfalls** against the German Federal Government's climate targets. Modelling macroeconomically cost-efficient climate paths for Germany to 2050, specifically focusing on the five sectors: industry, transport, household/commercial, energy/conversion, agriculture/waste management. **Identifying climate paths** for meeting the Federal Government's climate targets. Identifying political **areas of activity**. Describing necessary **additional investment** and **costs** for meeting climate targets. Discussing measures which have not yet reached technological/economic maturity but can significantly contribute to climate protection once mature **("game changers")**. Opportunities: growing markets/climate protection technologies; increase in German export opportunities	Identifying **solutions and a framework** for ensuring an optimized, sustainable energy system by 2050 and analyzing **realistic options** in four sectors with numerous sub-sectors. Providing **knowledge** and **requirements** for successfully shaping the second phase of the energy transition. **Identifying transformation paths** for restructuring the energy system and meeting climate targets. Bringing practical **indications** and **recommendations** to the fore. Creating a **guiding framework** for **investment** and the **development** of sustainable **business models** in an integrated energy system. Describing **investment trends** and **costs** for an integrated energy transition. Considering **macroeconomic costs** and impact on the **competitiveness** of the German economy and **security of supply**.
Methodology	**Three approaches**: 1) expert discussions 2) comparison of relevant scenarios 3) model calculations (model: REMod-D; calculation of cost-optimized development paths with hourly resolution) 7 runs: 60_free, 75_free, 85_free, 90_free; 85_H2 (focus: hydrogen), 85_PtG (focus: power-to-gas), 85_active (including major energy-saving measures).	Scenario and reference analysis based on a bottom-up process. Measures prioritized on the basis of macroeconomic avoidance costs. Prognos energy system and electricity market models. Scenarios: reference (R), national initiatives (N80, N95, highly ambitious in core Europe and South Korea) and global climate protection (G80, G95, highly ambitious in all industrialized and transition countries) Exogenous energy/CO_2 prices based on WEO (IEA).	Macroeconomic scenario and reference analysis based on a bottom-up process. Scenario analysis rather than optimization analysis. ER&S DIMENSION+ energy market model Modelled climate scenarios: reference (RF) – electrification (EL) and technology mix (TM), in each case with an 80 or 95 per cent climate target in comparison with baseline year of 1990.

Study	**ESYS** **Coupling the different energy sectors – options for the next phase of the energy transition**	**BDI** **Climate Paths for Germany**	**dena** **Study Integrated Energy Transition**
Central findings	A "business as usual" approach will result in Germany comprehensively failing to meet its climate targets. Electricity will become the dominant energy carrier. Achieving this will mean **expanding PV and wind generation capacity to some 5 to 7 times present levels.** Bioenergy will play a decisive role but will no longer be used for power generation. Gas and hydrogen will become important due to their versatility. **Synthetic combustion and motor fuels** will become one of the pillars of the energy system. Restructuring the energy system will result in **systemic additional costs** of approx. 2% of GDP, for which public consensus will be required. The most important control instrument is **cross-sectoral CO_2 pricing.** At the same time, **the system of levies, duties and taxes** will have to be reformed.	An 80% GHG reduction is technically possible and, in the scenarios considered, macroeconomically manageable. From today's perspective, a 95% GHG reduction is at the bounds of technical feasibility and social acceptance and can only be achieved with comparable ambitions across the globe. Only with CCS and e-fuel imports. A huge effort for society as a whole: achieving the climate paths cost-efficiently will require total additional investment of 1.5 to 2.3 trillion euro by 2050. 4/5 of the measures do not have an economic payoff. Uncertainty around learning curves will require intensive monitoring and, possibly, path corrections. A course will "soon" have to be set from the centre by policymakers (infrastructure).	In the absence of substantial, additional climate protection measures, Germany will fail to meet its national climate targets. A target corridor of **80 to 95% lower GHG emissions in comparison with 1990** is **achievable** with various scenarios. In the case of a **95% GHG reduction** by 2050, some sectors (building, transport and energy) will no longer be permitted to emit any **GHG** in 2050. The **climate targets** can be met not only with **electrification** but also with a wide **mix of energy carriers**. **Technology-neutral paths** are **more robust** and **less costly.** A significant **increase in energy efficiency** and expansion of **renewable energy sources** are required. **Synthetic motor and combustion fuels** complement electrification.

Scenarios from the studies to which reference is made in this comparison		
ESYS	**85% GHG reduction**	**90% GHG reduction**
	85_free: 85% GHG reduction in the energy sector by 2050; no separate technology specifications **85_active:** 85% GHG reduction in the energy sector by 2050; additional energy-saving and efficiency measures in the industrial sector and in electricity consumption, doubled capacity of cross-border links, earlier coal phase-out	**90_free:** 90% GHG reduction in the energy sector by 2050; no separate technology specifications
BDI	**80% GHG reduction**	**95% GHG reduction**
	BDI-80: aims for an 80% GHG reduction by 2050 in comparison with 1990. The path is macroeconomically optimized and the technologies are selected on the basis of a merit order of GHG avoidance potential and avoidance costs. The central levers are efficient heat generation in industry by solid biomass and in the buildings sector by heat pumps. There is major potential for efficiency in all sectors in the 80% climate paths.	**BDI-95:** aims for a 95% GHG reduction by 2050 in comparison with 1990. The path is macroeconomically optimized and the technologies are selected on the basis of a merit order of GHG avoidance potential and avoidance costs. Such a path is conceivable only if global ambitions are comparably high, at least among G20 countries. Once efficiency potential has largely been exhausted, synthetic energy carriers and CCS are used to avoid process emissions.
dena	**80% GHG reduction**	**95% GHG reduction**
	EL80: the electrification scenario assumes an increase in energy efficiency and widespread electrification in every sector. Synthetic energy carriers are taken into account if necessary. 80% GHG reduction in comparison with 1990. **TM80:** the technology mix scenario presupposes an increase in energy efficiency but permits a wider diversity in technologies and energy carriers. 80% GHG reduction in comparison with 1990.	**EL95:** the electrification scenario assumes an increase in energy efficiency and widespread electrification in every sector. Synthetically generated renewable energy carriers are taken into account when they become mandatory. 95% GHG reduction in comparison with 1990. **TM95:** the technology mix scenario also relies on an increase in energy efficiency but permits a wider diversity in technologies and energy carriers.

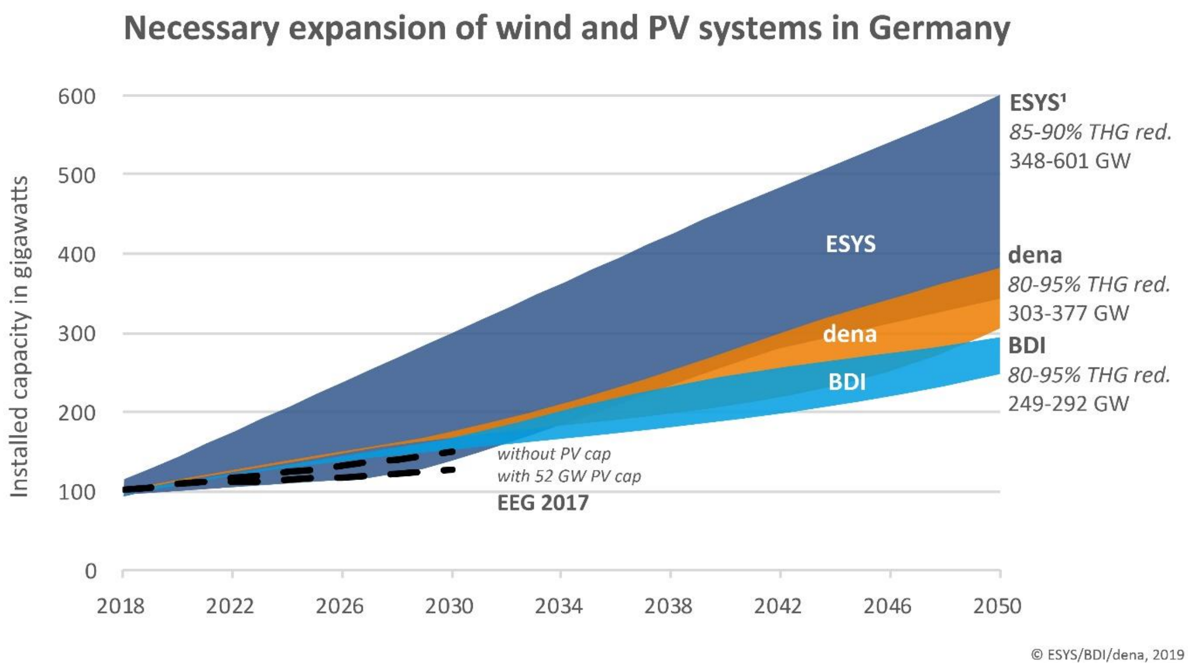
1 Expand renewable energies more quickly

If an extensively emission-free energy supply is to be achieved by 2050, renewable energy sources, in particular wind and photovoltaics (PV), will have to be expanded distinctly more than planned. This is because electricity, as the three studies clearly show, will become the most important energy carrier in all consumption sectors. The net expansion rates of about four gigawatts (GW) provided in the German Renewable Energy Sources Act (EEG) and the available land areas will not be sufficient. The special invitations to tender which have been agreed will also be insufficient to close the gap.

By 2050, Germany will need wind and photovoltaic capacity of at least 250 GW and up to 600 GW (capacity was just 105 GW in 2018). In the studies, demand varies depending on the assumptions made in terms of energy imports, the level of sector coupling (e.g. how widely heat pumps and e-mobility are used), the increase in energy efficiency and technological developments (e.g. hours for which wind turbines are under full load).

Conclusions:

- **Intensify expansion of wind and PV systems**: legislators must increase the statutory expansion corridor to at least 6 GW net per year (i.e. +50 per cent over EEG 2017).
- **Provide land area**: there is a need for a common strategy at federal and state level which
    - ensures sufficient potential land area by identifying priority areas,
    - adapts setback distances as required (if need be by setting standards at federal level) and
    - gains popular acceptance.
- **Push onward with grid expansion:** there is a need to work closely together with grid operators, licensing authorities and policymakers to accelerate expansion and to optimize power grid utilization by smart control systems and systemic approaches (e.g. spatial allocation of renewable energy sources, integrated gas and electricity grid planning) and so ensure the best possible integration of renewable energy sources.



[1]In the ESYS study, the GHG reduction only relates to the energy system, including the 85_active scenario.

The differences

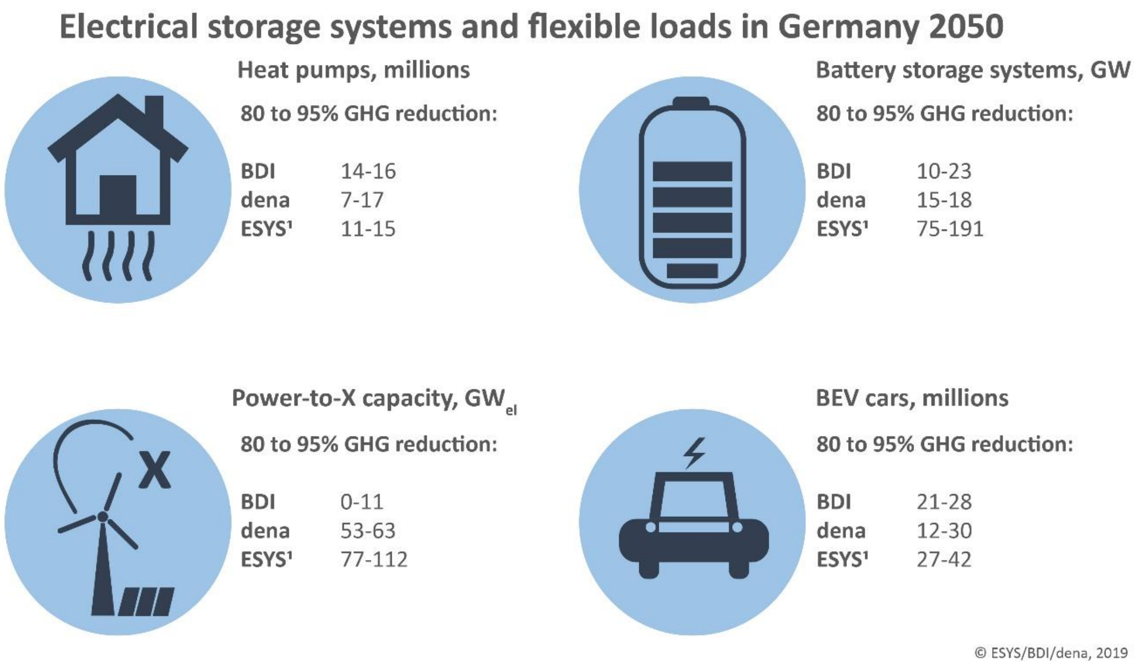
- The BDI and dena studies allowed **imports** of synthetic renewable energy carriers while the ESYS study ruled them out. Producing these energy carriers in Germany therefore requires major use of wind and PV systems in the ESYS study.
- Most of the scenarios in the ESYS study, unlike the BDI and dena studies, assume constant energy consumption in conventional electricity applications and in the industrial sector to 2050. This results in a higher total energy demand and greater expansion of renewable energy sources.

2 Secure supply: make consumption more flexible and provide dispatchable power plants

Due to weather conditions, wind- and PV-derived renewable energies cannot generate sufficient electricity to meet demand at all times. The three studies show that achieving an efficient and secure electricity supply requires firstly **a variety of technologies for short-term flexibility** and secondly **dispatchable power plants for sufficiently guaranteed capacity**.

Short-term flexibility

Various flexibility options for compensating short-term, local fluctuations are required to combine extensive integration of renewable electricity with an efficient electricity market: **stationary electrical storage systems (batteries)** complementing Germany's pumped-storage power plants and ongoing expansion of **demand-side management** for private and industrial consumers. In particular for **new electrical consumers such as heat pumps and electric vehicles,** it is important from the outset to ensure maximum flexibility when drawing load by smart control characteristics. **Thermal storage systems, whether central (in heating networks) or decentralized (in buildings), and power-to-X systems** can also store electrical power from renewable energy sources during peak generation periods and provide energy at a later point in time.



[1]*In the ESYS study: 85-90% GHG reduction in the energy system.*

The differences

- In the scenarios, the quantity of electrical storage systems is substantially dependent on the installed capacity of fluctuating renewables and on the use of synthetic combustion and motor fuels.
- Power-to-X system capacity in Germany is comparatively higher in the ESYS study since this study rules out imports of synthetic energy carriers. The remaining differences can be explained by different assumptions (e.g. costs, efficiency or demand trends for green hydrogen).

Security of supply

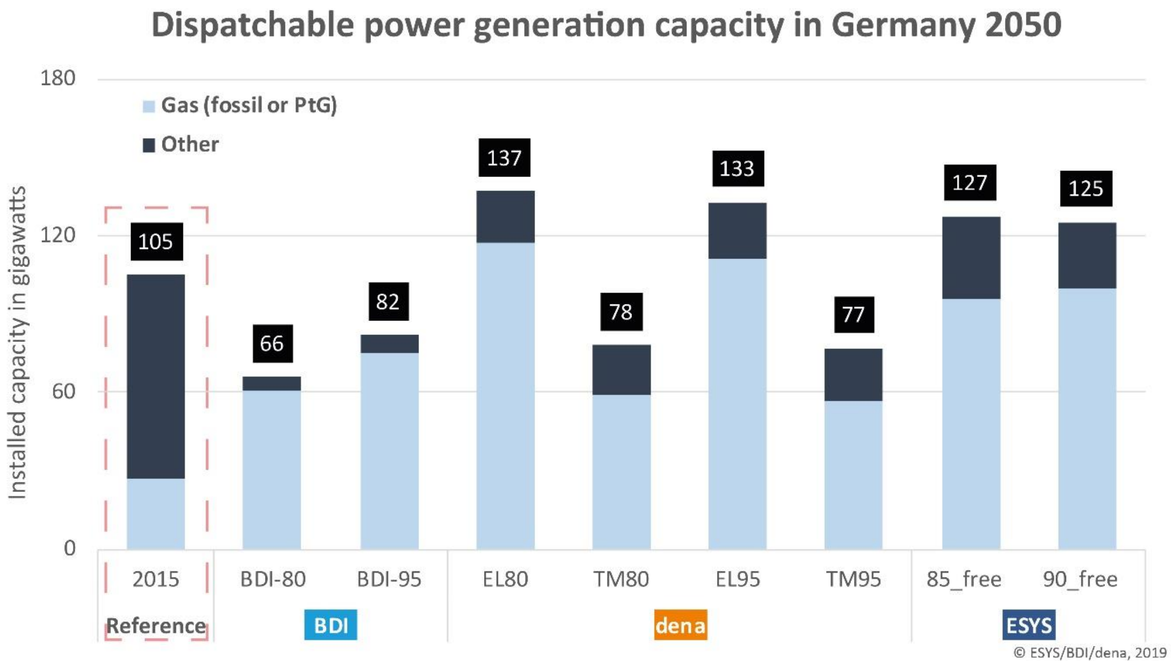
Short-term flexibility helps to attenuate annual peak load in the power grid. Guaranteeing security of supply over extended periods without sufficient wind and sunshine furthermore requires **dispatchable power plants** with an output of **between 60 and 130 GW** by 2050 (installed dispatchable capacity was about 100 GW in 2018). The high capacities are also required because all scenarios assume extensive electrification in the transport and heating sectors. It is therefore particularly significant that a secure supply of electricity will potentially also be the prerequisite for heating security.

Integration into the European energy system has an important role to play in providing the necessary power generation capacity: if more electricity can be imported from European neighbours in the scenarios, the need for reserve capacity in Germany falls to a limited extent.

Flexible gas-fired power plants and gas turbines, initially operated with natural gas and in future potentially with synthetic gas, are the primary providers of dispatchable capacity. Gas-fired generating capacity will likely have to be doubled by 2030 if security of supply is to be guaranteed. At the same time, dispatchable power plants will only be operated at a very low rate of utilization.

Conclusions:

- The Federal Government should **carry out a root-and-branch reform of the current system of fees, taxes, duties and levies** during the current legislative period. This is a prerequisite for optimizing sector coupling and making use of flexibility for the various applications on the market and on the grid.
- **Intensify the European electricity market:** working in close alignment with neighbouring countries and the European Union, the internal electricity market should be continuously further developed and transport capacity in the integrated grid expanded. This will permit more effective compensation of fluctuations in electricity supply and demand together with joint use of guaranteed capacity.
- Over the coming years, the Federal Government should closely observe (monitor) security of supply trends in Germany and, in the medium term, investigate the **possibility of refinancing dispatchable power plants with low operating hours** on the electricity market or the need for further development for reserve mechanisms.



The differences

- Requirements for dispatchable generating capacity depend on the degree of electrification and associated trends in annual peak load, assumed compensating effects in the European integrated grid through the use of flexibility, and on the assumptions made and methods used for determining the level of security of supply (e.g. during calm spells with low light).

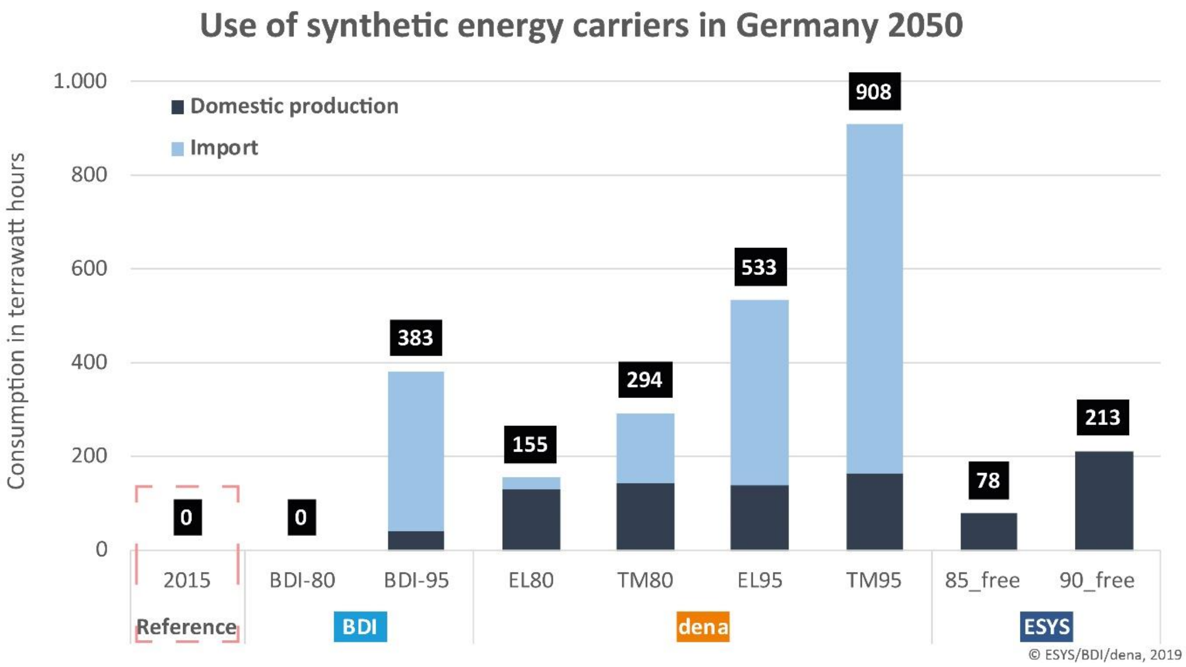
3 Develop market and technologies for renewable synthetic energy carriers

Renewable synthetic energy carriers are necessary for meeting climate targets. **Under the studies' ambitious targets, they will cover demand of about 200 to 900 terawatt-hours in 2050** (primary energy consumption in 2017 was about 3,800 terawatt-hours). As targets become more ambitious, they will close the gap which cannot be filled in Germany by energy efficiency or direct use of electricity from renewable energy sources. Applications of such energy carriers include motor fuel in the transport sector, a primary material in the chemicals industry and storable energy carriers for guaranteed generating capacity in the electricity system.

Renewable synthetic energy carriers can be produced in Germany or be imported from countries with better local conditions. Imports can limit the need to expand renewable energy sources for the production of synthetic energy carriers in Germany. It cannot as yet entirely be predicted how international supply and demand for synthetic energy carriers will develop. It is in any event clear that synthetic energy carriers and power-to-X technologies will be necessary if the energy transition is to succeed. This is why it is now particularly important to engage closely with other countries in order to initiate the development of a global market with initial international projects and to push onward with research and development.

Conclusions:

- Policymakers should work together with the energy sector and scientific community to push onward with **research and development of power-to-X technologies**. The aims here are to achieve distinct cost reductions and better systems integration and to optimize various production, transport and usage paths.
- The Federal Government needs a targeted **market introduction strategy adapted to Europe** in order to bring technologies continuously to market maturity and to ensure a German knowledge base.
- In parallel, the Federal Government should work on an international level (e.g. in the G20 or in energy partnerships) to promote international pilot projects in order to benefit from the opportunities offered by **global trade in synthetic energy carriers.**



The differences

- The wide range for synthetic energy carriers is the result of differing assumptions made among other things about costs for imports and about costs and the speed and complexity of transformation on the demand side.
- The ESYS study ruled out imports of synthetic energy carriers.

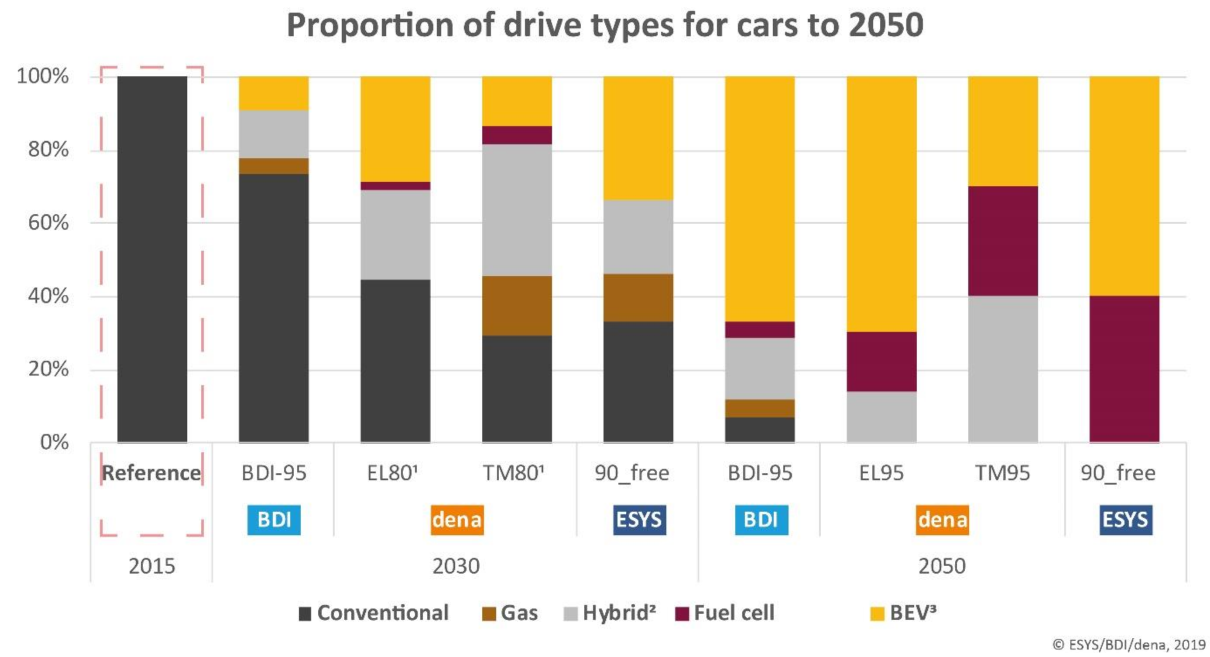
4 Shift to a new technology mix in the transport sector

Greenhouse gas emissions in the transport sector have in recent years risen above 1990 levels. Improvements in energy efficiency and the low levels of use of renewable energy sources in transport have not yet been enough to offset rising transport capacity. Moreover, freight traffic demand in all modes of transport is expected to continue to grow even over the long term.

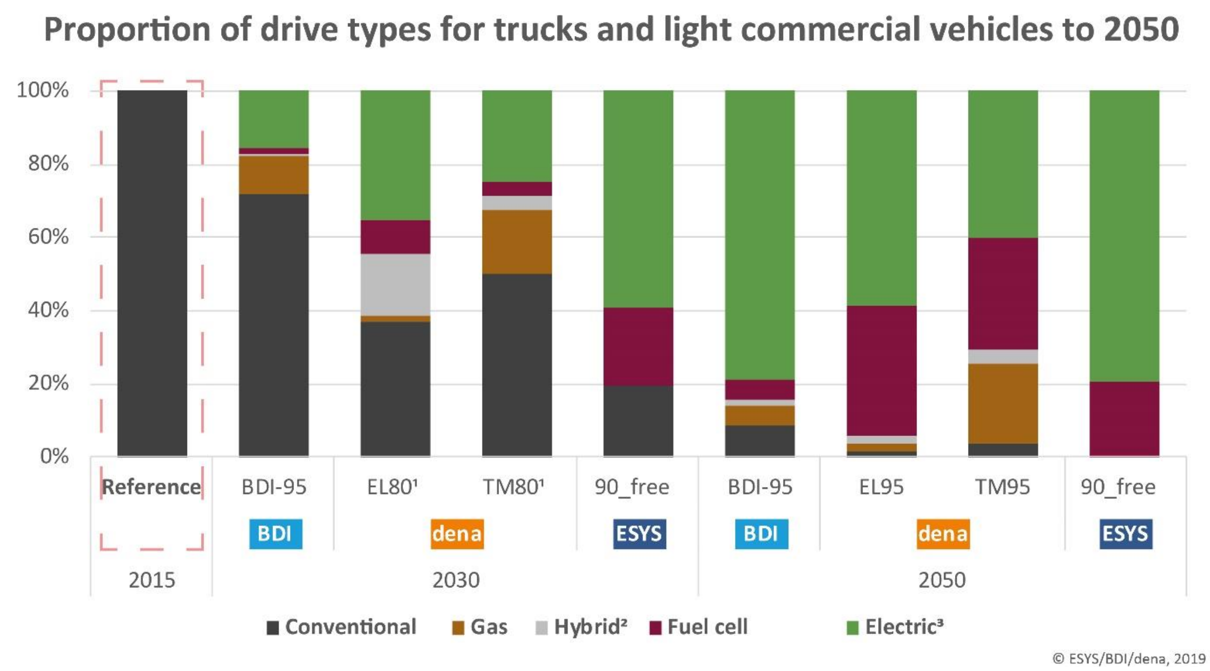
A single technology will not be enough to overcome the challenges. All three studies show that **a differentiated technology mix is required for transport.** Electrical drive systems are the central pillar for meeting targets in the car sector. In all three studies, hybrid and battery electric vehicles will account for over half of vehicle fleets by 2050. Biofuels and electricity-based, renewable motor fuels will furthermore be part of the solution. In heavy goods transport, the outcome of the technology race for the best solutions (including hydrogen, synthetic motor fuels, overhead line hybrid trucks, battery electric trucks) is as yet unknown. There is an urgent need for agreements with other countries in relation to heavy goods transport, shipping and air transport in order to implement in the near future ambitious international policies which are compatible with long-term climate targets.

Conclusions:

- **Instruments** should take an all-embracing, technology-neutral view of drive systems whether they are electric or use gas or CO_2-neutral motor fuels. This will ensure a wide range of vehicles, which will therefore be better accepted, for all mobility requirements and an efficient, uninterrupted process of transformation. Care must be taken to ensure that severely affected groups (commuters or financially disadvantaged sections of the population) are not unduly burdened.
- **Systematically enable electromobility in the car sector**: acceleration of expansion of private and publicly accessible charging infrastructure and support, conversion of public sector vehicle fleets.
- **European agreements for long-distance transport:** intensify strategic dialogue with EU Member States in order to arrive at internationally coordinated political decisions for the implementation of long-term infrastructure projects for long-distance passenger and heavy goods transport by the mid-2020s.
- **International cooperation in aviation and shipping:** Since the majority of air transport and shipping takes place in an internationally regulated environment, effective mechanisms must immediately be implemented which rapidly step up demand for sustainable, renewable motor fuels.



[1]Up until 2030, the dena study does not differentiate between the 80% path and the 95% path.
[2]Plug-in hybrids (conventional and gas).
[3]Battery electric vehicles.



[1]Up until 2030, the dena study does not differentiate between the 80% path and the 95% path.
[2]Plug-in hybrids (conventional and gas).
[3]Battery electric and overhead line.

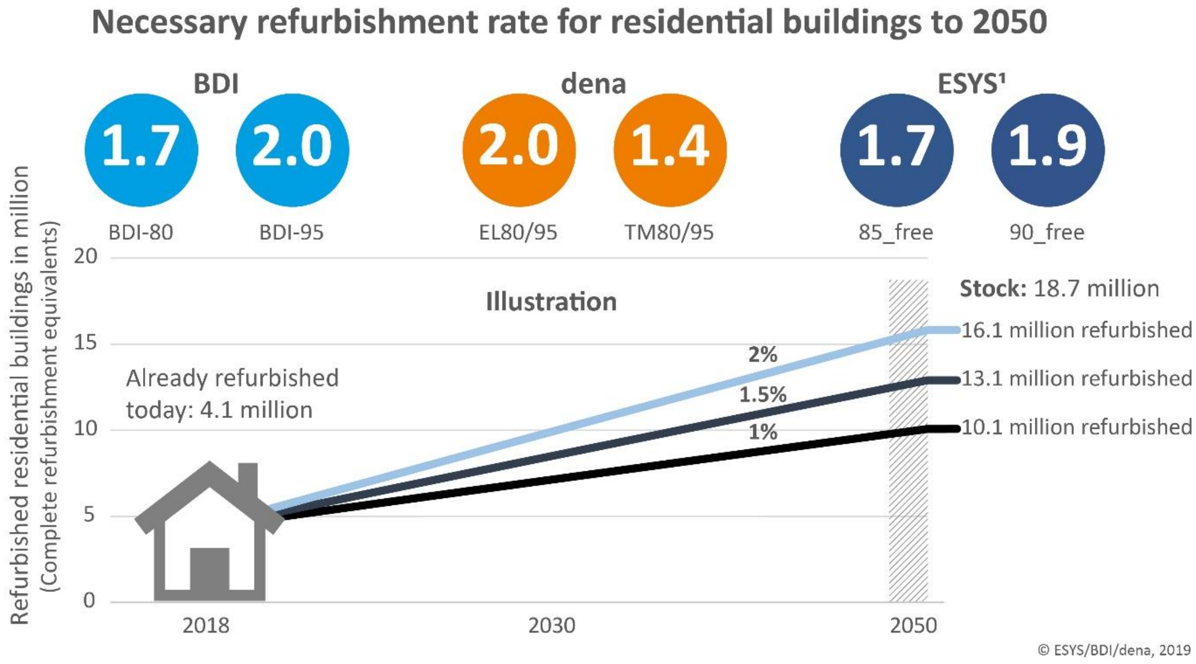
5 Increase the extent and speed of energy refurbishment for buildings

The pace of building energy efficiency refurbishment must be stepped up significantly if climate targets are to be met. At today's rate of refurbishment of about one per cent, by 2050 building stock which is unrefurbished or refurbished only to a low level will still include about 8 million residential buildings. If the energy transition is to succeed, Germany's building stock must be largely refurbished by 2050. The studies show that **the refurbishment rate must be raised to 1.4 to 2.0 per cent.** Investment in the efficiency of the building's envelope and its systems must go hand in hand with a move away from fossil energy carriers and a high level of use of renewable energy sources. Electrical heat pumps and heat storage systems will become distinctly more significant. It is important for measures to be coordinated with one another. For instance, using heat pumps makes particularly good sense if building efficiency is simultaneously increased.

In conurbations, **heating networks** combined with central **heat storage systems** have the potential to cut the costs of climate-friendly heating.

Conclusions:

- Investment in an energy-efficient building stock must be increased without delay by effective funding schemes. The government should provide tax breaks for building refurbishment and regularly monitor funding levels and effectiveness and interaction with other measures such as CO_2 pricing.
- **Endeavour to achieve a reasonable level for refurbishment standards:** existing buildings which are refurbished to inadequate energy standards will have to be refurbished again by 2050. This will result in huge additional costs.
- Local government decision makers should investigate **expanding heating networks and heat storage systems** in urban conurbations beyond current levels. It is important for legislators to take account of **neighbourhood planning** when considering the further development of the regulatory framework and funding schemes.
- In parallel, authorities at federal, state and local level should **provide more information and supportive market mechanisms** (e.g. incentive systems for individual renovation roadmaps), streamline funding mechanisms and, working together with training providers, improve **skills development for planners, advisers and tradespeople.**



[1]The refurbishment rates in the two ESYS scenarios relate to Germany's entire building stock.

6 Avoid industrial emissions by efficiency, renewable energy sources and new processes

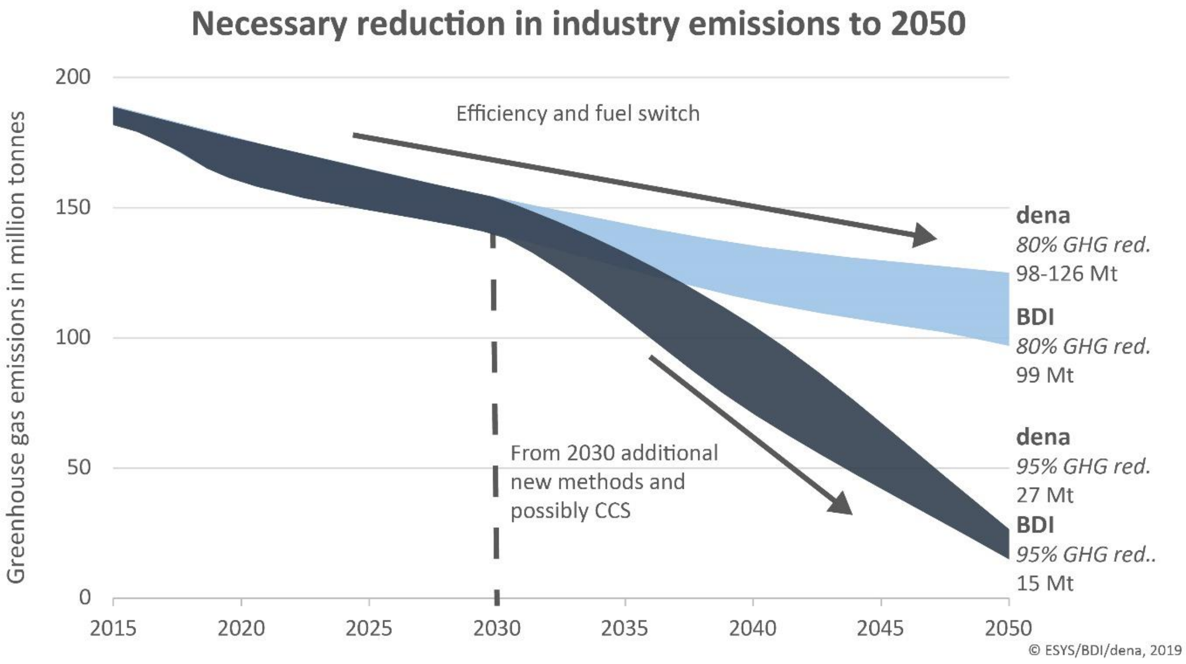
Industry accounts for about a quarter of Germany's final energy consumption with fossil energy carriers providing almost 90 per cent of industrial consumption. If climate targets are to be met in Germany, industry must **further boost energy efficiency and change over to renewable energy carriers** (including domestic biomass, hydrogen, synthetic methane and hybrid systems with gas and renewable electricity). Biogas and synthetic renewable gas in particular can play an important role as they can be used to provide high temperatures for process heat and can directly replace natural gas. At present, however, there is too little incentive to make changes to energy supply and use.

Industrial investment and innovation cycles run for up to 30 years: 15 years for development, 15 years for market exploitation. The right stimuli must therefore be put in place now and guaranteed over the long term.

If Germany's ambitious climate targets are to be met in the long term, industry must also cut its emissions by at least 90 per cent. This cannot be achieved solely by boosting energy efficiency and changing over to renewable energy carriers. Process emissions, which account for approximately 7 per cent of greenhouse gas emissions in Germany, cannot be completely avoided using currently available technologies. There is therefore a need for **new methods for avoiding process emissions**, for instance using green hydrogen in iron smelting. From today's perspective, Carbon (CO_2) Capture and Storage (CCS) will be a necessary complementary tool for meeting ambitious climate targets and can serve as a bridge technology. Methods both for avoiding and for storing CO_2 are, however, still in need of further development to make them technically and economically suitable for service.

Conclusions:

- **Provide greater support for research and development:** if climate targets are to be met by 2050, new methods for avoiding process emissions must be available as soon as 2030.
- In particular, successful transformation of the industrial sector requires the Federal Government to establish a **regulatory framework** for the energy transition which provides **long-term planning certainty**. Only in this way will businesses be able to take the necessary far-reaching investment decisions.
- **Protect industry exposed to international competition:** the European Union and Federal Government must furthermore provide flanking measures to ensure that businesses which are exposed to international competition do not relocate production operations to foreign countries due to rising energy costs ("carbon leakage").
- **Debate CCS in the industrial sector:** a new social debate should be initiated at the federal and state level in Germany as to whether and under what conditions use of CCS for avoiding process-related greenhouse gas emissions in industry might be socially accepted.



The differences

- The ESYS study did not consider industrial emissions separately but instead only energy system emissions.

7 Take an integrated approach to managing the energy transition to enable investment

Transforming the energy system involves considerable investment: if greenhouse gas emissions are to be cut by 80 per cent by 2050, the **additional costs in comparison with a "business as usual" scenario will rise by 15 to 70 billion euro annually depending on the study.** This amounts to between 0.5 and about 2 per cent of today's gross domestic product.

Two factors play an important role here:

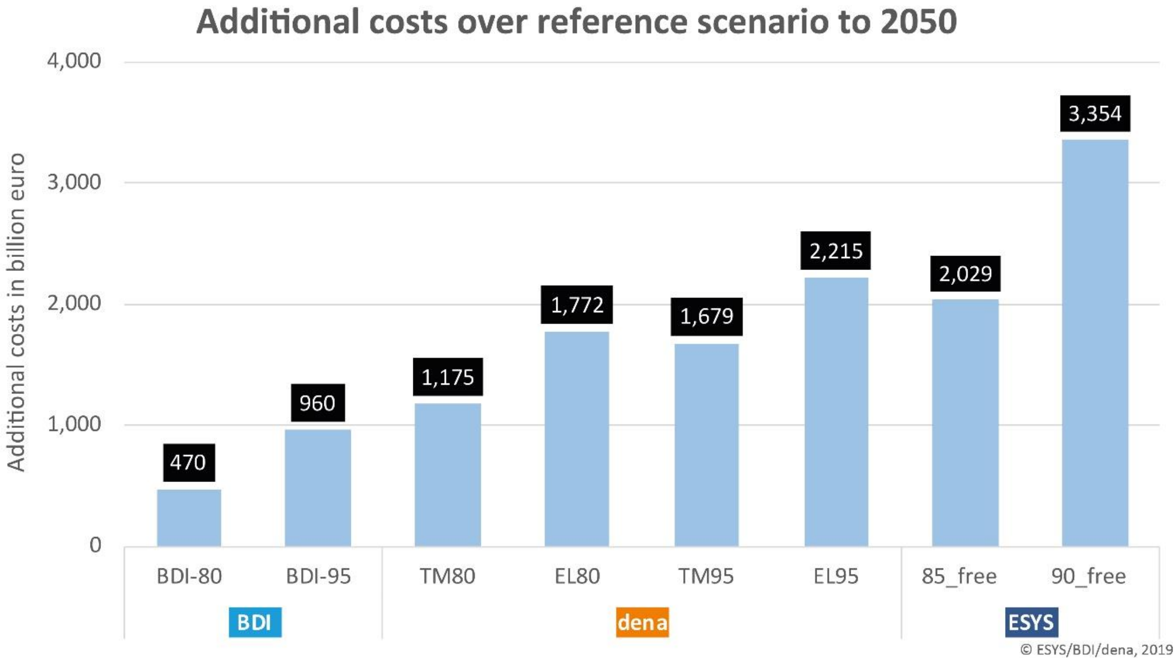
- Ambitious climate targets mean higher costs. Additional costs in the ambitious scenarios accordingly rise to 30 to 100 billion euro as an annual average depending on the study.
- The later the investment arrives, the higher are the costs. The process of transformation must therefore begin without delay in order to keep additional costs low and the impact on society, the economy and industry to a minimum.

These costs do not take account of the positive macroeconomic effects which might arise from technological development, new jobs and export opportunities for Germany's high-tech industries.

A major part of the additional investment required by 2050 will not occur by itself under the current regulatory framework. Targeted and integrated political control will be required. Isolated regulations, subsidies and fragmented funding initiatives often result in higher macroeconomic costs.

Conclusions:

- The Federal Government should create a regulatory framework which ensures **long-term planning certainty** in order to minimise investment risks.
- As a starting point, the Federal Government should carry out a comprehensive review of the system of duties, levies and taxes, if possible during the current legislative period. The centre point of the reform should be **CO_2-oriented pricing signals for all application sectors,** including those outside the ETS.



The differences

- The differences in additional costs are due *inter alia* to different assumptions about efficiency gains, energy import costs and different interest rates. In the ESYS study, producing synthetic energy carriers exclusively in Germany is a further cost factor.