Security-orientated Energy Policy

A financing strategy for Germany's independence from natural gas

Energy Independence Council

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Summary for decision-makers

The Russian war of aggression has heralded a geopolitical turning point. This turning point has an impact on security and foreign policy, but also requires a fundamental reorientation of energy policy that draws conclusions from the crisis and reduces energy dependencies. However, we are a long way from this reorientation. This report formulates action steps for politics, business and society on how natural gas independence can be prioritised as a building block of a security-orientated energy policy for Germany and how the potential it offers can be exploited.

Recognise risks. (→ to Chapter 2)

→ The EU and Germany have successfully decoupled themselves from lower Russian natural gas supplies in the short term by importing **66 % more liquefied natural gas (LNG) into the EU** between 2021 and 2022 and reducing consumption.

→ In the long term, the import dependency on LNG will afflict the economy and society with new **inflation and energy price risks, geopolitical dependencies and growing transition and climate risks.**

→ The associated **risks for public finances** were made clear not least by the support programmes for the energy crisis in 2022.

→ These risks call for a **fundamental reassessment** of the long-term direction of German and European energy policy.

Seize opportunities. (→ to Chapter 2)

→ Prioritising independence from natural gas as a key component of a security-orientated energy policy has the **potential to reduce security, economic and climate risks** and to highlight an alternative beyond natural gas as a bridging technology.

→ Germany can benefit as a centre of innovation from a **leading role in key green technologies**, particularly in mechanical and plant engineering and heat pump technology.

→ If Germany succeeds in catching up with global trends in green technologies, business and politics can increase **domestic and European value creation** and create new jobs.

Proceed strategically. (→ to Chapter 4)

→ This analysis presents a strategy on how policymakers **can activate key players for private investment in Germany's natural gas independence following the cuts to the federal budget.**

→ Redirecting capital flows into natural gas-free technologies, estimated at 482 billion euros in the buildings sector and around 44 billion euros in industry, can reduce **dependence on natural gas by 64 % and pave the way for overall savings totalling almost 78 %.**

→ The main areas of focus are **the number of gas heating systems in buildings** (50 % of heating systems) and the use of natural gas in **industrial process heat** (80 % of industrial gas consumption).

→ **Market-ready, proven and clean technologies** are the basis for the electrification of industrial process heat and the substitution of natural gas as feedstock, the conversion of heating networks, the switch to natural gas-free heating technologies and the increase in the renovation rate.

Create enabling conditions...

→ **Reducing dependence on natural gas by up to 78 % will be achieved**by changing structural and economic framework conditions and strengthening feedback mechanisms between politics, business and society. We present **ten policy recommendations**that enable economically efficient and socially effective investment dynamics in the area of tension between short-term affordability, long-term competitiveness and social acceptance. By **matching the supply of and demand for capital**, they activate key players for private investment.

→ **Institutional players such as housing companies (19 % of residential buildings), energy service providers and municipal utilities are central to natural gas-free buildings, with the craft sector playing a cross-sectional role.** A scaling programme for heating contracting, an enabling package for the municipal heat transition and practice checks mobilise housing companies, energy service providers and municipal utilities to invest, create economies of scale and involve them in the further development of the legal framework. A Heating-for-all programme ensures access to a natural gas-free heating supply even for homeowners with poor credit ratings. A skilled labour campaign promotes the training of the necessary skilled workers. **Overall, this can reduce total natural gas consumption by 38 %, paving the way for a further 12 % in non-residential buildings.**

→ **In industry, 51 % of industrial natural gas consumption (13 % of total German demand) is used for process heat in the four sectors of food and tobacco, paper, stone and earth processing and basic chemicals, which can be electrified with 9.5 billion euros in plant investments.** To this end, an Industry-transition-accelerator-platform is mobilising pioneering companies, especially **small and medium-sized enterprises**, to lead the way in the electrification of process heat and create confidence in the change through experience. These pioneers show the way to effectively prevent transition and climate risks and inspire other companies.

→ **Banks are becoming companions of the transformation for corporate and private customers.** Focusing sustainable finance regulation on the transition enables them to use their expertise in risk management to identify transition risks and strengthen confidence in investments.

→ A commission for natural gas independence, targeted public funding and temporary green TLTROs have a **systemic effect** across the board.

...that overcome investment barriers.

Buildings sector (→ to Chapter 7.1)

1. The greatest natural gas savings potential and investment needs lie with private homeowners, while **municipal utilities face high concentrated costs**.
2. **Deteriorating credit conditions and bureaucratic obstacles are putting housing companies and institutional homeowners** under pressure. As a result, housing companies are investing less and less in modernisation (only 38 % of investment costs). At the same time, institutional homeowners own 19 % of residential buildings.
3. **Municipal utilities** must now develop new business models to compensate for sharp declines in revenue from the gas business and secure their future competitiveness. **25 % of the total turnover** of large municipal utilities comes from the gas business.
4. **High liabilities and limited access to subsidy/support programmes** reduce the potential for energy service providers to play a major role in accelerating natural gas independence.
5. **15–30 % of private residential building homeowners have problems accessing capital**, and there are also structural barriers to investment. 40 % of homeowners state that they cannot afford to invest.
6. Lack of utilisation of advisory and funding services coupled with an **aversion to long-term loans** inhibit private investment. In general, investments with amortisation periods of more than two years are only considered in one in three cases (27 %).
7. **Skilled labour gap could triple by 2026.** The craft sector faces major challenges in securing and mobilising skilled labour – further measures to mobilise skilled labour are necessary.

Industrial sector (→ to Chapter 7.2)

1. **Industrial plants have long lifetimes**, which is why the timing of (re)investments is crucial. Utilising investment windows according to the renewal cycles can avoid stranded assets.
2. Compared with investment needs in buildings and energy costs, investments in plants for natural gas-free process heat are low, but typically in the sector they require **rapid amortisation**.
3. Depending on the size, location and specific energy demands of companies, **the significance of economic or structural challenges** when replacing natural gas varies.
4. A large proportion of the total cost of ownership of green industrial plants is attributable to **operational expenditures**, with only a small proportion attributable to capital costs. However, **electrification is expected to result in negligible OpEx increases for individual technologies in the basic chemicals, food and tobacco industries.**

Financial sector (→ to Chapter 7.3)

1. Where **risks, lack of collateral and low revenues** slow down investments, reliable regulation, public financing and risk assumption enable the crowding-in of private capital.
2. In order to reduce **high transaction costs**, financing solutions that effectively bundle loans are needed.
3. In order for banks to identify and address transition risks, financing instruments must be based on **standardised and binding targets and ongoing impact analyses**.
4. A reliable **data basis** and clear classification of investments in natural gas independence in the context of the EU taxonomy support the flow of capital into economic structural change.
5. In contrast, an **incomplete EU taxonomy**that does not clearly cover the industry's investments in gas independence leads to uncertainty.

Implement measures. (→ to Chapter 8)

Our recommendations deliberately expand the range of measures and go beyond regulation, CO_2 prices and subsidies. They aim to create an investment environment that promotes trust. The following ten points initiate processes and feedback mechanisms that spark a dynamic that makes Germany's independence from natural gas achievable.

1. Commission for natural gas independence

(→ to the proposal)

Setup of an **expert commission to accelerate natural gas independence**. The aim is to identify a realistic path to natural gas independence that is compatible with the German government's climate targets and socially acceptable, and to develop proposals for the necessary regulatory adjustments and financing commitments.

2. Enabling package for the municipal heat transition (→ to the proposal)

Accelerating the implementation of municipal heat planning by strengthening the adaptability of legislation, establishing effective municipal coordination, empowering local actors and taking a synergetic view of planning, financing and implementation. Five pillars form the backbone of the enabling package: the provision of **municipal heat transition teams**, the organisation of dialogues at federal level, the initiation of exchange and learning programmes at state level, the hosting of **innovation clusters for municipal utilities** and energy suppliers, as well as the increase and dynamisation of the **Federal Grant Programme for Efficient District Heating Systems**.

3. Scaling programme for heating contracting

(→ to the proposal)

The scaling of heating contracting enables **efficient financing of energy-efficient renovations and heating system replacements as well as new business opportunities for municipal utilities**. Central to this is the establishment of (regional) **special purpose vehicles** to bundle loans and leasing offers, making it easier to invest in renewable heating technologies such as heat pumps and energy-efficient envelope renovation. The special purpose vehicles act as a link between energy service providers, municipal utilities and property homeowners, improve credit conditions and increase acceptance through participation opportunities for citizens. Additional instruments such as scaling premiums and insurance against electricity price fluctuations improve the cost-effectiveness and security of the model, thereby achieving wider implementation in the residential sector.

4. **Practice checks for the heat transition** (→ to the proposal)
This measure aims to accelerate energy-efficient envelope renovation, heating system replacement and energy services in the buildings sector by **identifying and removing bureaucratic obstacles**. Through **participatory conferences with key actors** from the housing industry and energy service providers, obstacles to practical implementation such as municipal requirements and technical building regulations are analysed. The **heat transition enabling package** derived from this includes legal adjustments to promote a targeted reduction in bureaucracy and establish a mutual learning process.

5. **Heating-for-all programme for vulnerable homeowners** (→ to the proposal)
The aim is to facilitate access to loans for low-income households with poor credit ratings. The programme works through a **governmental guarantee**, which intervenes in the event of loan defaults. Misuse is prevented by strict control mechanisms, such as the direct transfer of the loan amount to certified contractors and confirmation of acceptance by the homeowners.

6. **Skilled labour offensive for heat transition** (→ to the proposal)
A strategic initiative to recruit and **retrain skilled labour from sectors undergoing structural change and the collapsing construction industry** in order to close the gap in finishing trades such as HVAC and building electrics. This offensive scales up tried and tested retraining programmes such as Vaillant's and supplements them with the German government's heat pump development programme.

7. **Industry-transition-accelerator-platform** (→ to the proposal)
The platform promotes the **exchange of knowledge** between pioneering companies investing in natural gas-free technologies and followers in order to create investment momentum and at the same time enable regulatory learning. It **reduces the risk perception** of companies when investing in new technologies and increases profitability through targeted investment incentives. The platform supports large companies and **small and medium-sized enterprises** (SMEs) with transformation planning and offers incentive programmes and status benefits for participants. The platform simplifies access to capital by forming technology and industry clusters and involving public and private banks.

8. **Aligning sustainable finance with transition** (→ to the proposal)
Changes to sustainable finance regulation can support the channelling of investments into natural gas-free technologies. Proposed changes include the **expansion of the EU taxonomy** to include additional sectors and electrification activities, the development of uniform and binding standards for transition plans for the risk assessment of transformation projects and an expansion of the Corporate Sustainability Reporting Directive (CSRD) to include more companies and harmonise their reporting obligations. This approach is intended to facilitate the **assessment of transition risks by financial companies** and improve the transparency and comparability of corporate investments.

9. **Targeted public funding** (→ to the proposal)
Targeted public funding enables private investment in Germany's independence from natural gas in areas that are not profitable in the short to medium term, but are necessary in the long term. The **estimated additional funding requirement of at least three billion euros** per year until 2030 covers areas such as heating networks, electrification in industry, the training of skilled labour and the Heating-for-all programme. Various options for closing this funding gap include reforms to the debt brake, modernising the expenditure side, introducing new sources of revenue such as increased CO_2 prices and inheritance tax, as well as closing tax loopholes.

10. **Interest rate advantages for investments in natural gas independence** (→ to the proposal)
A temporary green Targeted longer-term refinancing operations (TLTROs) programme of the ECB would provide **interest rate advantages for loans for EU taxonomy-aligned investments** to reduce the capital costs of investments in gas independence until transition risks are adequately reflected in financial markets. This temporary programme would **correct market failures** and thus enable long-term financial stability and a reduction in transition risks. In line with the ECB's mandate, the programme contributes to price stability and the EU's climate targets.

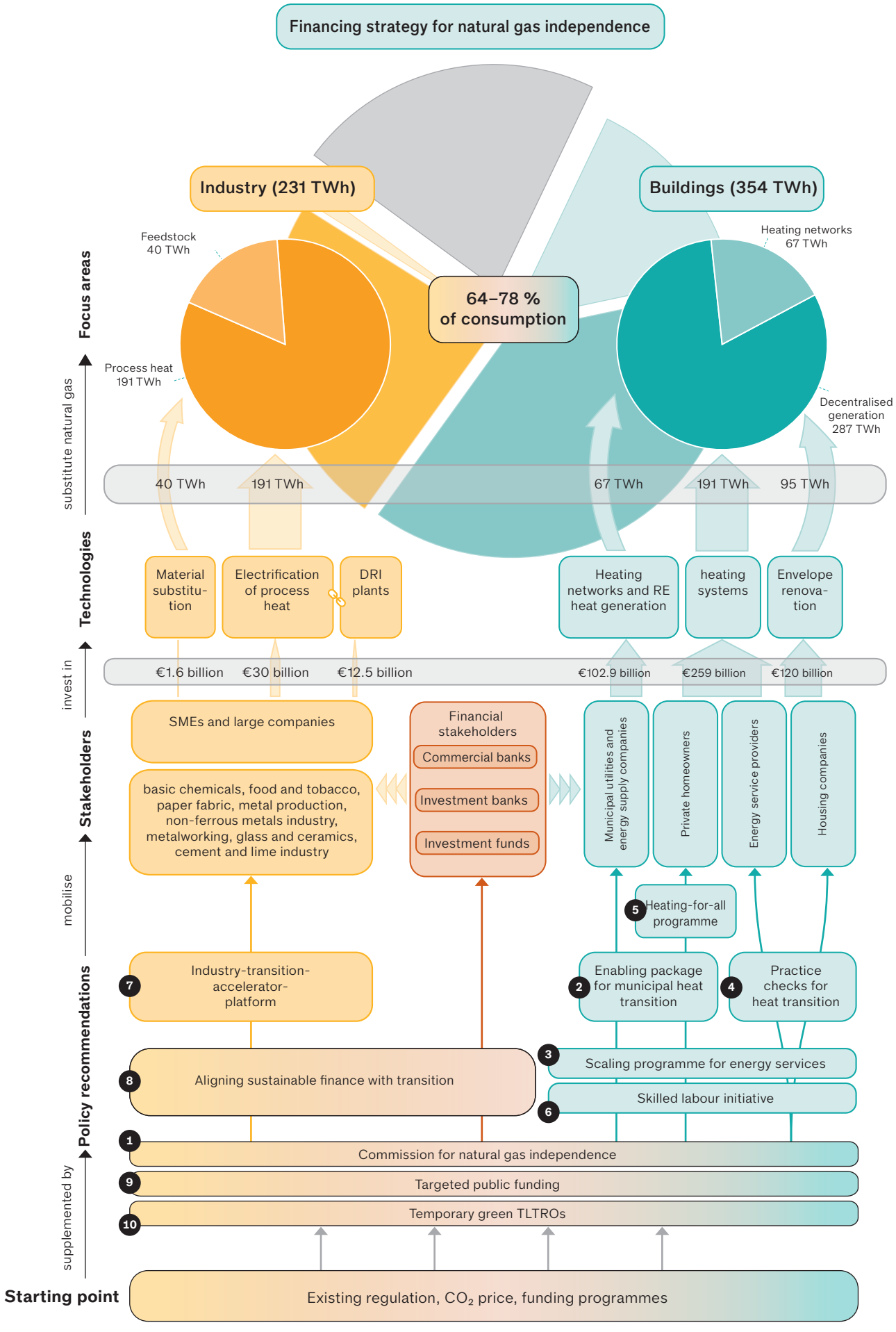


Figure 0.1: Financing strategy for natural gas independence – overview of stakeholders, policy recommendations, technologies and focus areas including investment volumes and natural gas reduction potential.

1. Introduction: Natural gas in the geopolitical age

The Russian war of aggression has heralded a geopolitical turning point. This turning point has an impact on security and foreign policy, but also requires a fundamental reorientation of energy policy that draws conclusions from the crisis and reduces energy dependencies. However, we are a long way from this reorientation.

The EU and Germany have successfully decoupled themselves from lower pipeline-bound Russian natural gas supplies by importing 66 % more liquefied natural gas (LNG) into the EU between 2021 and 2022 and reducing consumption. This was important in the short term to cushion the economic and social impact of the energy crisis. In the long term, however, the new import dependencies not only expose the economy and society to transition and climate risks, but also to potential global energy price shocks, new inflation risks and geopolitical dependencies. The associated risks for public finances were made clear not least by the support programmes for the energy crisis in 2022. This means that natural gas is no longer just a climate policy issue, but a security and economic policy risk that requires a decisive response.

This report presents a strategy on how Germany can tackle these risks and achieve a comprehensive mobilisation of private investment for natural gas substitution. We illuminate:

→ **where** consumption can be reduced,

→ **which** technologies are relevant,

→ **how much** capital is required,

→ **who** must be mobilised for these investments and

→ **how** this mobilisation is to be achieved.

The growing consensus that Germany can be an economic powerhouse even with less natural gas underlines the support for the transformation.

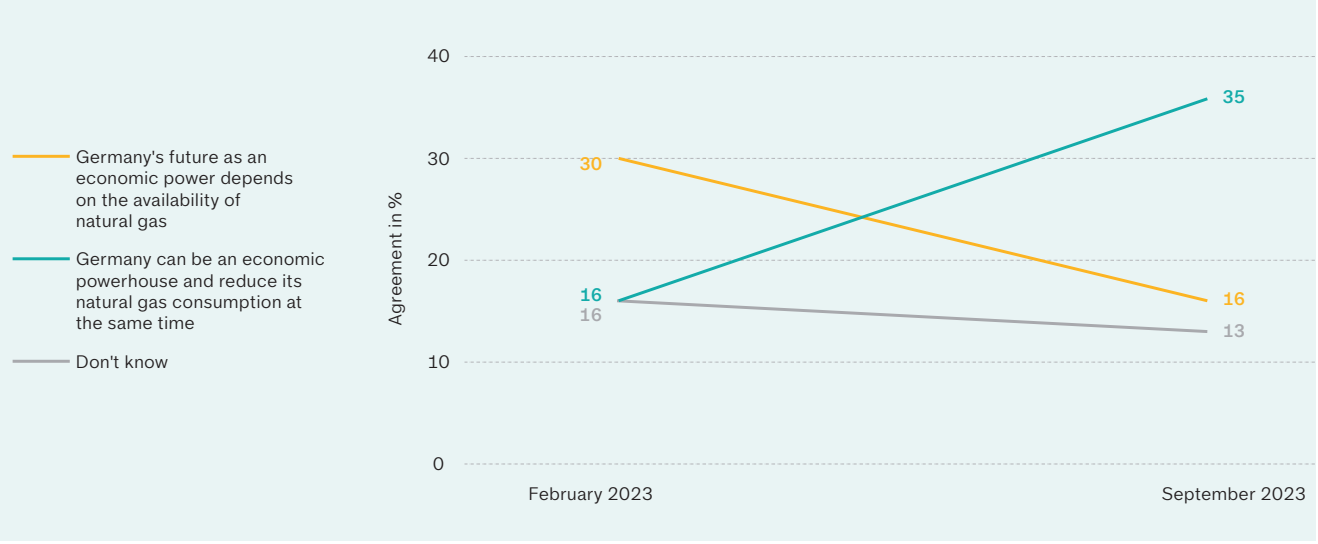


Figure 1.1: Survey on attitudes to energy and climate – agreement with the statements that Germany's future as an economic power depends on natural gas and whether a reduction in natural gas as an economic powerhouse is possible. Global tracker survey on attitudes towards climate and energy with nationally representative samples (n = 1000) (TGM Research, 2023).

We derive ten policy recommendations on how private capital can be mobilised for investment from the interaction between housing companies and homeowners, energy service providers and municipal utilities, SMEs and commercial banks, industrial companies and investment banks (Chapters 7 & 8). In both industry and the heat supply sector, we identify options that can achieve substantial savings in natural gas with relatively little effort.

With this report we want to move from last year's heated legislative debates to constructive implementation, objectify the discussion and create trust in the transformation process. In Germany alone the natural gas solution affects 550,000 km of gas pipelines, 21,000 km of heating networks and the municipal utilities and energy supply companies that operate them. Over 20 million homes and their homeowners as well as thousands of small and medium-sized companies and large-scale industry are in demand. An accelerated investment and implementation dynamic will only succeed if politics, business and society do not transcend into fear and rigidity in the face of these figures, but instead recognise the potential of forward-looking change and make targeted use of it.

By prioritising independence from natural gas, Germany has the opportunity to take on a global pioneering role in the field of sustainable key technologies. If the country plays to its strengths as a centre of innovation and industry, it can tap into new value creation potential, secure existing jobs and create additional employment opportunities. German companies already lead the world with the most patents in heat pump technology. The same applies to plant and mechanical engineering, which will play a key role in the electrification of industrial processes (Chapter 2).

In view of the worsening geopolitical situation, increasing competition for the technologies of the future and accelerating climate change, we need to act quickly. Politicians must act now to create the necessary framework conditions for natural gas independence, enable iteration and joint learning, ensure planning and expectation security for society and the economy and thus strengthen the resilience and competitiveness of Germany as an industrial location. The following chapters outline specific action steps for this path.

2. Motivation: Initiating the natural gas turnaround

Germany is facing the opportunity of an energy policy turnaround, which has broad public support (see Figure 2.3). Independence from natural gas is not only an energy policy response to a new geopolitical reality, but also harbours great potential for domestic value creation and technology leadership:

- → Germany can avoid potential **energy price increases, geopolitical dependencies and climate and transition risks** by reducing its dependence on natural gas.
- → Natural gas independence opens up new markets **and value creation potential in green technologies, especially in engineering, heat pump production and the craft sector.**
- → By prioritising natural gas independence, Germany can **harness its strengths as a knowledge economy and an innovation centre.**

Most of the technologies for the changeover are ready for the market, but are often not yet competitive under the current framework conditions. A coordinated effort by politics, business and society is therefore needed to generate an effective investment dynamic.

Short turnaround through substitution and savings

The year 2022 ushered in a geopolitical turning point. Russia's war of aggression against Ukraine and the halt in Russian gas supplies caused gas prices to rise by up to 250 % in 2022 compared to 2021 (Statista, 2022). The impending supply shortage (BMWK, 2022b) and inflation of up to 7.9 % associated with the supply shock led to drastic increases in the cost of living (Destatis, 2023a). The combination of the slump in demand, rising energy costs and interest rates in turn threatened the solvency of numerous German companies and became a stress test for the resilience of the German economy (CRIF, 2022).

Two strategies have succeeded in cushioning the impact of the energy crisis in the short term.

On the one hand natural gas consumption fell by 14 % compared to the average of the three previous years (2018–2021). Industry (15 %) as well as private households and commerce (14 %) (Federal Network Agency, 2022) managed to significantly reduce their consumption (Figure 2.1). For the energy-intensive industry in particular, this was also achieved through declines in production (BDI, 2023). Further reductions were agreed by the European regulation (2022/1369) as coordinated measures to reduce gas demand in the EU by 15 %.

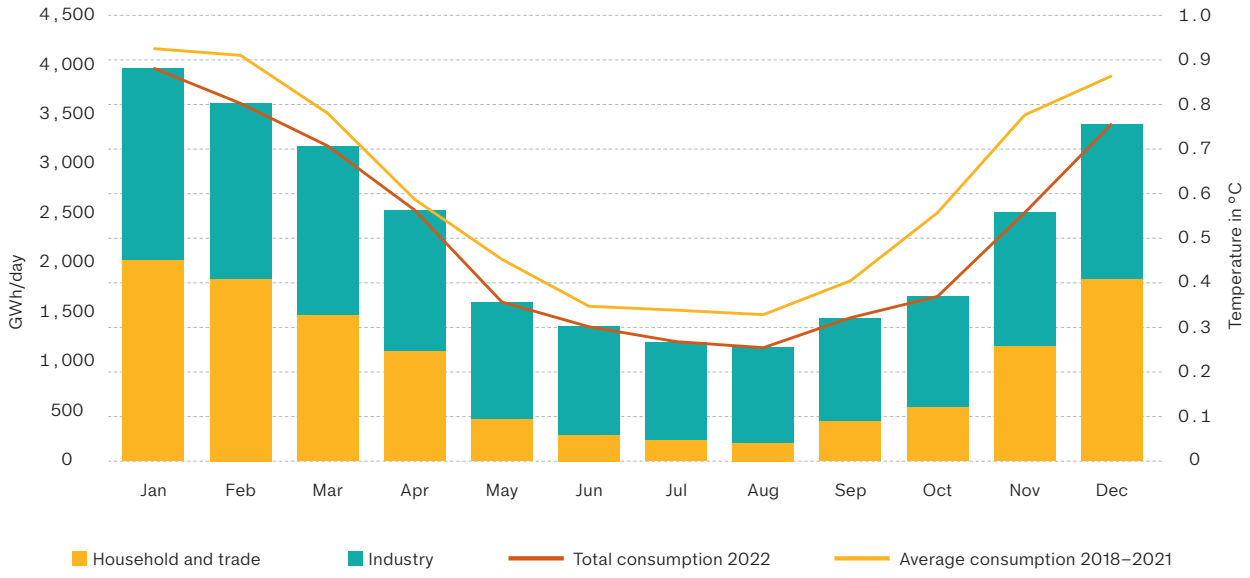


Figure 2.1: Gas consumption in Germany (monthly average) 2023 compared to 2022 and the average consumption 2018–2021 (Federal Network Agency, 2023c).

"The increase in LNG imports by 66 % substitutes Russian natural gas."

Secondly, the increase in European liquefied natural gas (LNG) imports by 66 % (between 2021 and 2022) (Figure 2.2) (vbw, 2023) was able to compensate for Russian imports to a considerable extent in the short term. In the same period Germany was able to reduce its dependence on Russia by increasing imports from Belgium, the Netherlands (both of which use LNG to a large extent) and Norway, raising the share from 28 % to 85 %. In addition, its own LNG import capacities have also been utilised since Q4 2022 (5 % of imports).

Will the long-term turnaround fail to materialise?

However, these short-term successes should not obscure the fact that the energy crisis calls for a fundamental reassessment of German and European energy policy and raises questions about its long-term direction. 83 % agree that Germany should replace natural gas with renewable energies as quickly as possible in order to be less dependent on Russian supplies. At the same time a large majority is in favour of reducing dependency on oil and gas imports from other countries by expanding solar and wind energy.

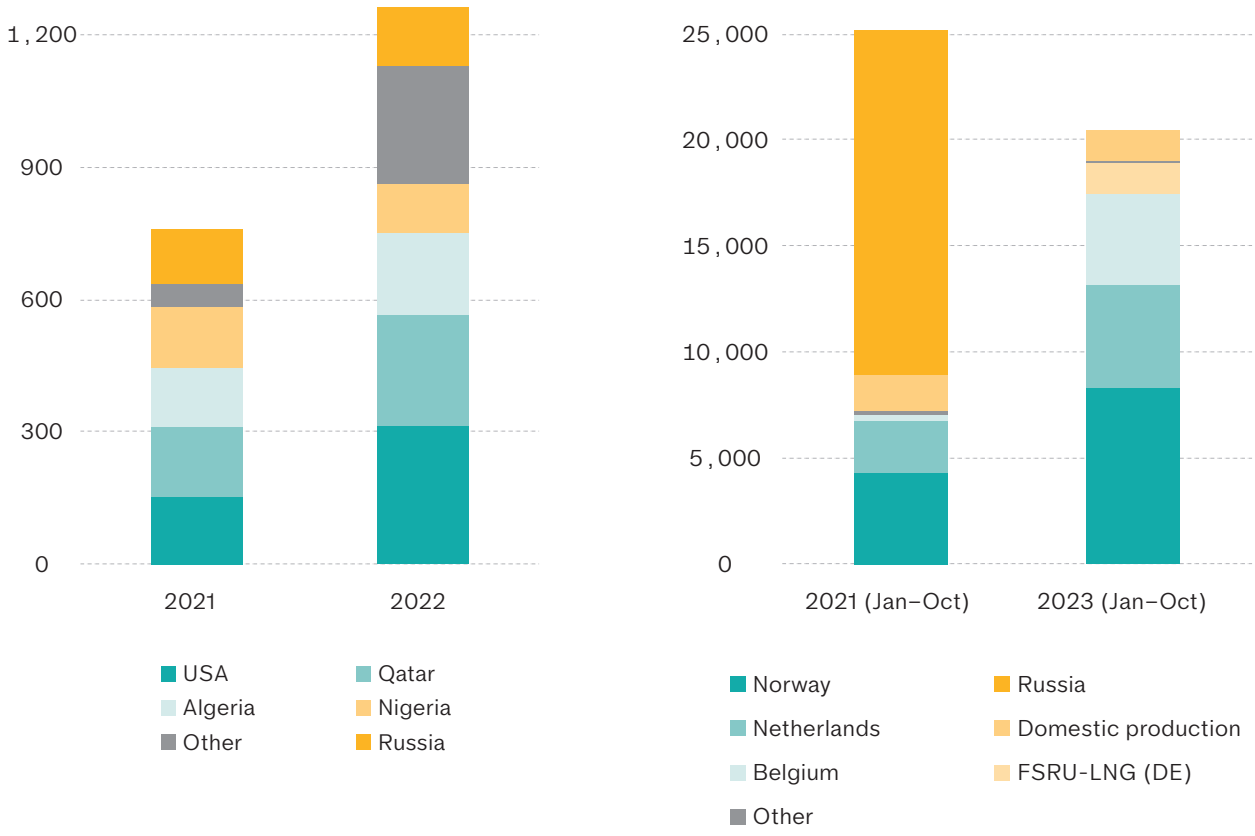


Figure 2.2: LNG imports of the EU-27 (left) and Germany's gas import structure (right) before and after the Russian war of aggression (Federal Network Agency, 2023c, 2023b; vbw, 2023).

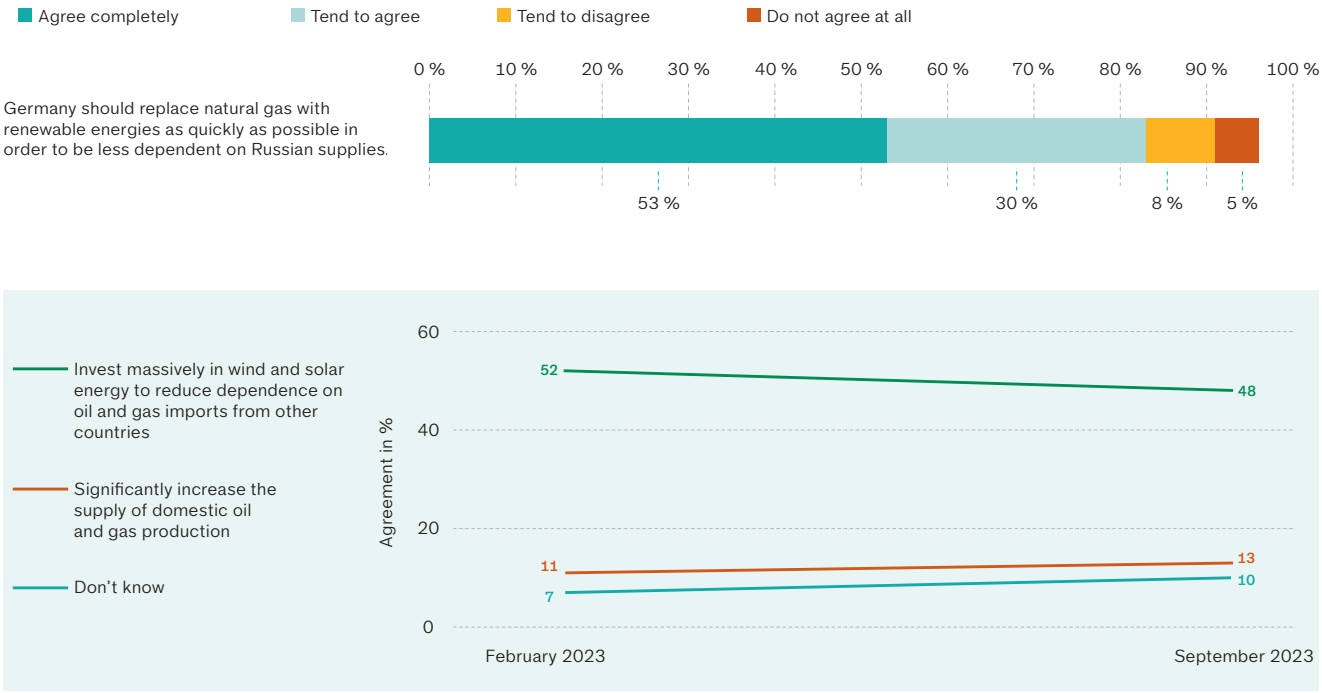


Figure 2.3: Survey on attitudes to energy and climate; top: Should Germany replace natural gas with renewable energies; bottom: Agreement values on the question of what Germany should do to reduce its dependence on oil and gas imports from other countries. Global tracker survey on attitudes towards climate and energy with nationally representative samples (n = 1000) (TGM Research, 2023).

By contrast, the early months of the turnaround seem almost forgotten in 2023, even if the alert level of the gas emergency plan remains in place. Gas storage facilities are well filled and current forecasts assume that there will be no gas shortage (Federal Network Agency, 2023a). The economic situation remains tense, especially for energy-intensive companies, but a recession has not materialised (German Council of Economic Experts, 2023). Instead, inflation in Germany is continuing its downward trend and was at 3.2 % in November 2023 (Statista, 2023a) and close to the price stability target in the EU (Eurostat, 2023a) at 2.4 %.

Against this backdrop, however, a long-term response to the energy crisis in Germany has thus far failed to materialise beyond the expansion of solar and wind power generation. Although the amendment to the Building Energy Act is aimed at the installation of natural gas-free heating systems such as heat pumps, it was primarily discussed in terms of climate policy without any particular consideration of geopolitical and energy policy issues.

In contrast, with REPowerEU the EU has accelerated the expansion of renewable energies and natural gas-free technologies such as heat pumps from the outset and focused on the long-term reduction of dependency on natural gas imports and Europe's strategic autonomy. In Germany, on the other hand, the continued high level of investment in natural gas-fuelled heating systems is perpetuating the country's dependence on natural gas (BDH, 2023b), which is also due to the potential overcapacity of the LNG infrastructure (DIW Berlin, 2023) and long-term supply contracts with German energy suppliers (Dezernat Zukunft & Agora Energiewende, 2023).

Current developments are exposing the German economy to future inflation risks, geopolitical dependencies and increasing transformation and climate risks. These challenges can be mitigated by prioritising independence from natural gas.

1. Inflation risks due to price volatility of LNG

Similar to the two oil price crises in the 1980s, the energy price shock triggered an inflationary dynamic.[1] The increasing dependence on imported LNG (40 % of all EU gas imports) continues this risk into the future (Figure 2.2). The most important countries of origin of LNG are the USA, Qatar and Nigeria, but also Russia. This exposes the EU to volatile price developments on the global LNG market (Baselli, 2023). In contrast to a large proportion of direct deliveries via pipelines, LNG prices are formed globally and are largely determined by demand from Asia. In September 2023, for example, this rose by 11 % compared to the same period of the previous year (China, India, Japan, Thailand). In combination with strikes in Australia during the same period, this led to extreme intra-day price jumps (Fitch Ratings, 2023).

"LNG accounts for 40 % of EU gas imports and increases vulnerability to external price shocks."

In the EU there are hardly any long-term contracts with more stable prices for the increased LNG imports – for many EU countries, LNG was a quick substitute for Russian natural gas. As a result the EU countries have to cover a large part of their demand via the LNG spot market, which is more volatile and characterised by high price peaks during periods of shortage (WPKS, 2023a). Flexible contracts avoid long-term purchase commitments, up to 20 years, which would not be compatible with European climate targets.

"Exposure to LNG price shocks poses a risk to public debt."

As 2022 showed, price shocks are cushioned by public support programmes and therefore have a direct impact on public budgets and debt. The UK is a good example of this, with a comparable import dependency on LNG (40 %). According to calculations by the Office for Budget Responsibility, the effects in a scenario of three price shocks by 2050 would increase the debt ratio by 13 % compared to the reference scenario (OBR, 2023).

2. Persistent geopolitical dependencies

With its high dependence on natural gas, Germany is vulnerable to geopolitical tensions and conflicts in natural gas-producing countries or transit countries. Europe is still dependent on Russia via Ukraine and the TurkStream pipeline as well as via LNG (13 %). If Russian natural gas were to be stopped in combination with very cold temperatures, security of supply would be jeopardised. Gas storage facilities would be almost completely empty over the winter and may no longer be able to achieve the target of 90 % utilisation (EWI, 2023). In addition, Germany is exposing itself to new political dependencies through contracts with Qatar.

Global impact of German LNG imports

Germany's and the EU's dependence on LNG imports and the resulting long-term contracts are driving the global expansion of natural gas production (Dezernat Zukunft & Agora Energiewende, 2023). This not only has an impact on energy security and geopolitical aspects, but also significantly contributes to exacerbating global inequalities and environmental crises (McCauley, 2018; UCLA IoES, 2020).

In many cases funding is provided in regions with sensitive ecosystems and vulnerable population groups. At the same time, natural gas extraction reinforces existing socio-economic inequalities. The extensive acquisition of land for natural gas projects often leads to land rights conflicts that affect indigenous peoples particularly severely. These groups depend on their traditional land for their livelihood and their cultural identity. They often face evictions and the loss of their ancestral land without receiving adequate compensation or legal recourse. The fact that they are not involved in decision-making processes further exacerbates this problem.

The environmental impacts of gas extraction – including water pollution, air pollution and habitat destruction – additionally pose a significant threat to both local ecosystems and global climate goals.

1 Experts have long debated the link between energy prices and inflation. It seems indisputable that there is a strong correlation for the current energy crisis (European Central Bank, 2023). Demand shocks in combination with limited short-term production capacities have led to high energy prices. The increase in EU demand for LNG and the associated price rises fit into this picture. Consumption and investments react particularly sensitively to energy price increases – up to four times higher than their pure cost contribution (Kilian, 2008).

3. Increasing climate and transition risks

Natural gas was long regarded as a bridging technology for a climate-neutral Germany. The reason for this was the lower emissions intensity in combination with cheap Russian natural gas, which is why projects such as Nord Stream 1 and 2 were deliberately pushed forward by the German government in the face of opposition from the EU (Karnitschnig, 2021). This dependency delayed the decarbonisation of the German economy. Transition risks increased due to demand shocks, stranded assets and higher prices for the externalisation of environmental costs (CO_2 prices) (Bundesbank, 2021). While only quantifiable effects of these risks on the financial sector were assessed for Germany, estimates of fiscal transition risks are also available for the UK: the Office for Budgetary Responsibility estimates the increase in the debt ratio due to delayed decarbonisation at 10–100 % of GDP by 2050 (OBR, 2023).

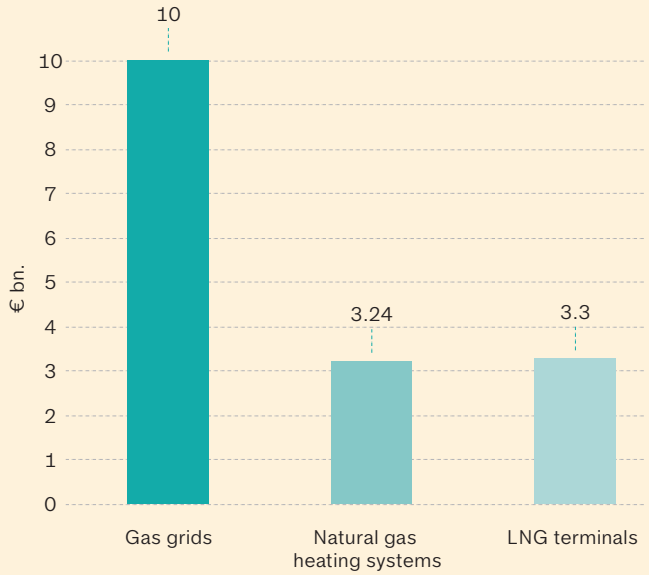


Figure 2.4: Possible stranded assets due to a delayed and unreliable path to natural gas independence (Agora Energiewende, 2023; WPKS, 2023b).

Transition risks from the delay in the transformation

In addition to fiscal risks, two other transition risks can be identified if the substitution of natural gas is delayed.

High certificate costs from emissions trading

An increasing reflection of environmental costs in the use of natural gas through rising emission prices has an impact on the operating costs of heat generation, both for households and companies. There is a risk that these costs will overstretch the financial scope in the medium term and that the state will have to step in. Studies show that a CO_2 price of 275 euros per tonne of CO_2 leads to a heavy net burden of over 40 % of households, even with full reimbursement through a climate fee (Endres, 2023). High net costs are primarily borne by people with high incomes and broad sections of the middle income distribution, as well as predominantly people in rural areas and homeowners.

Stranded assets

Stranded assets are the result of investing too long in gas infrastructure, networks or natural gas-powered technologies (see Figure 2.4). Agora Energiewende (2023) puts this risk at up to 10 billion euros for gas distribution grids. For the LNG terminal capacities built in Germany since 2022 in the form of floating regasification units (FSRUs) and fixed import terminals, there will be a lack of refinancing income due to the falling demand for natural gas, leaving stranded assets totalling 3.3 billion euros (WPKS, 2023). If 650,000 fossil fuel heating systems continue to be installed each year from 2024, as in 2022, until 30 June 2026 (BDH, 2023a), the date from which the GEG will take effect, 1.62 million households risk having to replace their fossil fuel heating systems early if they do not meet the quotas for renewable energy supply. The total volume of stranded assets would amount to an estimated 3.24 billion euros if they were to replace their heating systems ten years before the end of their technically possible service life.[2] For households that are still connected to the gas distribution grid, the falling number of gas customers and the resulting lower demand for gas means a significant increase, up to a quadrupling of the specific grid fees by 2044 (Becker Büttner Held, 2023).

2 Assumption of the costs of a natural gas heating system of 6,000 euros, amortised over 15 years at 400 euros per year; premature replacement with a heat pump or other solution after ten years results in 2,000 euros in stranded assets per household.

Natural gas independence as an economic opportunity

The three risk vectors emphasise the need for a fundamental turnaround in energy policy that goes beyond the measures of import substitution and the reduction of energy consumption. A strategic re-orientation towards independence from natural gas can unleash considerable potential for domestic value creation and the European economy. If Germany sets the right priorities, it can take a leading role in the race for key green technologies and position itself at the top.

The exponential success curves of key green technologies such as photovoltaic modules, electric vehicles, wind turbines and heat pumps (see Figure 2.5) show that this race has long since begun. Markets and production capacities are developing rapidly, driven by political support, ambitious corporate strategies and rising consumer demand. These trends are also reflected in the high growth in production capacities, as Figure 2.6 illustrates.

"Investment in heat pump start-ups in the EU increased by 630 %."

The EU plays an important role in this context. For example, investment in heat pump start-ups in the EU rose from 11 million euros in 2021 to almost 70 million euros in 2022 – an increase of 630 % compared to 151 % in other countries (Lyons et al., 2023). As in the past with solar and wind, this development promotes economies of scale and price reductions, making alternatives to natural gas increasingly competitive and globally available.

Is Germany seizing its opportunity?

Germany has thus far had only limited success in jumping on these trends at an early stage and tapping into their value creation potential. This can be seen, for example, in the solar and automotive industries. And this pattern threatens to repeat itself with natural gas independence technologies.

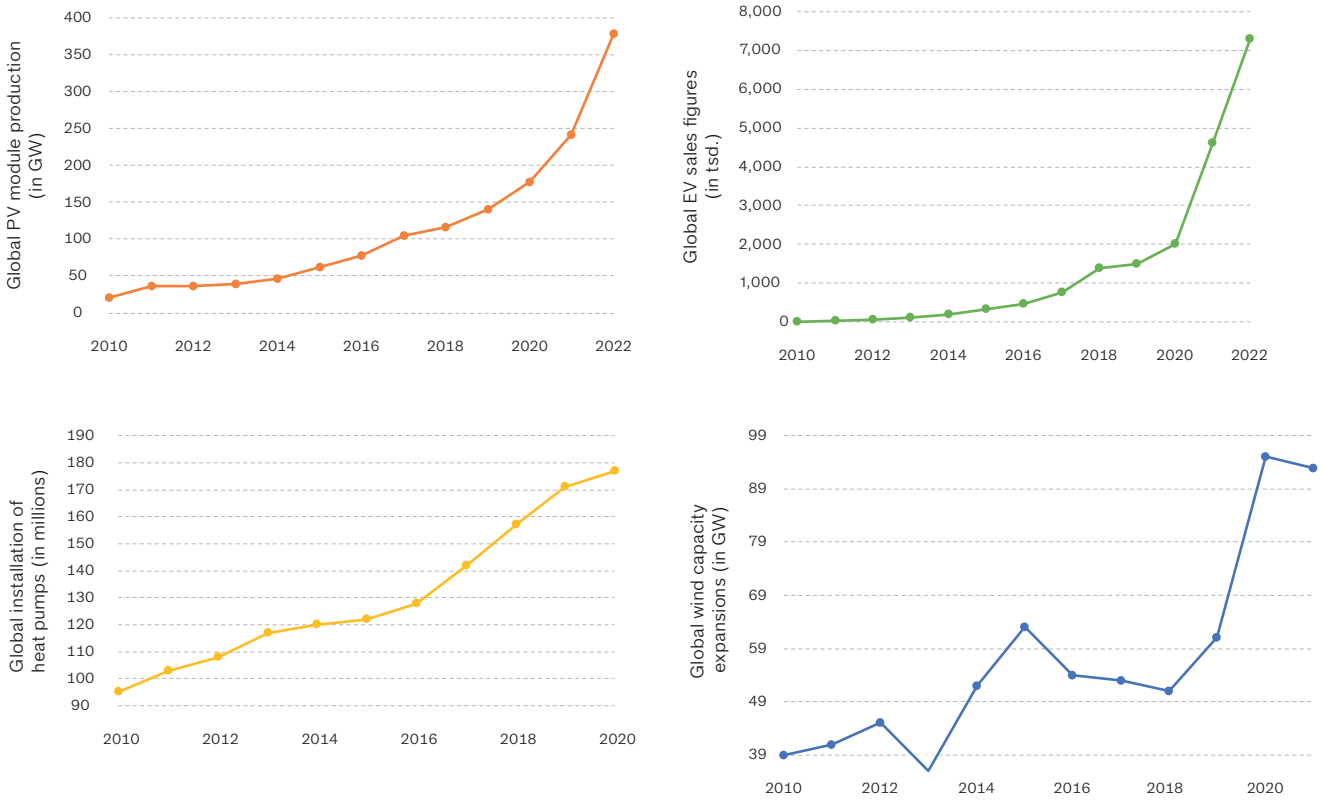


Figure 2.5: Development of production, sales and installation figures for selected key technologies (IEA, 2022, 2023b; IEA PVPS, 2023; Statista, 2023b).

While the German solar industry still had a turnover of 13.2 billion euros in 2011, this had fallen to 4.4 billion euros by 2022, as Figure 2.7 shows. This trend can also be seen in the employment figures. In 2012, the industry employed 120,000 people; by 2022, this figure had fallen to just 55,000 (BSW-Solar, 2023). Meanwhile, global production capacity for photovoltaics (PV) increased by more than 40 % to almost 640 GW in 2022, as Figure 2.5 shows, with China responsible for over 90 % of the new production capacity compared to 2021 (IEA, 2023a).

German manufacturers have also lost market share in the automotive industry, as Figure 2.8 shows. This is particularly due to the increasing importance of electromobility. According to the German Association of the Automotive Industry (VDA), German car manufacturers sold 4.4 million cars in China last year, which corresponds to a market share of 19.1 %. However, the market share in the rapidly growing electric drives business was only 5 % (Automobilwoche, 2023).

Heat pump production had until recently managed to develop a strong growth dynamic. However, there were signs of a trend reversal in the last quarter, as can be seen in Figure 2.9 (left) – this is in contrast to the ambitious targets of installing one million heat pumps per year by 2030, as shown in the figure above right. One reason for this is the lack of domestic demand. In terms of installations, Germany ranks third to last in Europe with 6.7 devices sold per thousand households (bottom right). Norway, on the other hand, tops the list with almost ten times the volume.

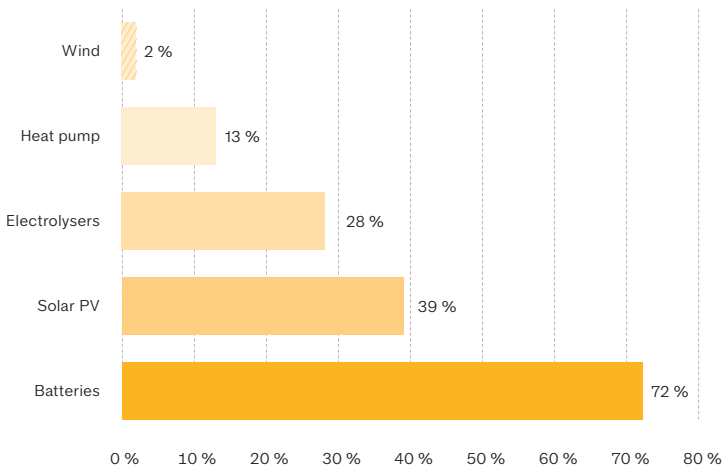


Figure 2.6: Growth in global installed production capacities for green technologies (2022) (IEA, 2023a).

Heat pump roll-out in Poland

In 2022, sales of heat pumps in Poland increased by a total of 120 % compared to 2021, while Germany only showed growth of 53 %. In total, more than 200,000 units were sold in Poland. Heat pumps will account for around 30 % of heating appliances sold on the Polish market in 2022. Taking into account the air conditioning systems with heating function sold, it was already almost every second heating appliance sold (EHPA, 2023). This trend is driven by a broad investment dynamic: a quarter of Bosch's investment of 1 billion euros by 2030 will be invested in Poland (Buchenau, 2023). Viessmann and Daikin are investing 200 million euros and 300 million euros respectively in heat pump plants in Poland (Daikin, 2022; Hoffmeister, 2022).

After the Building Energy Act and the budget crisis: Prioritise economic strengths

Economic policy should respond to these trends with foresight and aim to create investment momentum. Debates about the Building Energy Act, economic weakness and possible budget cuts harbour the danger that the public debate will focus on the weaknesses of the German economy and forget the strengths.

Until recently the global momentum was also reflected in investments in technologies to replace natural gas in Germany – in addition to heat pump production, this also affected green plant engineering and green steel production. Despite the tense economic situation, numerous German companies announced investments. They were responding to an increasingly reliable investment environment thanks to climate protection contracts and investment subsidies.

The substitution of natural gas in industry primarily requires the replacement of systems and the adaptation of machinery. Germany is a global leader in this field. The mechanical and plant engineering sector employs one million people (BMWK, n. d.). The industry has an outstanding innovation performance and international competitiveness. It is ideally positioned to complete the conversion of industrial plants (Agora Energiewende, 2020). This can also be seen in the example of green steel. The German SMS Group is the world's leading plant manufacturer and owner of the licence agreement for the design of the Midrex technology for the direct reduction of steel (SMS group, 2021) – one of only two currently commercially available technologies that Thyssen also uses for its new plants (thyssenkrupp, 2023).

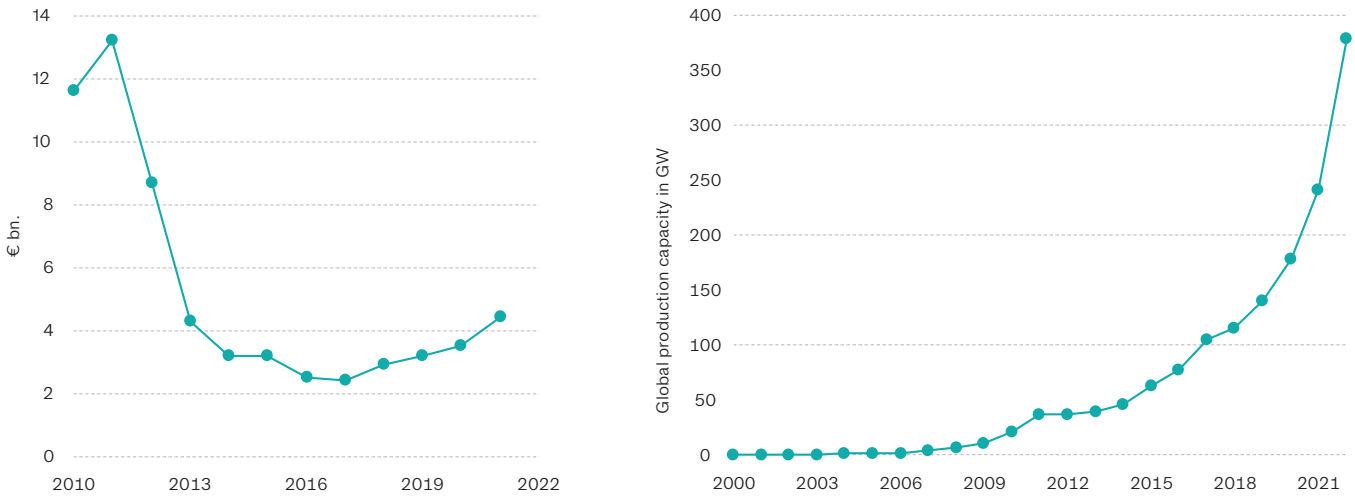


Figure 2.7: Turnover of the German solar industry (left) compared to global production of PV modules (right) (Destatis, 2022; IEA, 2023a; IEA PVPS, 2023; Statista, 2023a).

The same applies to natural gas-free technologies in the buildings sector. Germany is at the forefront of heat pump innovation leading to valuable patents, far ahead of Japan and Korea in second and third place (Figure 2.10) (Lyons et al., 2023). The country thus makes a significant contribution to the leading role of the EU, which accounts for 45 % of global inventions for heat pumps (Toleikyte et al., 2023).

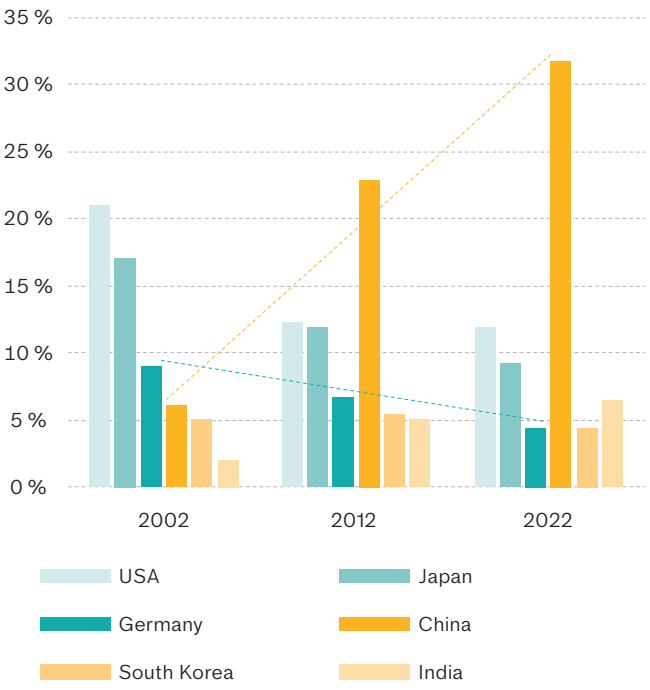
Neither low prices nor taxes are the strength of the German economy (Figure 2.11). Rather, the knowledge economy and innovative strength enable a strong domestic economy and high productivity, as the Competitiveness Index emphasises (IMD, 2023). They are the result of training a skilled workforce and a globally leading scientific infrastructure.

The Complexity Index, a measure of the knowledge intensity of an economy, emphasises this potential. Germany has ranked in the global top 10 for years, far ahead of China and the USA (Figure 2.12) (OEC, 2021). The index describes the competitiveness and innovation potential of a country better than comparable analyses of competitiveness, which are narrowed down to price competition (Graebner & Hafele, 2020).

Dynamism and innovative strength of the European heat pump industry

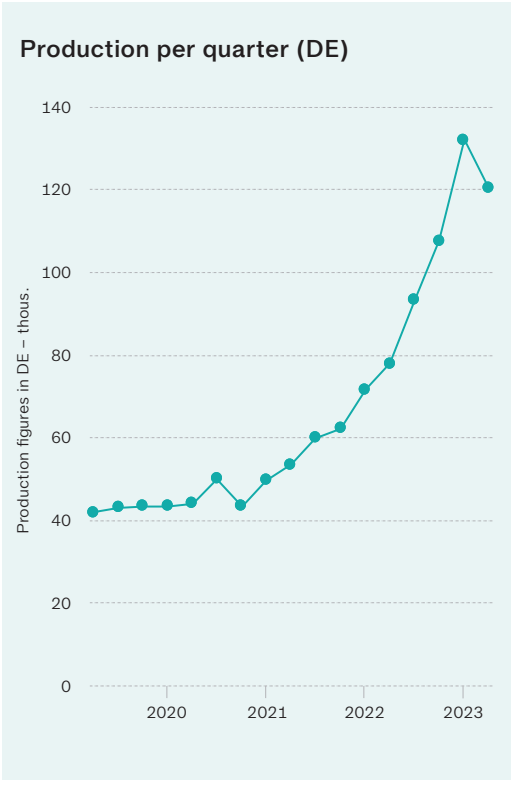
With its innovative strength in heat pumps, Germany is part of a well-positioned European innovation system. Recently published studies by the European Joint Research Centre confirm the strong positioning of the European heat pump industry (Toleikyte et al., 2023). 41 % of innovating companies are based in Europe (Lyons et al., 2023). As a result, the EU is the world market leader in heat pump innovations. While only 3 % of innovations are considered ‘valuable‘ in China, this figure is over 60 % in Europe.

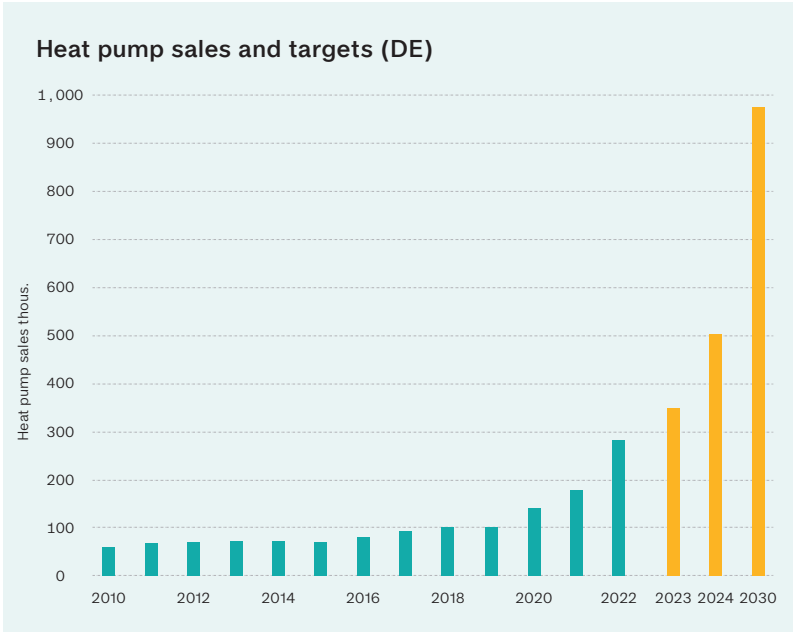
According to estimates, the heat pump sector for heating employed around 100,000 people in 2020 and has seen a significant increase in jobs since 2017 (Toleikyte et al., 2023). The EU sector consists of many small and medium-sized enterprises (SMEs) and some larger manufacturers. However, no single company dominates the entire market. There are around 170 heat pump factories in Europe, most of which only assemble and do not also manufacture components. There are around 130 heat pump installation companies and as many as 15 component suppliers. A number of consolidations have recently taken place: Midea (China) acquired a majority stake in the Italian Clivet Group, Stiebel Eltron (DE) took over Danfoss Varmepumpar (DK), Hisense (China) acquired Gorenje (SI), and Nibe (SE) took over Waterkotte (DE) (Toleikyte et al., 2023).



In the following chapters we present a strategy for successfully shaping the path to natural gas independence. The main aim of this strategy is to reduce the risks of inflation, transition and climate change, while at the same time capitalising on the economic opportunities offered by the move away from natural gas. If politics, business and society set the right priorities, it will be possible to create an investment dynamic in which private investment, public funding and a regulatory framework consisting of CO_2 prices and regulatory policy are effectively interlinked.

Figure 2.8: *Market share of German manufacturers in in global automotive production (OICA, 2022).*





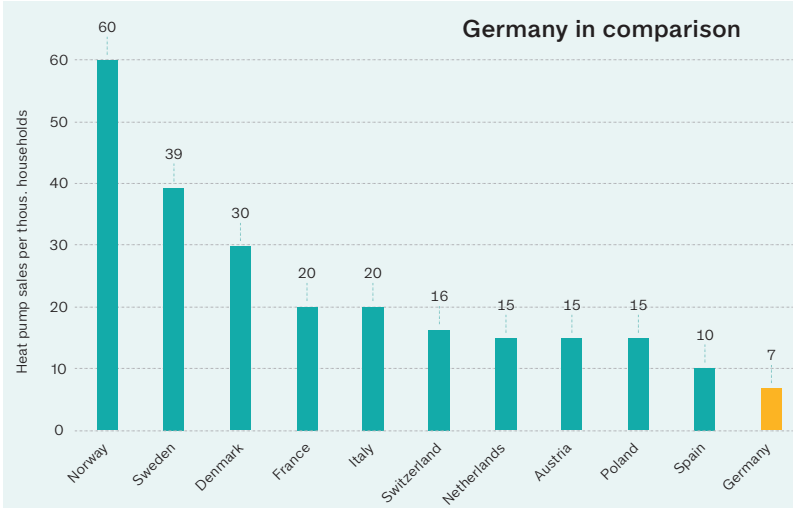


Figure 2.9: *Production figures for Germany in tsd. units (left); heat pump sales in Germany from 2010–2022 and targets (orange) until 2030 (right, top), heat pump sales in Europe in 2022 (right, bottom). (BMWK, 2023o; BWP, 2023a; Destatis, 2023c).*

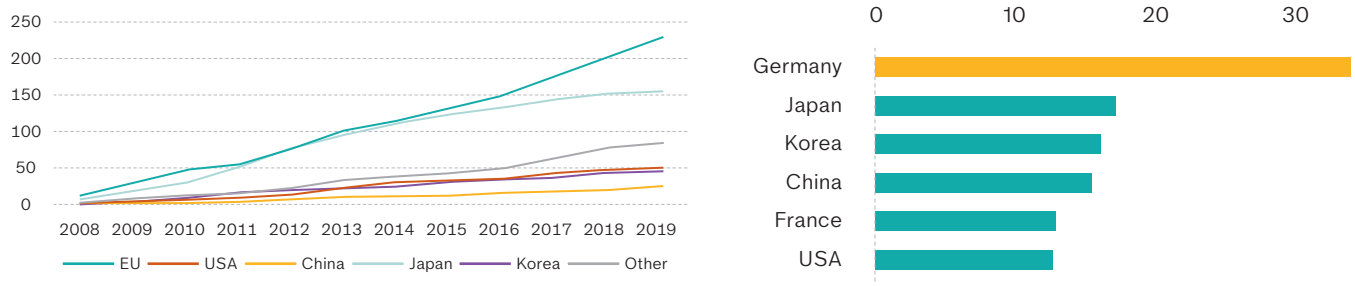


Figure 2.10: Cumulative number of valuable patents for heat pumps in a global comparison (left) (Toleikyte et al., 2023), top 6 countries with valuable inventions in the field of heat pumps between 2018 and 2020 (right) (Lyons et al., 2023).

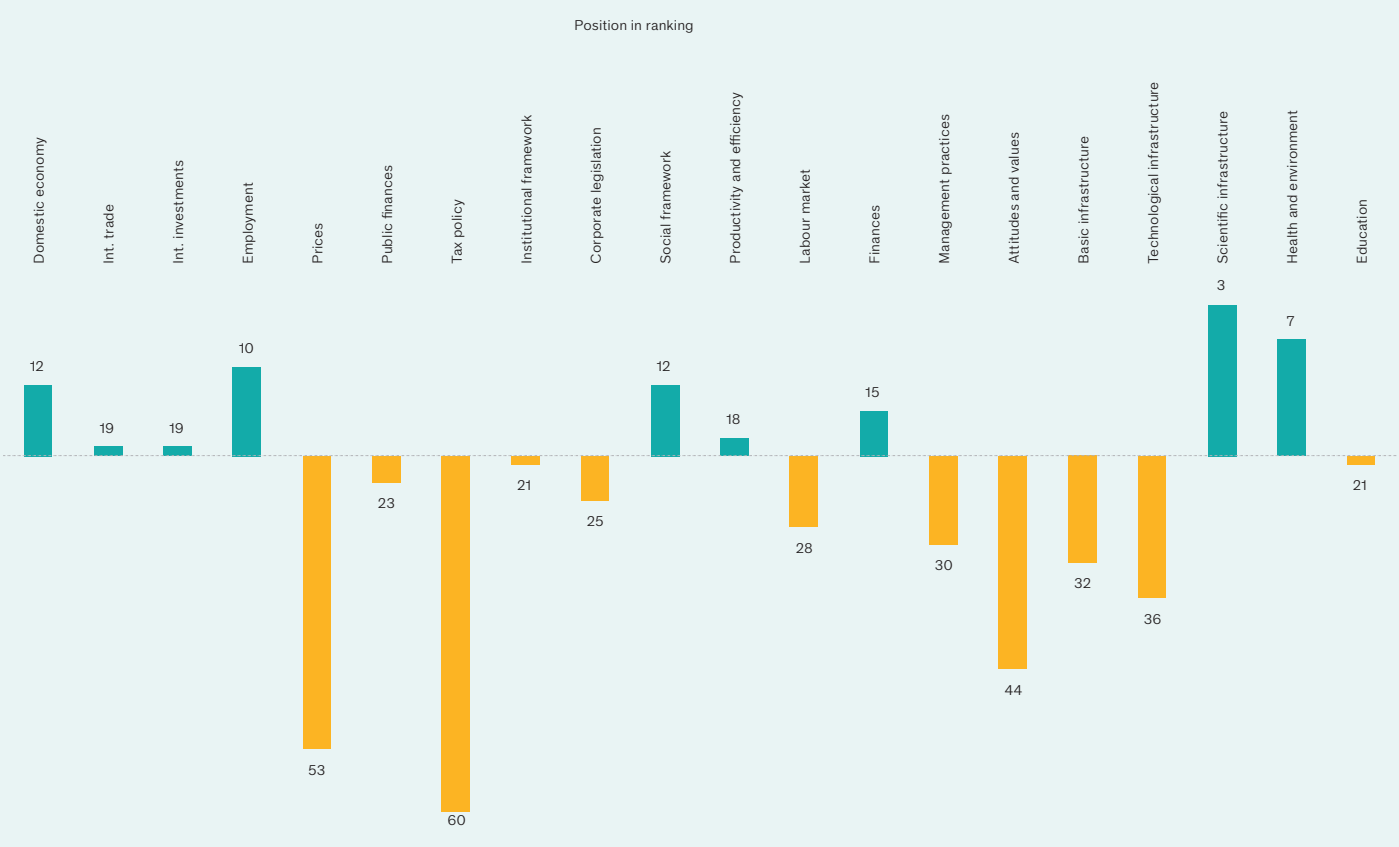


Figure 2.11: Germany's positions in the World Competitiveness Ranking (IMD, 2023b).

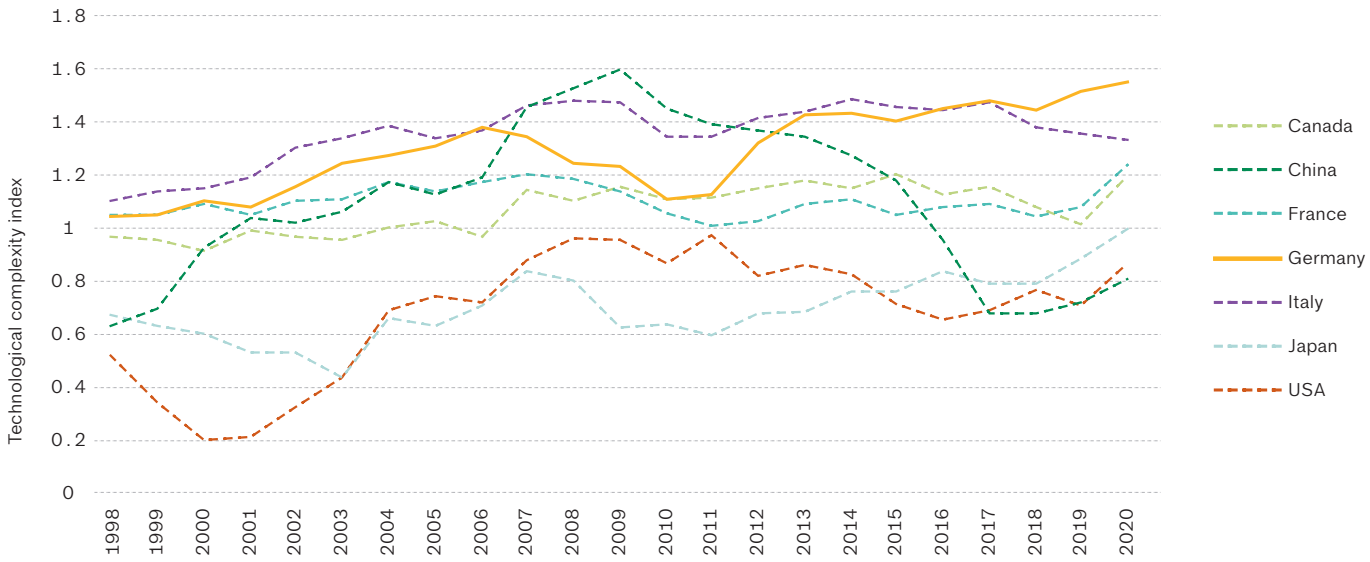


Figure 2.12: Country comparison of economic complexity measured by the ECI (Economic Complexity Index) (OEC, 2021).

3. Existing political framework: The path to natural gas independence between regulation, CO_2 prices and subsidisation

Despite the geopolitical turnaround, high price volatility of liquefied natural gas (LNG) imports and the economic potential of new technologies, there has been no discussion of a long-term solution to Germany's dependence on natural gas.

The political momentum of an immediately effective policy framework for gas independence is limited to individual initiatives in response to the halt in Russian gas supplies, including the EU's coordinated measures to reduce gas consumption in 2022. Most of this discussion is motivated by climate policy.

The range of regulatory permissible, technically available and economically viable technologies for the substitution of natural gas results from the interplay of market-based instruments, regulation, subsidisation and sustainable finance (Figure 3.1).

→ The **CO_2 pricing** determines the economic viability of renewable and natural gas-based technology options in comparison (Chapter 3.1).

→ The **regulations** and **expansion targets** define the transformation path (Chapter 3.2).

→ **Subsidies** enable the expansion of natural gas-free technologies despite the lack of short-term profitability (Chapter 3.3).

→ **Sustainable finance** guides investments through disclosure obligations and transparency requirements (Chapter 3.4).

Prices for CO_2 define a long-term corridor

In the EU, CO_2prices define the price corridor that secures long-term independence from natural gas in industry and buildings by enabling the competitiveness of natural gas-free technologies. On the one hand the EU Commission has increased the CO_2reduction target from the existing emissions trading system (ETS) sectors (ETS 1, energy generation, energy-intensive industry, intra-European aviation) and from maritime transport – to 62 % by 2030 compared to 2005. The price now averages around 80 euros/t CO_2 (Ember, 2023) and therefore offers a relevant incentive for companies to avoid fossil fuels.

In addition to ETS 1, following the revision of the ETS Directive, the EU is introducing a separate emissions trading system for buildings, road transport and the use of fossil fuels in certain industrial sectors (ETS 2), which should contribute to an additional 42 % reduction in emissions from 2027 compared to 2005 (European Union, 2023b).

For all sectors not covered by ETS 1 and ETS 2, the Effort Sharing Regulation sets individual targets for the member states. The reduction target for the EU as a whole is 40 % compared to 2005, while the specific target for Germany is 50 % (European Commission, 2023e).

Nationally, ETS 1 is supplemented by the Federal Emissions Trading Act (BEHG), which defines a price path until 2026 for all sectors covered by ETS 2 (plus waste incineration); this will be transferred to ETS 2 from 2027. Without an adjustment to the price corridors of the BEHG, sharp price increases are to be expected: the BEHG envisages a price of 50 euros per tonne of CO_2 in 2025 (Agora Energiewende & Verkehrswende, 2023), and a price corridor of 55–65 euros per tonne of CO_2 from 2026 (DEHSt, 2023). From 2027, however, the upper and lower price limits will be dissolved and transferred to ETS 2; it is unclear in which corridor the price will move (Agora Energiewende & Verkehrswende, 2023).[1]

1 The steering effect of ETS 2 is weaker than that of the BEH. The ETS 2 provides for a Europe-wide reduction of –40 % compared to 2005 for the entire EU, while the BEH aims for –50 % in line with the ESR targets.

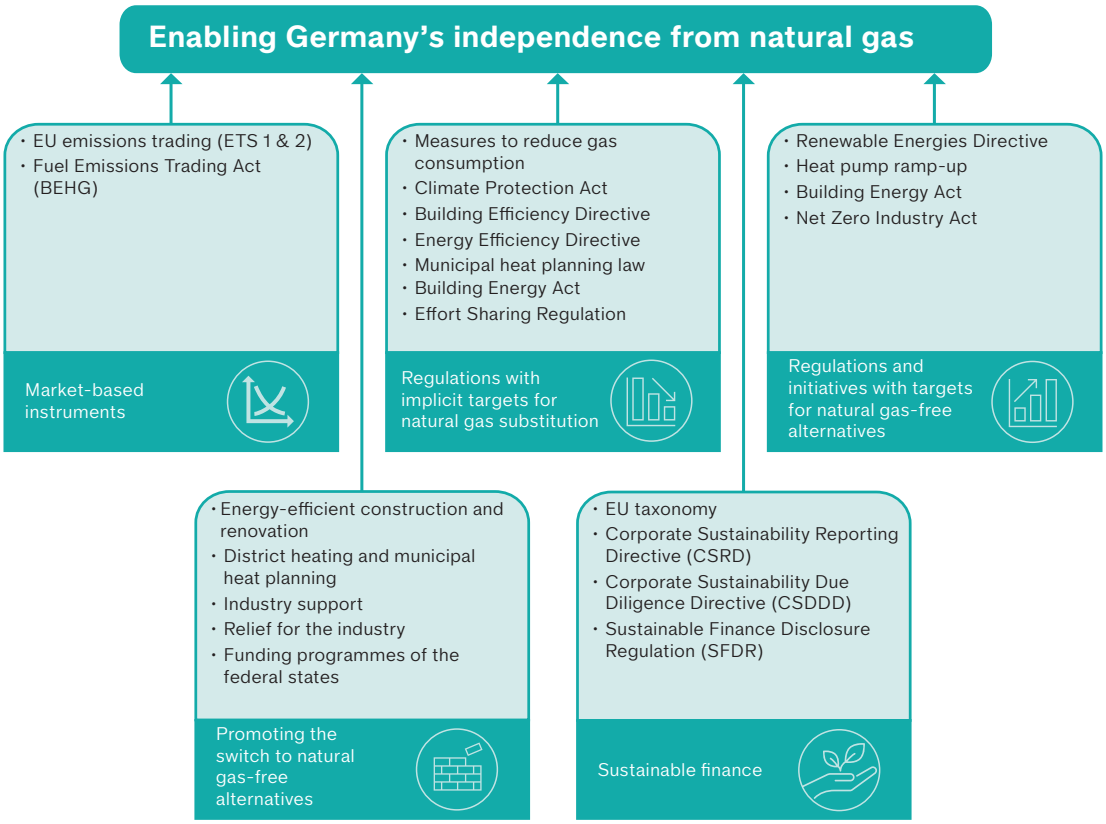


Figure 3.1: Market-based instruments, regulations, expansion targets, subsidies and sustainable finance support the substitution of natural gas-based with natural gas-free technologies (own presentation).

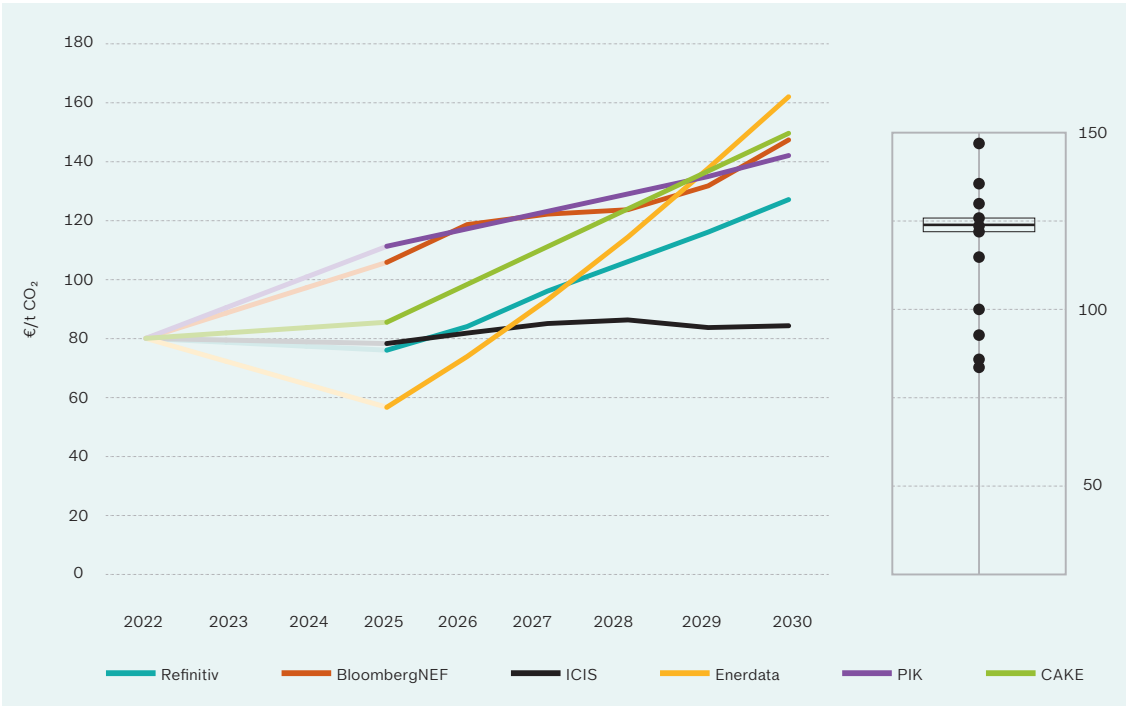


Figure 3.2: ETS 1 prices in the standard Green Deal/FF55 COM scenario (left) (Pahle et al., 2022)[2]; variation of the 2030 ETS 1 CO_2 price in the LIMES model after the ETS reform (right) (Pahle et al., 2023).

2 The prices of Refinitiv and BloombergNEF are nominal; the other prices are real and have been harmonised to EUR 2022 using EUROSTAT inflation rates.

Future forecasts on the development of CO_2 prices are subject to a high degree of uncertainty. Figure 3.2 shows the results of different models for the current regulation of ETS 1. The price of ETS 1 will therefore settle between 80 euros and 160 euros per tonne of CO_2 in 2040 (Pahle et al., 2023). The estimates show a wide range, as the price is determined by supply and demand, but the market stability reserve of ETS 1 also has a significant influence on pricing. The level of this forecast is still far below the price path that some climate models indicate as cost-effective and necessary for achieving the climate targets (Pietzcker et al., 2021). Further reductions in certificate volumes are therefore not ruled out in order to achieve the European and global CO_2 reduction targets.

For the transition from the BEHG to ETS 2, other studies assume that the CO_2 price will rise from 55–65 euros per tonne of CO_2 (BEHG) in 2026 to 200–300 euros per tonne of CO_2 in 2027 (tripling) if the price corridor is left (Kalkuhl et al., 2022; Rickels et al., 2023). Without any preparatory flanking measures, the price jump would therefore correspond to an increase in natural gas prices of 4–6 ct/kWh.

The steering effect of emissions trading systems on the speed of natural gas independence depends largely on the level of the price. This puts politicians in a dilemma. Low prices reduce the incentive to take short-term measures. They delay competitiveness and thus investments in natural gas-free technologies. High prices, on the other hand, harbour the risk of a price shock that, without accompanying measures, leads to major economic and social adjustment difficulties (transition risk). The resulting social and political resistance undermines the long-term political stability of emissions trading systems (see Chapter 6).

Regulatory targets offer certainty of direction

One problem with CO_2 prices in the management of investments is their volatility. The resulting uncertainty inhibits investment (see Chapter 6).
In contrast, the regulatory targets of European and German climate policy offer certainty of direction. The target corridors envisage a significant reduction in natural gas consumption.

In the following we concentrate on regulations that are relevant to the buildings and industrial sectors, excluding the electricity sector, as these form the focus of the analysis (see Chapter 4).

"The target corridors of climate policy imply a significant reduction in natural gas consumption in order to achieve climate neutrality."

The EU has set itself the target of reducing its greenhouse gas emissions by at least 55 % by 2030 compared to 1990 levels (European Parliament and Council, 2021) and plans to present a climate target for 2040 before the end of this legislative period (European Commission, 2023a). Germany is aiming for a target of 65 % savings by 2030 – and 88 % by 2040 (German government, 2022).[3]

These overarching climate targets have now been followed by granular targets – both for the ramp-up of green technologies and for energy efficiency and heat generation in buildings. As part of the Net-Zero Industrial Act, the EU is planning to define targets for the domestic production of key products for natural gas independence (photovoltaics & solar thermal energy, electrolysers & fuel cells, onshore wind energy & renewable offshore energy, sustainable biogas/biomethane, batteries & storage technology, carbon capture and storage (CCS), heat pumps & geothermal energy and grid technologies). By 2030, 40 % of the key green technologies required annually for the climate targets set are to be produced in the EU itself (European Commission, 2023d). In addition, the use of renewable energies is to be quadrupled by 2050 and the use of heat pumps is to be increased six-fold. The German government is also aiming to expand the number of decentralised heat pumps in buildings from around 1.5 million at present to 6 million in 2030 (BMWK, 2023a).[4]

3 The targets are not yet sufficient to avoid exceeding global tipping points in the climate system. This would require a reduction of 69 % for Germany by 2030 (Climate Action Tracker, 2023).

4 This does not apply to large heat pumps in industry and heating networks.

The best energy is that which is not consumed

The aforementioned targets are flanked by the Energy Efficiency Directive (EED), which establishes the principle of energy saving obligations in European energy policy (European Parliament and the Council, 2023). By 2030, energy efficiency is to increase by 11.7 % compared to 2020, with the member states gradually being required to make energy savings. The annual energy saving obligations for the member states are set at an average of 1.5 % of their final energy consumption from 2024 to 2030, compared to the current level of 0.8 %, and will gradually reach 1.9 % by the end of 2030.

In Germany, the Energy Efficiency Act (EnEfG) implements the revised EED. Accordingly, Germany's final energy consumption is to be reduced by 45 % by 2045 compared to 2008. An interim target with a reduction in final energy consumption of at least 26.5 % is to be achieved by 2030.

Buildings: EPBD and GEG generate new momentum

The EU and the German government have defined sectoral targets for buildings. As a result of the amendment to the Energy Performance of Buildings Directive (EPBD), which is still being negotiated, all new buildings in the EU are to be emission-free by 2030; public buildings will have to fulfil these requirements from 2027. In addition, EU-wide minimum efficiency standards and renovation regulations for buildings are being discussed in order to reduce energy consumption.[5] According to the new provisions of the EPBD, at least 16 % of non-residential buildings with the worst values must be renovated by 2030, and 26 % by 2033. Energy consumption in residential buildings must be reduced by 16 % by 2030 and by 20–22 % by 2035, with early efforts being rewarded.

In Germany, the Building Energy Act (GEG) will enter into force on 1 January 2024. It stipulates that from 2024, at least 65 % of the heating systems installed in new construction areas must be powered by renewable energies or unavoidable waste heat. The use of fossil fuels is permitted on a transitional basis for the replacement of defective heating systems, although existing heating systems may continue to be operated entirely with fossil fuels until the end of 2044, provided that repairs are carried out (German government, 2023b).

The implementation of the GEG was linked to municipal heating planning. This includes the expansion of heating grids, whereby existing grids are to be 80 % renewable by 2044, while new grids must be 65 % renewable from 2024 (BMWSB, 2023).

5 Current negotiations indicate that standards and regulations will not apply to residential buildings or will only be included in the directive as a general savings obligation.

Table 3.1: Overview of selected targets in Germany and the EU with reference to the reduction of natural gas (own presentation based on case law)

Law	Area of application	Timing	Target value	Reference indicator
European Union				
European emissions trading 1	Energy production, energy-intensive industry, intra-European air transport, maritime transport (from 2024)	2030	–62 %	CO_2e compared to 2005
Effort Sharing Regulation (ESR)	Reduction targets for all sectors not covered by ETS 1	2030	–40 %, for DE –50 %	CO_2e compared to 2005
Energy Efficiency Directive (EED)	Efficiency savings of all EU countries in the energy and non-energy sectors	2030	Efficiency increase of 11.7 % by 2030; mandatory upper limit of 763 million tonnes of oil equivalent for final energy consumption in the EU	2020 reference scenario calculations
Energy Performance of Buildings Directive (EPBD) (in trialogue negotiations)	Emission-free buildings (including existing buildings) (no fossil CO_2 emissions on site)	2030 2035 2040	Reduce the primary energy demand of existing residential buildings by 16 %; Renovate 16 % most inefficient non-residential buildings; Reduce the primary energy demand of existing residential buildings by 20–22 %; Phasing out the use of fossil fuels for heating and cooling	2020 reference scenario calculations
NZIA (in trilogue negotiations)	Production of the key green technologies required annually in the EU	2030	At least two fifths (40 %)	–
Renewable Energies Directive	Increase the share of renewable energies (RE) in the electricity, heating and transport sectors by 2030	2030	42.5 % Increase the use of RE in industry by 1.6 % annually 42.5 % RE in buildings	Share of renewable energy sources in total energy consumption in the EU
Measures to reduce the demand for gas	Voluntary reduction in demand for natural gas to ensure security of supply	2022–2024	–15 %	Average of the last five years between 1 August and 31 March
Germany				
Climate Protection Act	Cross-sector reduction targets for DE	2030 2040	65 % –88 %	CO_2e compared to 1990
Energy Efficiency Directive (EnEfG)	Reduction of energy consumption	2045	45 %	2008
Building Energy Act (GEG)	Operation of heating systems with renewable energies or unavoidable waste heat	From 1 Jan 2024 From 2026	Heating with at least 65 % renewable energies	In the new development area Outside a new development area
Municipal heat planning law	Generation of conducted heat Expansion of heating networks	2030 2044	50 % 80 % renewable	Renewable share of heat generation

Subsidies enable forward-looking action

Regulation creates the framework. CO_2 prices channel expectations and ensure the long-term competitiveness of natural gas-free technologies. Subsidies stimulate action and support the development of alternative technologies. Comprehensive programmes are in place to achieve this.

"Loosened state aid rules allow subsidies to be granted for the production of green technologies."

European funding for green technologies

Germany has received a share of 28 billion euros from the EU Recovery and Resilience Facility (RRF), 47 % of which is earmarked for climate-related expenditure. Various measures are planned for the 2024 financial year, including research and innovation in the area of the National Hydrogen Strategy, decarbonisation of industry, climate protection contracts and the promotion of energy-efficient insulation renovation.

In addition to these funds, there is also funding at EU level from the EU Innovation Fund (European Commission, 2022c). This is limited to the demonstration of highly innovative pioneering projects in energy-intensive sectors, which must be unique in their nature and whose technology is not ready for the market. It comprises an estimated 38 billion euros. This rules out the promotion of market-ready technologies that could already make it possible to substitute natural gas today (see Chapter 7 – Industry).

In addition, 10.6 billion euros was made available for research into hydrogen applications as part of the Important Projects of Common European Interest (IPCEIs) to mobilise private investment (European Commission, n. d.). These programmes are supplemented by research innovations as part of Horizon Europe and the LIFE Fund for innovation and key industries. Investments totalling 160 billion euros are still planned through the Strategic Technologies for Europe Platform (STEP), although the exact details are still being negotiated.

The relaxed state aid rules as part of the Temporary Crisis and Transition Framework (TCTF) also allow member states to temporarily support the production of green technologies (e. g. heat pumps, sustainable gases, geothermal energy), the decarbonisation of industrial processes through electrification or renewable hydrogen (subject to certain conditions) and measures to increase energy efficiency from their own funds (European Commission, 2023b).

Federal funding programmes

German government funding programmes offer further opportunities. We list the programmes of the Climate Transformation Fund (KTF) in their original version in Table 3.2.[6] Figure 3.3 shows the funding volumes of the individual plan and the financial plan in total (left) and over time (right). To mobilise private investment, the German government planned to provide public support of up to 80 billion euros in the buildings sector and up to 30 billion euros in the industrial sector. Subsidies are awarded via BAFA and KfW in the form of grants, guarantees, relief or low-interest loans.

In Germany, energy-intensive industry in particular benefits from high levels of support totalling several billion per year – through relief and other measures as shown in Table 3.3, although these funds are only partially covered by the KTF.

6 After the ruling of the Federal Constitutional Court, the new business plan of the KTF for 2024 as of 17 November 2023 is not yet available, which is why we are presenting the original version here.

Table 3.2: Overview of the most important German government subsidies from the KTF

Funding area	Support programmes	Total planned funding in 2024
Building promotion	· Promotion of energy efficiency and renewable energy measures in the buildings sector (until 2034) · Subsidy programme for climate-friendly new construction and home ownership for families (until 2034) · Energy efficiency consulting (until 2027) · Serial renovation (until 2028) · Funding of measures for energy-efficient urban renovation (until 2034)	19.4 billion euros
Expansion of the heating network and district heating	· Transformation of heating networks (until 2029) · Subsidies for the operation of decarbonised heating infrastructures (until 2034) · Federal financial aid to the federal states to promote measures for municipal heat planning (until 2028)	0.9 billion euros
Industrial promotion and hydrogen production	· Decarbonisation of industry (by 2041) · Energy efficiency in industry and commerce (until 2029)	3.7 billion euros
	· Implementation of the National Hydrogen Strategy · Hydrogen use in industrial production (until 2028) · IPCEI Hydrogen (until 2029) · Hydrogen Strategy for Foreign Trade – International Hydrogen Cooperation (until 2034) · Application-orientated basic research into green hydrogen (until 2028)	Of which hydrogen: 2.9 billion euros

Table 3.3: Relief and subsidies for the industry

Support programme	Funding purpose	Financial scope
Peak equalisation[a] (Section 10 of the StromStG)	· Reimbursement of up to 90 % of electricity tax for energy-intensive companies · Absolute tax relief may be lower, linked to pension insurance contributions (Section 55 of the EnergieStG)	~1.7 billion euros per year for around 9,000 companies
Electricity price compensation[b] (funding guideline)	· Compensation for the additional CO_2 costs in the electricity price · Depending on electricity efficiency benchmark · Limited eligibility group	27.5 billion euros for 2021–2030 2024: 2.6 billion euros
Electricity price package[c]	· Further reduction in electricity tax for all manufacturing companies · Extension and expansion of electricity price compensation, abolition of the deductible	12 billion euros per year (incl. peak equalisation)
Free allocations in the ETS	· Expires in 2034 with the introduction of CBAM	
Relief through BEHG[d]	· Compensation for energy-intensive companies with carbon leakage risk (65–95 % depending on emissions intensity) · Beneficiaries must invest at least 50 % (80 % from 2028) in efficiency measures or decarbonisation measures	6.5 billion euros by 2031
Climate protection agreements[e]	· Compensation of CO_2-neutral production over 15 years · Requirements for emissions, renewable electricity, hydrogen	Budget 2024: 343 million euros
Promotion of transformation technologies[f]	· Aid for investments in certain technologies and key components (production of batteries, solar panels, wind turbines, heat pumps, electrolysers, CCUS systems)	Maximum 15 % of costs, budget 200 million euros in special cases
Growth Opportunities Act	· **Investment promotion:** Tax incentives for investments in the amount of 15 % of the subsidised expenses · **Accelerated amortisation:** Degressive amortisation in the amount of up to 25 %, a maximum of 2.5 times the linear depreciation for movable assets	Total amount of aid may not exceed 30 million euros Budget: 390 million euros to 2 billion euros
Special equalisation scheme[g]	· **Reduction of the EEG reallocation charge for companies with high electricity costs**	1 billion per year (after cessation of the EEG reallocation charge, previously 6 billion)
Reduction in transmission grid fees[g]	· **Promotion of even grid usage, which benefits**large electricity consumers in particular, especially the paper, chemical and aluminium industries	13 billion per year

(a) Schäfers (2023); (b) European Commission (2022b); (c) German government (2023c); (d) European Commission (2023e); (e) BMWK (2023d); (f) BMWK (2023b); (g) Eicke et al. (2023).

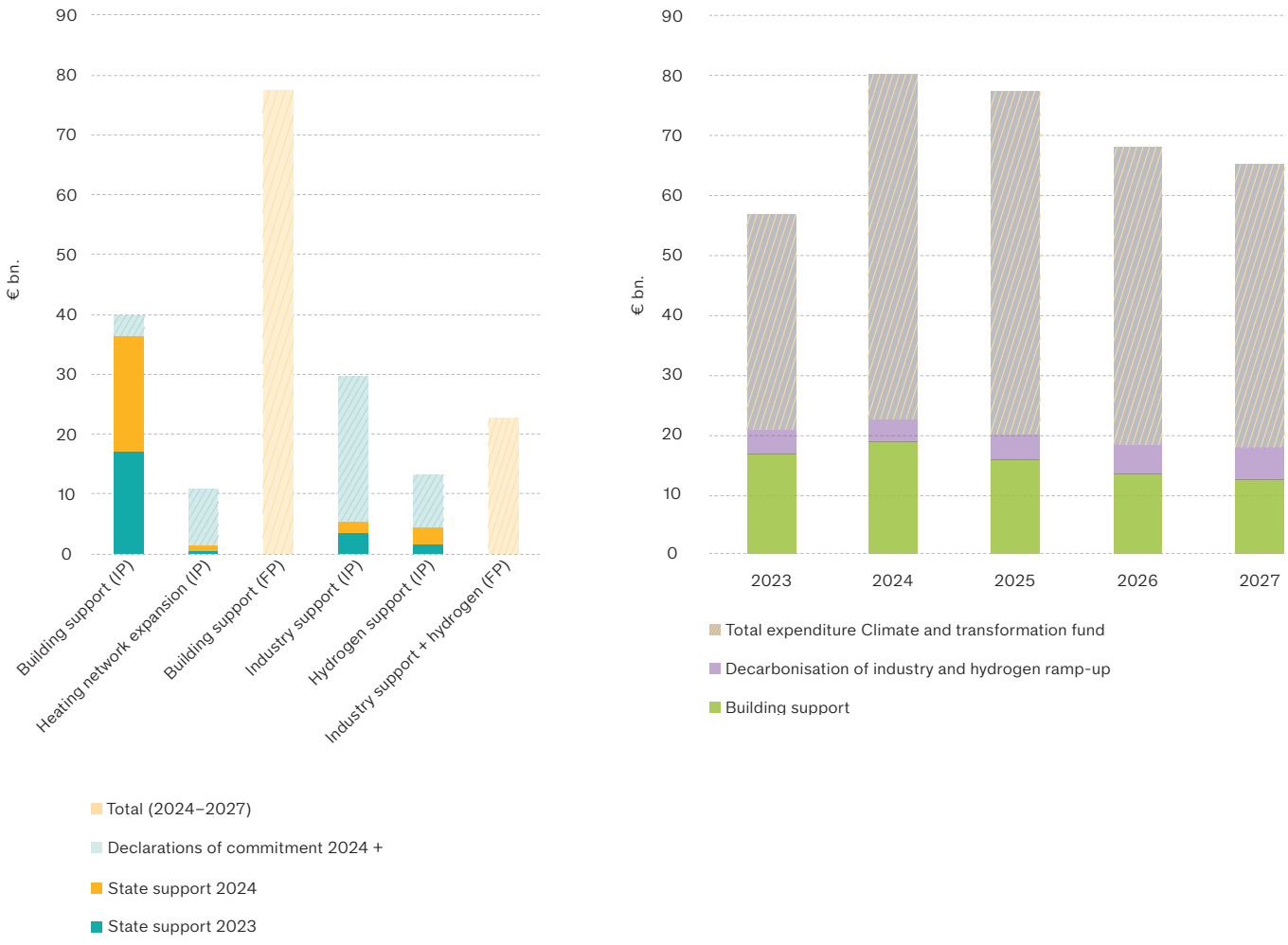


Figure 3.3: Federal funding for natural gas-free technologies in the buildings and industrial sector according to the individual plan (IP) for 2023, 2024 and declarations of commitment after 2024, as well as the 2023–2027 financial plan (FP) of the Climate Transformation Fund (Bundestag, 2023). Totals (left) and time course based on FP (right). For allocations of budget titles, see appendix.

Mobilising billions: The channelling of private capital

In addition to the aforementioned regulations for buildings and industry, emissions trading and subsidies, transparency standards and disclosure obligations under sustainable finance regulation are intended to channel more investment into sustainable economic activities – including those that promote the substitution of natural gas. The combination of the EU taxonomy, the Sustainable Finance Disclosure Regulation (SFDR), the Corporate Sustainability Reporting Directive (CSRD) and the planned Corporate Sustainability Due Diligence Directive (CSDD) motivates companies to review their business areas with regard to climate risks and to introduce measures to minimise them. This includes both physical risks from climate change-related events and transition risks arising, for example, from adapting to more demanding climate regulations (European Commission, 2021b). Reporting under the CSRD is based on the principle of dual materiality. On the one hand organisations must disclose the effects of their business activities on people and the environment (looking from the inside out), including effects on the climate. On the other hand social and ecological aspects create risks and opportunities for organisations (view from the outside in). Examples include potential stranded assets from investments in value chains that are not sustainable and therefore not competitive in the medium term, the introduction of new sustainable finance regulations, price increases and traditional reputational risks. The CSDDD is currently in the European legislative process. On 14 December 2023, the European Council, Parliament and Commission presented a provisional outcome of the negotiations, which is expected to be adopted in 2024.

Rethinking reporting: CSRD, CSDDD and SFDR

The CSRD, CSDDD and SFDR reporting systems relate to sales and investments, as well as real and financial activities. The steering of corporate investments is achieved both directly and indirectly. The reporting requirements of the CSRD will initially apply to a limited group of companies for financial years starting from 1 January 2024, which will then be successively expanded. Simplified for European companies, this results in the following levels of applicability:

- → For financial years beginning on or after 1 January 2024: companies of public interest with more than 500 employees.
- → For financial years beginning on or after 1 January 2025: all other large companies under accounting law.
- → For financial years beginning on or after 1 January 2026: capital market-orientated SMEs, unless they make use of the option to defer until 2028.

The planned CSDDD sets out environmental and human rights standards as well as the obligation for large companies to draw up a climate plan. It is more narrowly defined and is only intended to affect companies with more than 500 employees and a turnover of more than 150 million euros, although the scope of application was still being negotiated in the trialogue at the time of publication of the report.

"Large companies must submit transition plans with reduction targets from 2024."

As a result, affected companies must submit transition plans with reduction targets for their value chains that are aligned with a consistent 1.5-degree Celsius scenario. In doing so they must ensure that their plans are comprehensive, strategic and embedded in the context of their organisation (business strategy and financial plan). Criteria for these transition plans are defined in the European Sustainable Reporting Standards (ESRS). Compared to the German Supply Chain Due Diligence Act (LkSG), the current version plans to integrate stricter requirements in important aspects, in particular by introducing civil liability and extending the scope of sanctions.

Along the SFDR, stakeholders active in the financial market, such as commercial banks, institutional investors and insurance companies, must explain whether and to what extent their investment decisions have a negative impact on sustainability and the climate. The basis for the sustainability assessment of investments was initially formed by the ESG criteria developed by various institutions and organisations (EFRAG, 2022; IFRS, 2023; SASB, 2023), which are now being supplemented by the EU taxonomy.

All products under the SFDR must disclose information on sustainability risks in accordance with Article 6. In addition, the disclosure obligations under Article 8 apply where a financial product advertises, inter alia, environmental or social characteristics or a combination of these characteristics, provided that the companies invested in apply good corporate governance practices (Regulation (EU) 2019/2088). In contrast, Article 9 refers to financial products that aim for a sustainable investment. Financial products that are classified in accordance with Article 9 are also referred to as dark green and are considered to be particularly sustainable. In contrast to financial products under Article 8, which only take environmental and social aspects into account, financial products under Article 9 pursue an explicit sustainable investment objective.

The data obtained in the course of the disclosure and transparency obligations supports the steering of real economic investments away from fossil technologies and thus investments in natural gas independence:

1. Lenders decide against granting loans due to the transparency of climate and transition risks because, for example, the credit ratings of companies by rating agencies change.
2. The available data is incorporated into the ECB's climate stress tests (ECB, 2022a, 2023b), which can thus have an additional medium-term steering effect on investments away from unsustainable forms of investment if capital requirements for banks depend on the result of their climate risk assessment.
3. The demand for credit increases as the sustainability classification can offer slight incentives for investments via an interest rate advantage of 15 to 25 basis points, depending on the bank's credit conditions (Löffler et al., 2021).

How the EU taxonomy works

Under the EU taxonomy, companies covered by the CSRD must report on the environmental impact of economic activities (revenues and investments) that are related to the environmental objectives of the Taxonomy Regulation. These activities include activities of non-financial companies, such as steel production and its sub-processes, as well as activities of financial players, such as consumer credit, mortgages or long-term loans for industry.

A distinction is made between taxonomy-eligible and taxonomy-aligned activities. The former presuppose that the activity can generally be assigned to an economic sector of the EU taxonomy (*eligibility*). Of the taxonomy-eligible activities, those that fulfil the associated technical screening criteria are considered taxonomy-aligned (*alignment*). The average taxonomy-eligible capital expenditure (CapEx) for the economy as a whole was 37 % in 2022, with only around a quarter (~9 %) reported as taxonomy-aligned. The average taxonomy-eligibility of operating expenses (OpEx) is 27 %, with only 8 % being taxonomy-aligned (PwC, 2023b).

"Only around 9 % of capital expenditure in 2022 was taxonomy-aligned."

Taxonomy-alignment requires that an activity 1) makes a significant contribution to one of the six defined environmental objectives, 2) does not significantly harm any of the environmental objectives (*Do no significant harm* or DNSH), 3) fulfils the technical test criteria in relation to the environmental objectives and 4) complies with minimum social standards. In addition, a distinction can be made between three types of activities (European Parliament and the Council, 2020). The goal of climate protection is particularly relevant for natural gas independence. The European Commission has specified extensive technical test criteria for assessing whether an activity makes a significant contribution to climate protection (European Commission, 2021a, 2022b). The criteria follow the principle of technology neutrality.

The activities relevant to this report can therefore be categorised as follows with regard to the climate protection target:

4. **Green activities:** make a significant contribution to reducing CO_2 emissions (Article 10, paragraph 1).
5. **Transition activities:** reduce CO_2 emissions, even if the technology is not climate neutral, without hindering the development and deployment of low-carbon alternatives and without creating lock-in effects for plants that are incompatible with the objective of climate neutrality, taking into account the economic lifetime of these plants (Article 10, paragraph 2).
6. **Support activities:** enable other activities to make a significant contribution to the climate targets (Article 16).

If an activity is not eligible, the company's turnover cannot be recognised as eligible or taxonomy-aligned. However, capital expenditure on the technologies used in the activity can be recognised if they relate to an eligible activity and meet the relevant test criteria.

4. Mission natural gas-free future: Priorities and scenarios

Germany has long discussed natural gas as an opportunity for climate policy, as a bridging technology until suitable technologies are ready for the market. The collapse in Russian gas imports and the associated supply shock shed new light on the discussion. Not only has this bridge collapsed, but the new situation also enables a reorientation of the economic objective towards independence from natural gas in the buildings and industrial sector. The following chapter shows which priorities should be set for this, who is affected and which technological development paths we are assuming. We derive six core statements:

1. The greatest reduction potential for natural gas lies in the buildings and industrial sectors.
2. In the buildings sector, the priority is on the substitution of natural gas in existing buildings.
3. In the industrial sector, the changeover is focused on the provision of process heat.
4. Electrification is the priority for making buildings and industry independent of natural gas.
5. The material substitution of natural gas is achieved through the use of hydrogen.
6. For steel production in direct reduction installations (DRI), sufficient hydrogen must be available in good time so that operation with natural gas is minimised.

Substitution potential for natural gas lies in the buildings and industrial sectors

The utilisation of natural gas is concentrated in four fields of application (Figure 4.1).

1. **46 %:** Decentralised heat generation in **buildings** accounts for the largest share of natural gas use in Germany. Of this, 68 % is attributable to the provision of heat in residential buildings and 32 % to non-residential buildings in the trade, commerce and services sector and the industrial sector. The report analyses the challenge for residential buildings more specifically, but implies that the same efforts must be made for the conversion of the heat supply and the energy-efficient renovation of non-residential buildings. District heating generation (7 %), which is part of the energy industry sector in balance sheet terms, is analysed in Chapter 7.1 – Buildings, as it is largely used to provide heating for buildings.

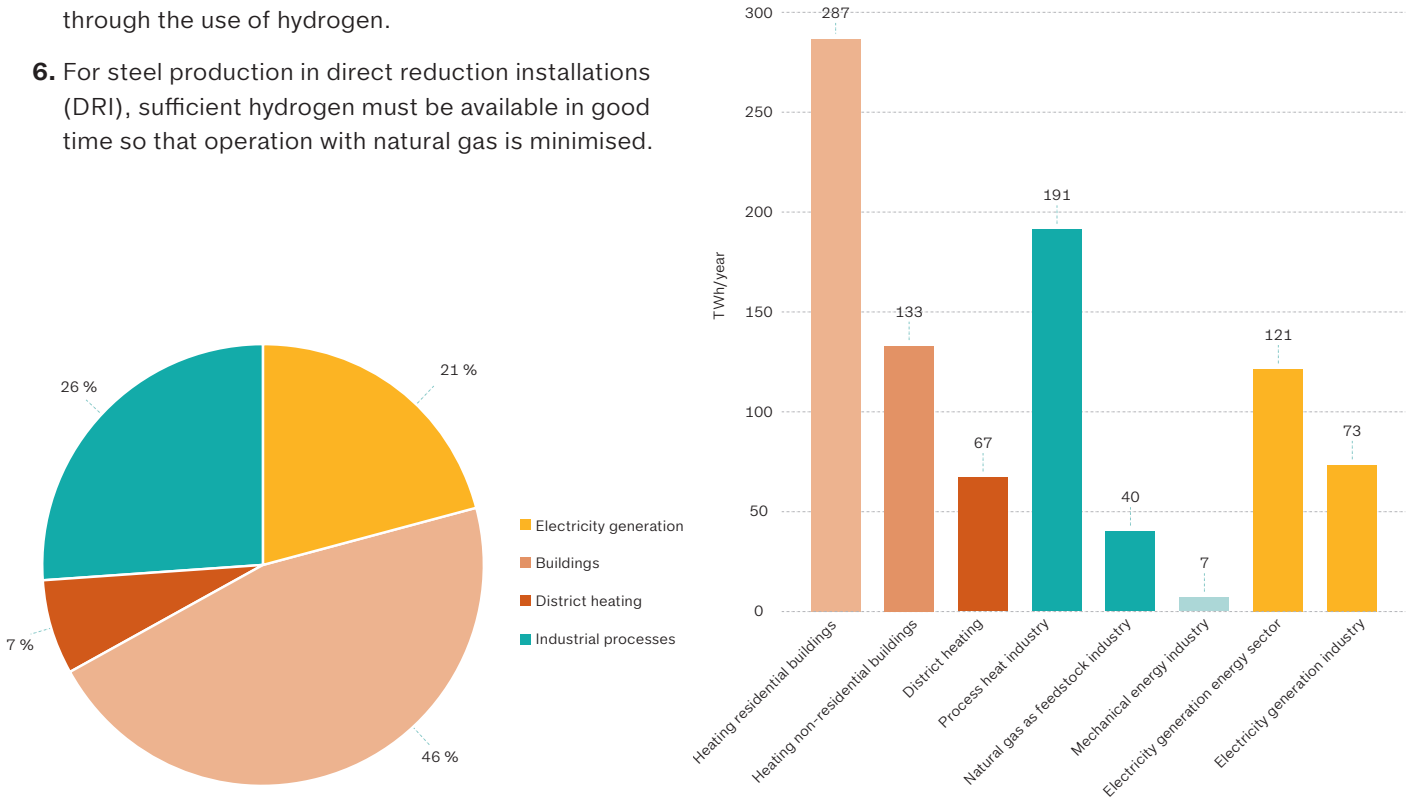


Figure 4.1: Natural gas utilisation in Germany by field of application (left) and by specific forms of use in 2021 (right) (AGEB, 2023; BDEW, 2023a; Fraunhofer ISI, 2022; Zukunft Gas, 2022a).

2. **26 %: In industrial processes, natural gas is used to provide process heat** in steam generators and industrial furnaces. Use for the provision of mechanical energy plays a minor role. Natural gas is also used as a non-energy molecule, particularly in basic chemistry.
3. **21 %: Natural gas-fired power plants for electricity generation** are used both in the energy sector and for in-house electricity generation in industry (62 % energy sector, 38 % industry). For both sectors, the flexibility of the power plants plays a particularly important role in the supply of electricity. As a rule, natural gas is combined with combined heat and power in power stations and then utilised directly in industry or fed into heating networks.

In this report we focus on the substitution of natural gas in heat generation in buildings (including district heating) and in industrial processes as well as in material utilisation – and thus on 78 % of German natural gas consumption.

"Buildings and industry account for 78 % of natural gas consumption."

There are two reasons for this: Firstly, although natural gas plays an important role in the electricity market – gas-fired power plants often have a price-setting effect – electricity generation only accounts for 21 % of German natural gas consumption (BDEW, 2023d; Zukunft Gas, 2022a); secondly, the electricity sector is already experiencing a successful investment dynamic in solar and wind energy generation. By contrast, the buildings and industrial sectors are lagging behind in the switch to renewable energies (Ariadne, 2023). Investment momentum is still a long way off. However, the switch to renewable energies in the electricity market also means less availability of heat from combined heat and power generation. Renewable heat generators must therefore be expanded in the near future for district heat generation, which is why they are included in our analysis.

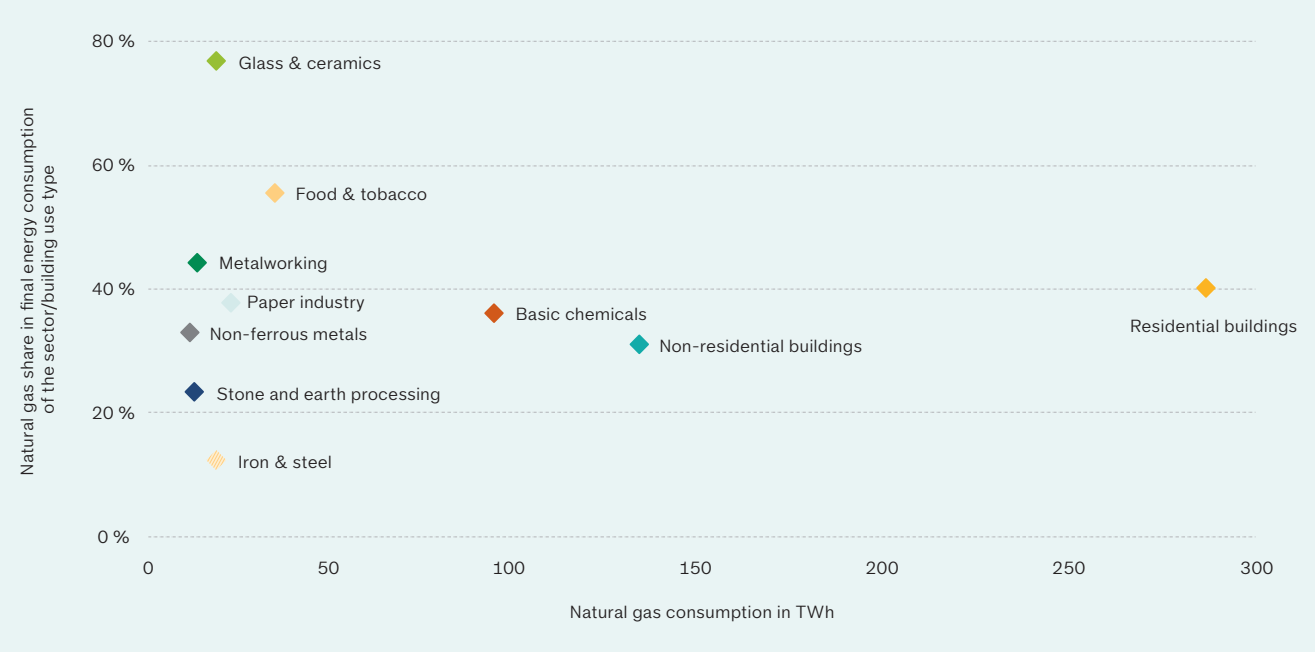


Figure 4.2: Natural gas consumption and dependency of the eight industrial sectors with the highest natural gas consumption and building types in 2021 by natural gas consumption and share of natural gas in their final energy consumption (BDEW, 2023a; Fraunhofer ISI, 2022; Zukunft Gas, 2022a).

Heat generation and material utilisation are the main areas of application for natural gas

Figure 4.1 clearly shows that buildings (420 TWh) have the greater savings potential compared to industry (238 TWh). Figure 4.2 further breaks the sectors down and shows where the greatest substitution potential lies. The chart categorises the eight industries with the highest natural gas consumption in the industrial sector and the building types based on their natural gas consumption in 2021 (x-axis) and the share of natural gas in the final energy consumption of the industry/building type (y-axis).

In the **buildings sector**, residential buildings are by far the largest consumers of natural gas. Here it is used to generate space heating and provide hot water. The building stock is particularly relevant, as the example of residential buildings makes clear. Half of all heating systems are based on natural gas (BDEW, 2023d). Developments in new construction are pointing in the right direction: 57 % of newly constructed residential buildings are heated with a heat pump, and the trend is increasing. District heating is also becoming increasingly important here (BDEW, 2023c).

*"**1 in 2** heating systems in existing buildings are natural gas heating systems."*

Natural gas is the most important energy source in **industry**, accounting for 32 % of the total. In addition to material utilisation, a large proportion (80 %) is used to generate process heat; mechanical energy is a marginal application (Figure 4.4).

*"Industry uses **80 %** of natural gas for process heat."*

For some sectors, above all the glass and ceramics industry with a 77 % (Figure 4.2) share of natural gas in the final energy consumption (FEC) of this branch of industry, the dependency is particularly high (Destatis, 2023c). Natural gas is used for process heat at high temperatures for smelting and rolling processes (Zukunft Gas, 2022b). The same applications can also be found in metalworking (44 % share of FEC). The food and paper industries (56 %), on the other hand, use natural gas for drying processes in lower temperature ranges. The basic chemicals industry (36 %) uses natural gas for process heat in the form of steam, heat or cooling. 42.3 % is used as a material in this sector (Zukunft Gas, 2022a). Natural gas is the basic raw material for organic base chemicals such as ammonia and methanol (VCI, 2023). The use of natural gas in these processes was already significantly reduced during the energy crisis, and ammonia in particular was increasingly imported.
Material utilisation accounts for 17 % of the entire industry (Figure 4.4).

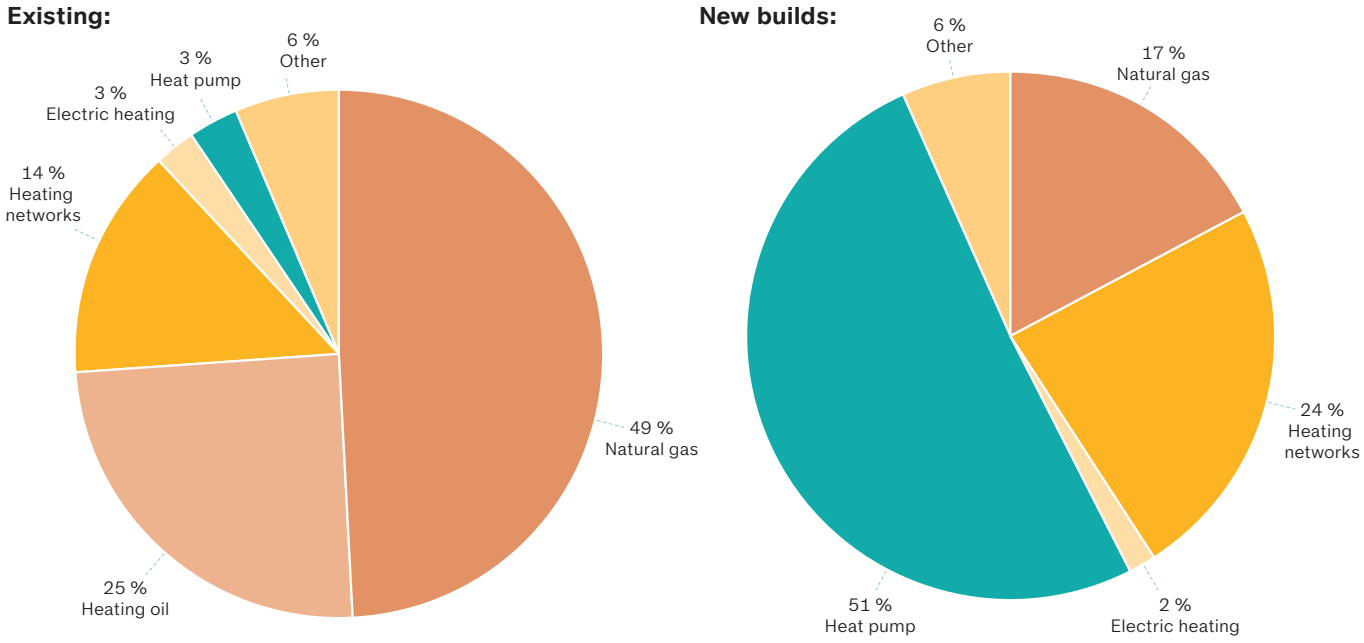


Figure 4.3: Natural gas utilisation in the buildings sector: heat generators in existing buildings (left) and new builds (right) in 2022, as of 08/2023 (BDEW, 2023b, 2023c).

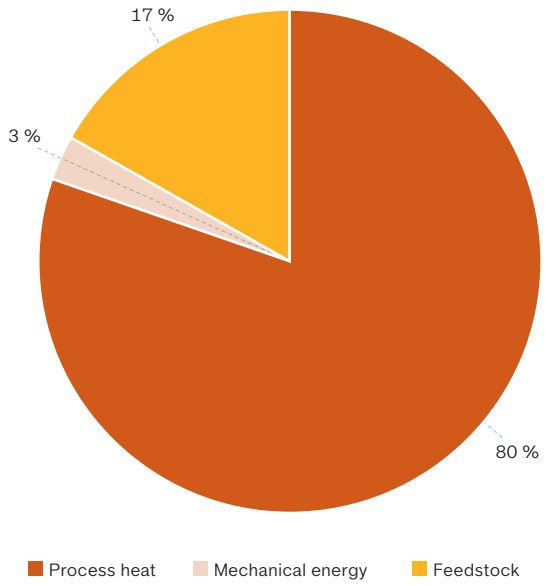


Figure 4.4: Areas of application of natural gas in the industrial sector (Fraunhofer ISI, 2022).

The technical prerequisites for independence from natural gas are in place

The technologies that can lead Germany out of its dependence on natural gas are available in all areas of application. Innovation is only needed in a few exceptional cases. This means that the reduction paths in the individual sectors can already be modelled and an end to dependence on natural gas can be estimated. In November 2022 the BMWK published initial results from the long-term scenarios project, in which all sectors are modelled with the aim of achieving greenhouse neutrality by 2045 (Fraunhofer ISI et al., 2022). The two scenarios of the project selected for this report are the economically most favourable T45-Electricity and the scenario of accelerated natural gas independence T45-RedGas calculated in response to the gas crisis in 2022. Figure 4.5 shows the reduction paths for both scenarios based on the primary energy demand for natural gas up to 2045. The modelling shows that the substitution of natural gas can be significantly accelerated.

"The substitution of natural gas can be accelerated."

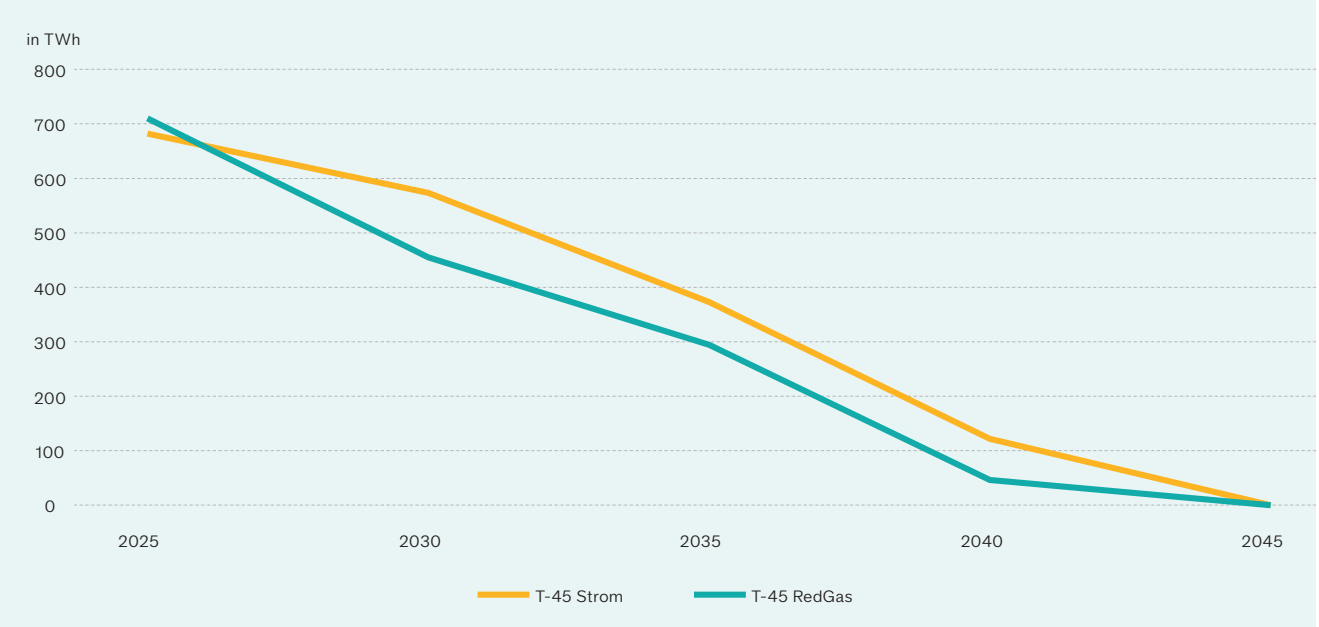


Figure 4.5: Natural gas reduction paths in primary energy consumption in the BMWK long-term scenarios (Fraunhofer ISI et al., 2022).

Three measures for natural gas-free buildings

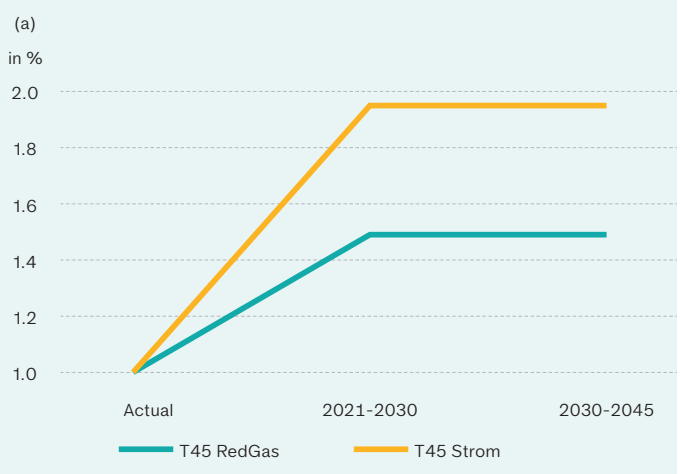
In the buildings sector, replacing natural gas in heat generation and increasing energy efficiency were the key strategies. This can be achieved in a decentralised manner by switching to renewable heating systems, particularly heat pumps. Energy efficiency through energy-efficient insulation renovation has a supporting effect. Heating networks also play a role in the conversion of the heat supply and should be expanded where a centralised supply makes economic sense. At the same time, the main challenge here is to generate heat without natural gas, for which renewable technologies such as deep geothermal energy and solar thermal energy are available. The largest share of renewable generation will be provided by large heat pumps (Ahrendts et al., 2023).

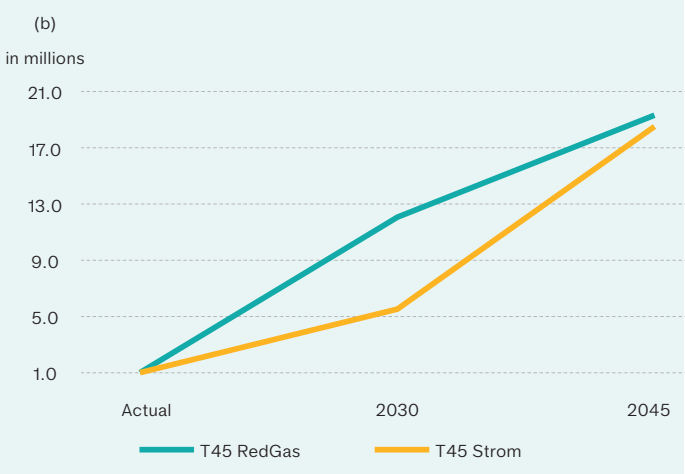
According to current figures, hydrogen will play a subordinate role for the heat supply of buildings, especially in decentralised heating systems, as only 10 % of households are located near the hydrogen core network and electrification is significantly cheaper in operation (Aunedi et al., 2023; Braungart & Bürger, 2023).

This is also reflected in the plans of the municipal utilities. At least 83 % of municipal utilities are not currently planning to convert their supply grids to hydrogen (BDEW, 2023b). Municipal heat planning will provide planning security in future and can be expected to pacify the social debate.

"90 % of households are not located in a hydrogen potential area."

Current BMWK studies show ambitious target scenarios for the diffusion of the technologies required for natural gas independence. Figure 4.6 shows the transformation paths in the two scenarios T-45 Electricity and T-45 RedGas for the energy-efficient renovation of insulation (a), the expansion of heat pumps (b) and the supply from heating networks (c). The renovation rate must be almost doubled to 1.95 % for the period up to 2045. To achieve the target of 6 million heat pumps in 2030, at least 500,000 appliances must be installed every year from 2024, according to the German government's plan (Öko-Institut et al., 2023).





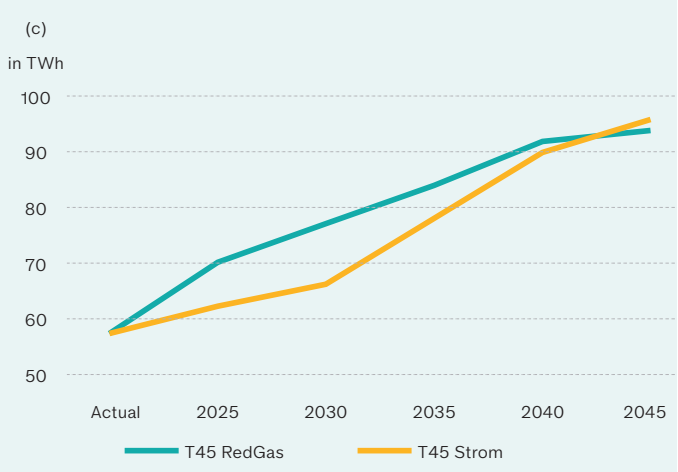


Figure 4.6: Transformation paths in the BMWK long-term scenarios for natural gas-free technologies in the buildings sector: (a) energy renovation rate, (b) installed heat pumps and (c) building supply from heating networks (Fraunhofer ISI et al., 2022).

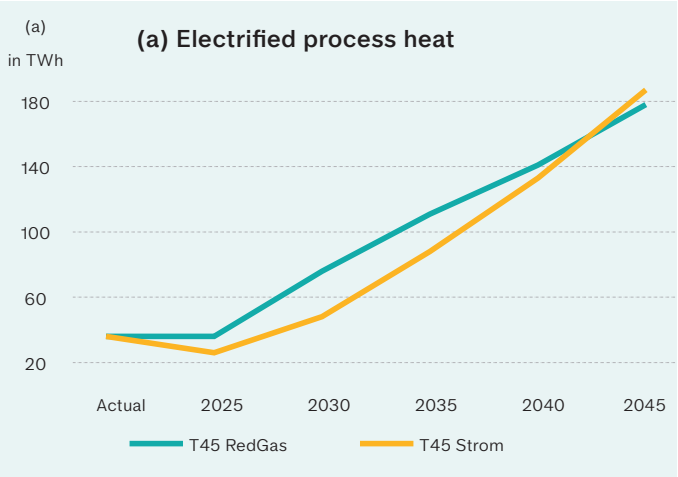
In the case of heating networks, it should be noted that the supply must also be decarbonised at the same time as the expansion. At least 100,000 new buildings must be connected to heating networks every year and 800 km of new pipes must be built each year (BMWK, 2023m) and, depending on the assumptions, up to 103.5 GW of large heat pump capacity must be added (Ahrendts et al., 2023).

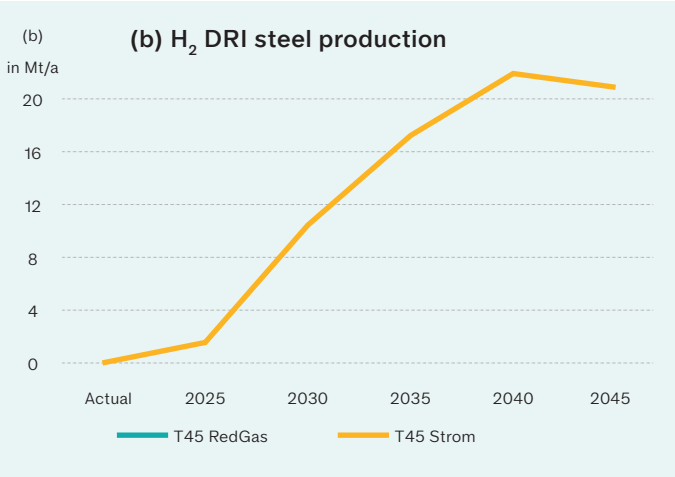
Electrification of process heat and focused use of hydrogen are alternatives to natural gas in industry

For the industrial sector, the change is focused on the electrification of process heat and the replacement of natural gas as a raw material, for which green hydrogen can be used. The specific technologies available to the industrial sectors for process heat and to the basic chemicals and steel industries for material substitution are described in more detail in Chapter 7.

Figure 4.7 shows the transformation paths of natural gas-free technologies for industry. The electrification of process heat (a) reaches a demand of approx. 180 TWh per year in both scenarios. Between 2025–2040, electrification is somewhat more ambitious in the T45-RedGas scenario. There are no major differences between the scenarios for the other transformation paths, as technological availability, e. g., of hydrogen, plays a decisive role here rather than economic considerations.

Steel production using hydrogen DRI plants (b) will only increase significantly from 2025 onwards; before then, some of the plants will still be operated with natural gas (see Chapter 7, text box): *Future of steel*). To illustrate the use of hydrogen as an alternative to natural gas in the chemical industry, the capacities of three production processes are summarised in (c): the production of ammonia and methanol from hydrogen and the production of ethylene using the methanol-to-olefins (MTO) process.





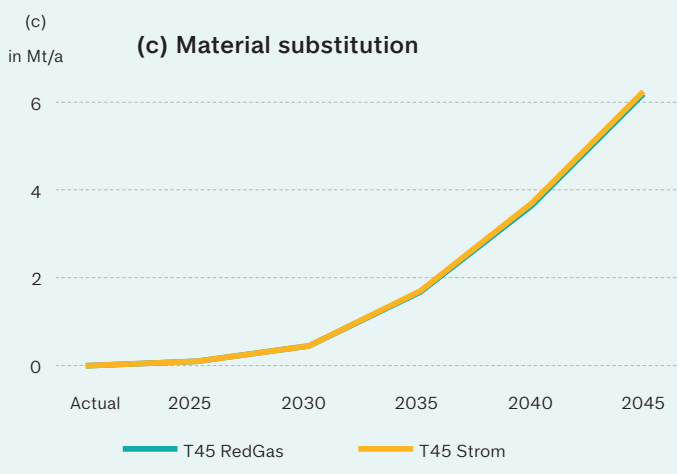


Figure 4.7: *Transformation paths according to BMWK long-term scenarios for natural gas-free technologies in the industrial sector: (a) Electrified process heat, (b) H_2 DRI steel production and (c) production of chemical base materials from hydrogen (ammonia, methanol, ethylene) (Fraunhofer ISI et al., 2022).*

5. Challenge: Mobilising investment – when the status quo is not enough

The latest developments indicate that the investment speeds defined in the scenarios in Chapter 4 and the political targets from Chapter 3 will not be achieved. This development harbours the risk of Germany's prolonged strategic dependence on liquefied natural gas (LNG) and natural gas imports and drives up demand pressure on CO_2 prices, which in turn could undermine their social acceptance in the long term. Germany is therefore not fully utilising the economic potential of natural gas independence (see Chapter 2).

At present, the renovation rate remains below 1 % , far below the required value of 1.9 % (Behr et al., 2023). To achieve the expansion target of 500,000 heat pumps per year by 2025, annual growth of 53 % would be required – however, growth is currently only 35 % (PwC, 2023a). The changeover is also not happening fast enough in the case of large heat pumps and heating networks. While new large heat pumps with a capacity of 4.5 GW would have to be installed each year, which corresponds to 340–410 projects, just 30 projects are under construction or in planning in 2023 (Ahrendts et al., 2023). Each year, around 130,000 to 150,000 new heating network connections would be required (+ 8 % per year) as well as the addition of 800 km of distribution grid routes, with only 423 km added in 2020 (Ahrendts et al., 2023). Without additional measures, the industrial sector will miss the climate target for 2045 by 29 percentage points (German Environment Agency, 2023).

In order to achieve the ambitious targets and drive forward Germany's independence from natural gas, a consistent redirection of investment capital is essential.

Based on the available data, we proceed differently in the sectors when identifying investment needs. In the industrial sector investments for the replacement of industrial plants are described, and in the buildings sector the additional investments for the replacement of natural gas (see Figure 5.1). Chapter 7 provides a further breakdown of the investment needs.

The investment costs of the industrial sector thus include all investment costs that are necessary to replace natural gas-fuelled plants with natural gas-free technologies. Fleitner et al. (2023) quantify investments for the electrification of natural gas-powered industry reference processes in which natural gas is used for process heat. We extrapolate this to the total natural gas consumption of the sectors. We also use the targets for green chemical and steel production capacities in Germany and their specific investment

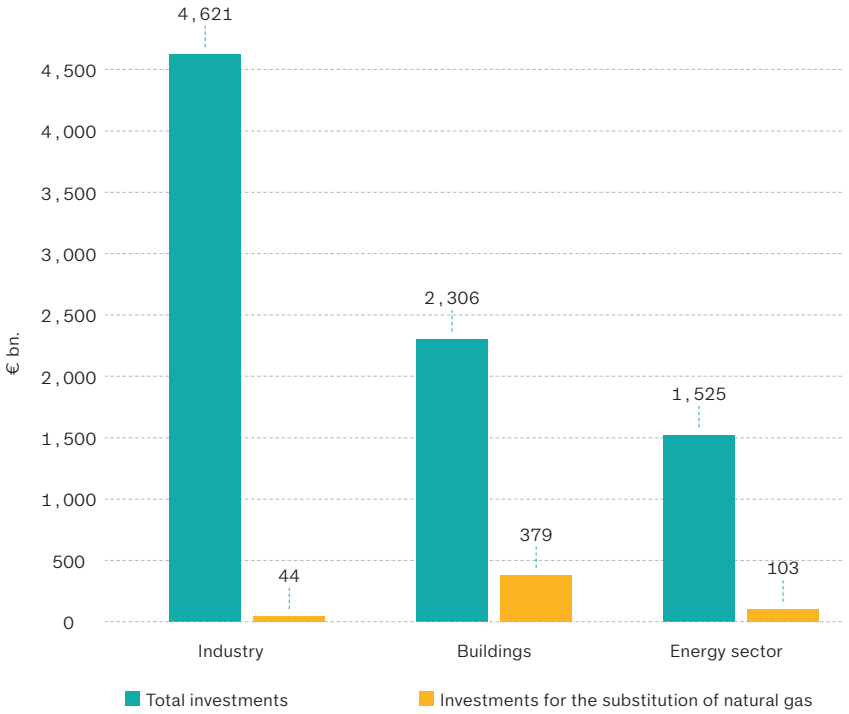


Figure 5.1: Investment needs for the substitution of natural gas in industry, buildings and heating networks compared with total investments in the sectors by 2050 (Agora Industrie, 2023; Burret et al., 2021; Fleiter et al., 2023; Hauser et al., 2022).

costs for decarbonisation to calculate the investment volumes for the material substitution of natural gas and for green crude steel production (German Environment Agency, 2023). This results in total investment needs of 44 billion euros for small and medium-sized enterprises (SMEs) and large companies in the industrial sector.

For buildings, we show the additional investments required to achieve a climate-neutral portfolio compared to the reference development. Here, investments in energy-efficient insulation renovation and the conversion of heating systems in residential buildings (including building connections for district heating) are quantified. These amount to 379 billion euros for private and institutional homeowners combined (Prognos et al., 2022). Total climate protection investments for residential buildings are estimated at 635.7 billion euros (Burret et al., 2021). In addition, heating networks must be expanded to be natural gas-free and heat generation must be decarbonised in order to enable a technological changeover in the buildings sector. In total, the investments for the expansion of heating grids, the necessary conversion to low-temperature grids and the expansion of large heat pumps add up to an investment requirement of 103 billion euros (Ahrendts et al., 2023; Biesl et al., 2023).

"The investments for a natural gas-free industry are very small in relation to the total investments expected in industry by 2050 (1 %)."

A look at the total investments of the sectors helps to categorise the reported requirements. Investments to replace natural gas amount to just 1 % of total investments in the industrial sector, 16.4 % in the buildings sector and 6.7 % in the energy sector by 2050 (Burret et al., 2021). If these investment volumes are compared with the overall financial investments in the EU, a revealing picture emerges: companies in the EU have financial assets totalling 35 trillion euros (Eurostat, 2023b). The 526 billion euros needed to make buildings and industry independent of natural gas equates to just 1.5 % of this sum. The real problem is therefore not a lack of available capital, but the allocation of these funds.

6. Classification in terms of economic theory: investment theory and political trade-offs

In view of the current political discussions about budgetary priorities in Germany, it is crucial to develop a deeper understanding of which policy measures can actually mobilise private capital effectively. Economic theory can help to identify key factors that influence investment decisions for natural gas independence. We analyse how path dependencies and uncertainties can lead to delays in investments in natural gas-free technologies and infrastructure.

From theory, we derive four possible policy objectives facing policymakers when it comes to mobilising private capital. These include

1. static efficiency and technological openness

2. dynamic efficiency and economies of scale

3. high investment momentum

4. social and political acceptance.

It will not be possible to achieve all goals at the same time – a fact that characterises every economic policy debate.

Standard theory

In neoclassical investment theory, investments are made in order to maximise profit. This applies as long as the marginal value of an investment is greater than its marginal costs (positive marginal product). The calculation of value and costs depends on various factors. In the following we limit ourselves to selected aspects that are relevant for analysing the barriers to investment of the stakeholders mentioned in Chapter 4.[1]

In neoclassical models, the net present value (NPV) of an investment plays a decisive role (Dixit & Pindyck, 1994; Pindyck & Rubinfeld, 2012). The NPV is calculated by discounting the future net cash flows to the present date. A positive NPV indicates that the investment is profitable.

The higher risk of an investment is reflected by a higher discount rate. From a business perspective, the expense items of the net cash flow include capital expenditure (CapEx), operating costs (OpEx), financing costs including interest expenses, as well as depreciation, amortisation and opportunity costs. On the income side, cash flows from sales revenue, operating cost savings and financial benefits such as tax advantages are taken into account. These cost types are particularly relevant for the stakeholder analysis in Chapter 7 in order to assess the impact on profitability.

"The political conclusions drawn from neoclassical equilibrium models are subject to important limitations."

It is essential for the political categorisation that the standard theory is based on specific basic assumptions. Models assume, among other things, rational investors who have complete information about future developments and convex adjustment costs. These assumptions also underlie the macroeconomic dynamic equilibrium models according to the approach of Nordhaus (1993) and related integrated assessment models (Krusell & Smith, 2022), in which investments are optimised intertemporally.[2] These models underline that the internalisation of costs through environmental taxes or emissions trading systems is the most cost-effective method of addressing climate change – a demand that is also reflected in the recommendations of the German Council of Economic Experts (German Council of Economic Experts, 2019).

Models and theory have been continuously expanded over the years through different approaches, even if these developments are often neglected in the public debate. We focus here on analyses based on the work of Acemoglu et al. (2012, 2016) on competition between green and fossil technologies and path dependencies and, for microeconomics, on real options theory for investments under uncertainty (Dixit & Pindyck, 1994).

1 We also refer to the literature for a more in-depth discussion (Pindyck & Rubinfeld, 2012).

2 For a detailed discussion of further basic assumptions of macroeconomic equilibrium models, see Krebs (2023a), among others.

Investing under path dependencies

The political conclusions drawn from neoclassical equilibrium models are subject to significant limitations, especially if technical progress in green technologies is assumed to be exogenous (as is also the case in the latest model by Barrage & Nordhaus (2023)) or if no differentiation is made between different technologies.

In contrast, the work of Acemoglu (2012, 2016) considers the competition between green and fossil technologies and models technical progress and its development endogenously. His work sheds light on the path dependencies that arise in the substitution of fossil technologies.
Fossil technologies benefit from a larger market volume and initially higher productivity, which steers investment and innovation in this direction. These path dependencies can be observed at various points. Investments in fossil fuels still exceeded investments in clean energies until 2015 (IEA, 2023b). The construction of LNG terminals was also accelerated during the energy crisis due to the lack of alternatives that could be realised in the short term.

"CO_2 prices alone do not lead to a socially optimal result."

Acemoglu's model (2012, 2016) shows that CO_2 prices alone do not lead to a socially optimal reduction pathway for emissions. Although they have a direct impact on the profitability of an investment, they only have an indirect effect on the steering of innovations. As a result, the productivity level of green technologies will not remain competitive for a long time. However, innovations that lead to productivity increases through economies of scale and learning effects are crucial for the diffusion of green technologies. One example of this is the exponential growth of photovoltaic production, which is now driven by cost advantages over fossil technologies – also as a result of the early German EEG subsidisation. According to Acemoglu (2012, 2016), for CO_2 prices to drive not only investment but also innovation, they would have to reach excessive levels that are not socially feasible.

The logic of path dependencies can also be applied to other areas in which technologies are expected to prevail under unfair competitive conditions. The expansion of production capacities for heat pumps, the electrification of industrial plants – all of this is taking place under distorted market conditions that are the result of years of investment in fossil-fuelled economic activities. Drivers of unfair competition are not only price advantages, but also the existing infrastructure, knowledge, skills of the population, existing standardisations or habits.

Without taking these factors into account and creating fair competition that addresses all these differences, economic policy risks either delaying investment or continuing to channel capital into fossil fuel technologies that still enjoy a productivity advantage. In the short term, the competitive advantages of natural gas-free technologies could theoretically be offset by CO_2 prices (static efficiency, see text box). However, the price level required for this would be difficult to implement politically and would be accompanied by significant reductions in production and consumption (Acemoglu, 2012). A policy mix of CO_2 prices with subsidies is the more effective instrument for realising long-term productivity potential and creating dynamic efficiency.

Static and dynamic efficiency

Static efficiency exists when existing resources are used optimally at a certain point in time and maximise the overall benefit. It concentrates on the efficient distribution and use of *existing resources and technologies.*

Dynamic efficiency exists when overall benefits are maximised over time and takes into account the long-term allocation of resources, with a view to future production, technological development and changing market conditions. It also reflects investments in innovation and infrastructure, among other things.

Investing under uncertainty

In addition to path dependencies, uncertainty and the irreversibility of investments play a key role in investment decisions. Instead of complete information, as the standard theory assumes, companies are confronted with incomplete information – be it regarding future technological developments, changing regulatory conditions, capital interest rates or price fluctuations.

The real options theory according to Pindyck and Dixit (1994) helps to understand the effects of these uncertainties on investment decisions. The starting point is that companies can invest, but do not have to. Under certain circumstances, it may be optimal for companies to delay investments, even if the net present value is positive. Once capital has been invested, it is either impossible or costly to withdraw it.

"Potential income from an investment must not only exceed the costs but also the value of the waiting option."

The option value of waiting is decisive for whether an investment is made. This value increases when waiting can provide more accurate and informative data that leads to more informed decisions. In uncertain market conditions, the potential income from an investment must not only exceed the costs but also the value of the waiting option. This leads to companies setting higher hurdles for investments and delaying them until there is greater certainty, which has also been empirically observed (Fleten et al., 2016).

As Pindyck and Dixit argue, it is primarily measures that reduce economic volatility and uncertainty that mobilise investment (Dixit & Pindyck, 1994). This includes secure sales trends for certain technologies as well as stable tax conditions and reliable regulatory requirements. But financial incentives such as tax breaks, subsidies or grants can also make immediate investments more attractive. CO_2 prices alone are therefore not only in tension with dynamic efficiency and social acceptance. The resulting uncertainty also risks delaying early investments. The same applies to technological openness.

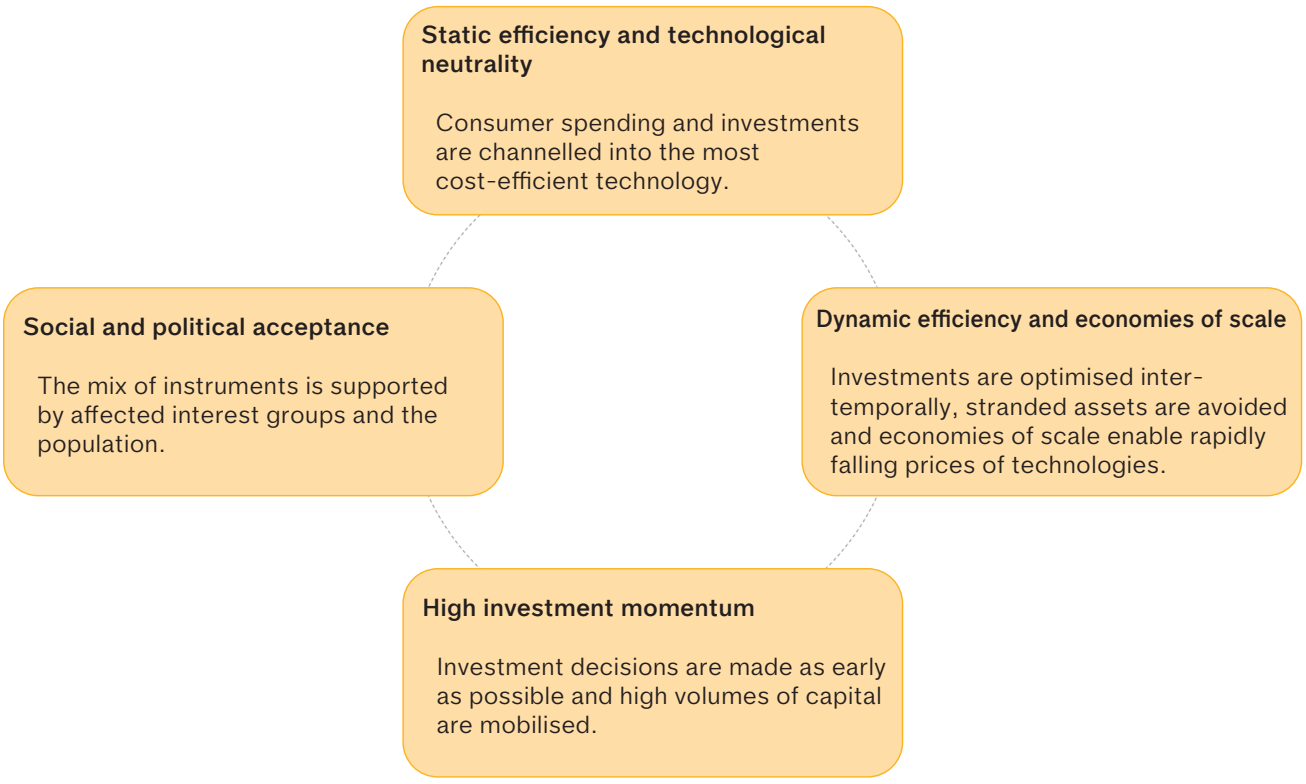


Figure 6.1: Possible political trade-offs in a socially balanced transformation towards natural gas independence (own presentation).

Political trade-offs characterise the debate

Affordability is a key issue in any energy policy debate and investments have a direct impact on it. The discussion often focuses on the relationship between the short-term costs resulting from direct price increases, the shift from consumption to investment or debt, and the long-term costs resulting from a prolongation of natural gas dependency, energy price shocks, climate costs or missed value creation potential. These are also weighed up against the short and long-term effects on competitiveness.

"Any policy mix to accelerate investment must prioritise between four policy objectives."

These comparisons can be objectified on the basis of the theories discussed. Since investment decisions are not determined by profitability alone, but are characterised to a considerable extent by path dependencies and uncertainties, political decision-makers are faced with the dilemma of balancing four objectives that cannot be realised simultaneously when creating cost efficiency (Figure 6.1).

Any policy mix of market-based instruments such as CO_2 pricing, regulation and promotion must prioritise between these four objectives, as we show in Table 6.1. This also applies to the measures presented in Chapter 8.

Table 6.1: Political trade-offs in the acceleration of investments through CO_2 prices, regulation and subsidies in comparison (own presentation)

CO_2 prices	Regulation	Subsidies
· Strengthen static efficiency and technological openness. · Do not achieve dynamic efficiency without additional funding, especially not in the short term. · Excessively high CO_2 prices could undermine social acceptance. At the same time *market prices* are more difficult to attack than *policy regulation*. · Risk the delay of investments in the event of uncertainty and volatile prices.	· Can limit static efficiency by excluding certain technologies. · Contributes to dynamic efficiency and economies of scale if it clearly specifies investments in promising technologies and decisions are made on the basis of evidence. · Impairs social acceptance in the short term, but can promote social acceptance in the long term through price reductions resulting from dynamic efficiency. · Creates a high level of investment momentum through binding framework conditions. · Easily politically vulnerable, as it is often directed at specific technologies or economic activities.	· Can impair static efficiency in the short term, but support dynamic efficiency. · Under the assumption of path dependencies, dynamic efficiency and economies of scale are promoted, in particular through targeted support for new technologies. It must be ensured that funding not only strengthens the availability but also the competitiveness of the new technologies. · Supports high investment momentum by mobilising capital and ensuring profitability. · Improves social and political acceptance by mitigating distributional effects and facilitating access to capital.

7. Deep dives: The buildings, industrial and finance sectors

In three deep dives, we analyse which stakeholders policymakers need to mobilise in order to pave the way to natural gas independence and which priorities need to be set to achieve this.

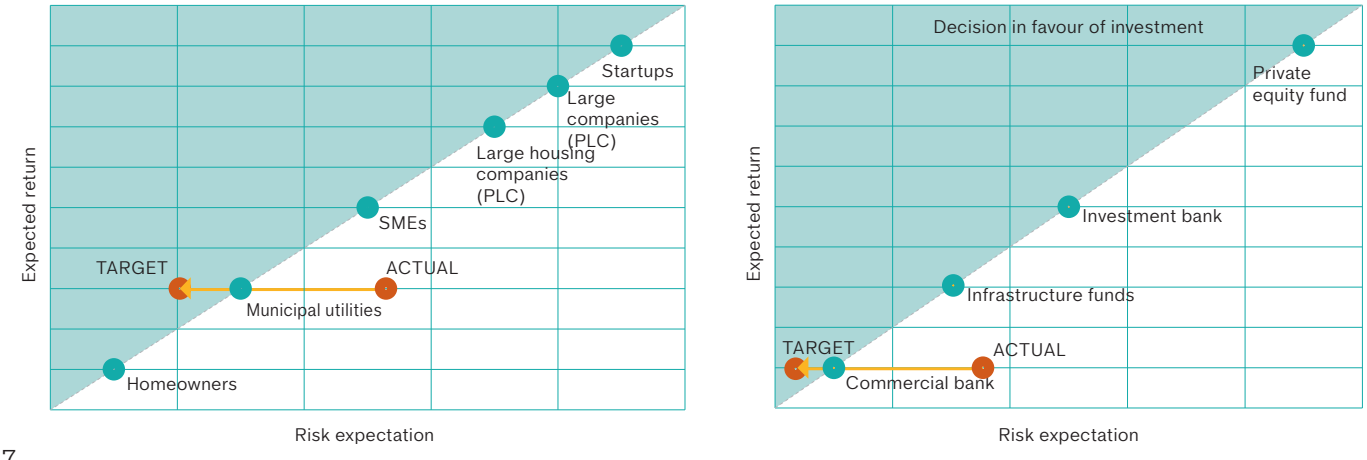
In Chapter 2, we already explained that natural gas independence not only reduces energy price volatility and geostrategic dependencies, but also minimises transition and climate risks while opening up new markets and value creation potential. This requires a clear and coherent policy framework that mobilises a commitment from society as a whole to overcome the many obstacles that prevent financial companies, the real economy and citizens from investing in natural gas-free technologies. The following results outline a prioritisation of the obstacles. They are based on analyses by the Council, stakeholder interviews and literature evaluations and form the basis for the development of targeted measures in Chapter 8.

The transition to independence from natural gas requires a decisive redirection of capital flows: by 2045, around 480 billion euros in the building sector and around 44 billion euros in industry will have to flow from current fossil fuel plants to investments in natural gas-free technologies (see Chapter 5). In order to realise this objective, successful matching between capital takers – including private homeowners, housing companies, municipal utilities, small and medium-sized enterprises (SMEs) and large industrial companies – and capital providers such as commercial banks, investment banks and investment funds is essential. The efficient dovetailing of both sides is central to the successful financing of structural change.

Two factors play a central role here:

1. From the perspective of the stakeholders, the ratio of expected return to risk is decisive for investment decisions. This varies depending on the stakeholder and is illustrated schematically in Figure 7.1: homeowners tend to have a lower risk tolerance and return expectation than large companies, while commercial banks tend to have a lower one than investment funds. Too high a risk or too low a return can inhibit investment decisions (shown in the white area of Figure 7.1). It is important to differentiate between perceived and actual risk.
2. In addition, the stakeholders must not only be able to make the necessary investments financially, but also structurally. For example, homeowners need access to a heating network for connection, municipal utilities need internal planning capacities for the expansion of district heating and companies need a suitable electricity grid connection for the electrification of processes. Every stakeholder needs access to the necessary technologies and skilled labour.

Figure 7.1: Illustrative representation of the return and risk expectations of capital demand stakeholders (left) and capital supply stakeholders (right). Yellow arrows illustrate the possibility of promoting investment decisions by changing the perception of risk (Baker & Whitaker, 2023; Whitehouse et al., 2020).



Five overarching conclusions can be drawn, which are specified and supplemented in the following chapters:

1. Available technologies offer **alternatives to natural gas** and have been **proven in use**with a few exceptions.
2. **In the sectors considered here, hydrogen should primarily be used in industry in order to optimally utilise its potential.**
3. **In the buildings sector, the transition is particularly complex** due to the diverse stakeholder structure, differentiated interests, the long-term infrastructure conversions required and the high investment volumes. This requires extensive coordination.
4. **The cost types are distributed differently within the sectors:** While the buildings sector has significant capital expenditure (CapEx), operating expenditure (OpEx) is the main problem for industrial companies.
5. In individual industrial sectors, considerable savings can be achieved through **reasonably low costs**.

7.1 Heat transition for natural gas-free buildings

In the buildings sector, private homeowners, municipal utilities and energy service providers as well as housing companies must be mobilised to accelerate further investment in insulation renovation and renewable heat generation (see Figure 7.2). For the sake of simplicity, the analysis of the measures and investment barriers of the stakeholders in this chapter refers to residential buildings. This analysis also provides important insights for non-residential buildings, as the necessary measures and challenges are similar. Accordingly, the proposals outlined in Chapter 8 can also mobilise investment in non-residential buildings.

Nine conclusions can be drawn for the buildings sector:

1. **Conversion of heat generation**
   The transition to natural gas-free buildings primarily requires the replacement of technologies and the corresponding infrastructure and is supported by an increase in energy efficiency.
2. **Mobilising institutional stakeholders**
   Institutional stakeholders such as housing companies, energy service providers and municipal utilities are the key to the efficient allocation of private-sector capital and the scaling of the heat transition.
3. **Savings potential and investment requirements** vary – The greatest natural gas savings potential and investment needs lie with private homeowners, while municipal utilities face high concentrated costs.
4. **Two brakes on housing companies**
   Deteriorating credit conditions and bureaucratic obstacles are putting housing companies under pressure.
5. **Natural gas-independent municipal utilities**
   Municipal utilities must now develop new business models in order to compensate for sharp declines in revenue from the gas business and secure their future competitiveness.
6. **Unharnessed potential of the energy service providers**
   The complexity in the case of apartment blocks, limited access to subsidies and high liabilities reduce the potential of energy service providers to play a major role in the heat transition.
7. **Access to capital for private homeowners**
   15–30 % of private homeowners have problems accessing capital, and there are also structural barriers to investment.
8. **Fostering investment readiness**
   Lack of utilisation of advisory and funding services coupled with an aversion to long-term loans inhibit private investment.
9. **Shortage of skilled labour in the craft sector as a cross-sectional challenge**
   The craft sector faces major challenges in securing and mobilising skilled labour – further measures to mobilise skilled labour are necessary.

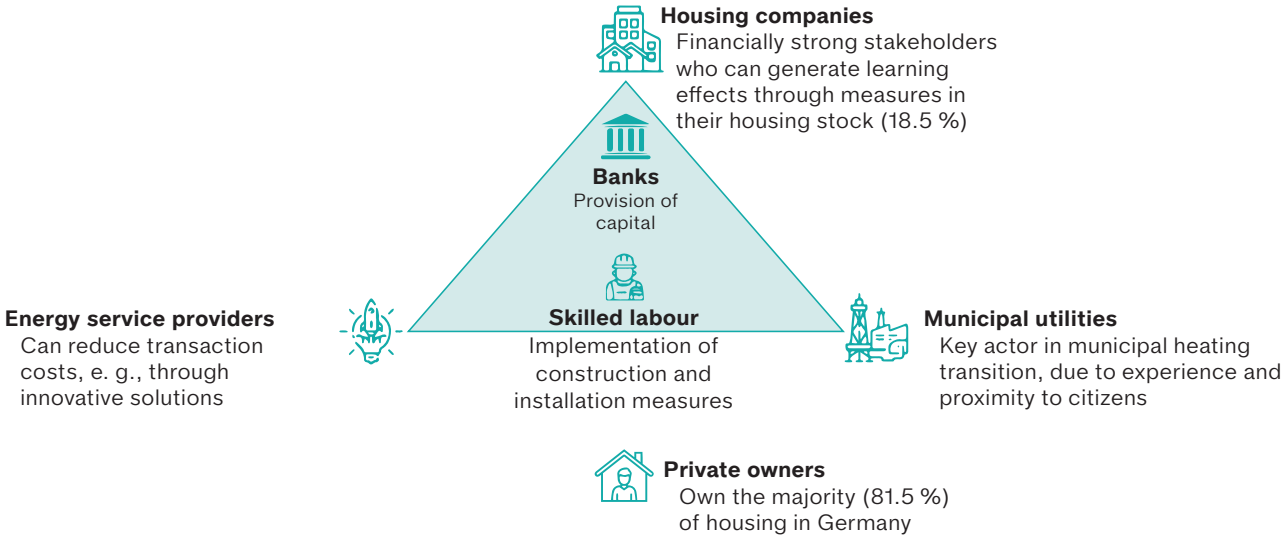


Figure 7.2: Stakeholders in the heat transition (BMWSB, 2022).

Conversion of heat generation

The transition to natural gas-free buildings primarily requires the conversion of technologies and the corresponding infrastructure and is supported by an increase in energy efficiency. The most important technologies for this are:

1. **Heat pumps** are the most cost-effective and energy-efficient technology for decentralised heating in the long term (Gibb et al., 2023; IEA, 2022) and could be the fastest way for Germany to achieve gas independence (Altermatt et al., 2023).
2. In sufficiently populated areas, instead of decentralised heating technologies, **heating networks**that are fed CO_2-neutrally from renewable energies or unavoidable waste heat are worthwhile, with large heat pumps playing a key role.
3. In parallel, an **energy-efficient renovation of insulation** can reduce the energy demand for both technologies.

Depending on the requirements of the building, other (hybrid) heating systems can also be a technical solution in some cases. However, hydrogen-powered heating systems are only an option for the heat transition in exceptional cases. Even if all buildings in the vicinity of the planned hydrogen network were to be heated with hydrogen (which seems unrealistic), this would only affect 10 % of the German building stock (Öko-Institut, 2023). In addition, hydrogen should be reserved for applications with no alternative (see text box *The role of hydrogen for natural gas freedom*) – This keeps price pressure low, thus ensuring the competitiveness of the industry and minimising Germany's dependence on hydrogen imports.

The role of hydrogen for natural gas independence

Hydrogen should primarily be reserved for applications for which there is no alternative. These 'no regret' applications currently include ammonia production in basic chemicals and electricity generation in combined heat and power (CHP) plants (Wietschel et al., 2021). Steel production, shipping and aviation will be added in the future. In a further series of application areas, it is still unclear whether hydrogen or direct electrification is the most cost-effective alternative. Examples of this include high-temperature heat, heavy goods vehicles on the road and seasonal electricity storage. Due to the lack of clarity with regard to costs, technological lock-ins should be avoided in these sectors.

Heating is not one of the fields of application in which hydrogen could play a role. Numerous studies show that direct electrification is the more cost- and energy-efficient option compared to hydrogen (Agora Energiewende & Industrie, 2022; Cebon, 2020; Gerhardt et al., 2020; Wietschel et al., 2021). Green hydrogen for heating requires six times more electricity to produce than heating with a heat pump (Cebon, 2020; Gerhardt et al., 2020). The higher electricity costs for production will also be reflected in the price for households, even if the hydrogen were imported from abroad.

The supply of green hydrogen in Germany will be scarce and dependent on imports from abroad. The National Hydrogen Strategy (NHS) aims for a domestic electrolysis capacity of ten GW (BMWK, 2023g). However, this will most likely not be enough to cover all demand in industry, the energy sector and transport (Merten & Scholz, 2023). Germany must therefore be prepared to become dependent on hydrogen imports.

It is also to be expected that the uncertainties regarding the timing and quantity of available green hydrogen and the associated competition for utilisation could cause prices for households to rise sharply.

In view of this shortage and the significant economic risks associated with it, an increase in the demand for hydrogen through hydrogen heating in existing buildings should be viewed with great caution. This would further increase dependence on imports and merely lead to a problem shift between natural gas and hydrogen. In addition, increased demand raises the price, so that industry in particular would be faced with higher costs. An unnecessarily high demand for hydrogen would therefore also damage the competitiveness of Germany as an industrial location.

Table 7.1: Fields of application of hydrogen according to Wietschel et al. (2021)

No alternative → No-regret	Unclear → Avoid lock-ins	Electrification is cheaper
· Basic chemicals, ammonia · Steel production · Shipping and aviation	· High-temperature heat · Heavy goods traffic (road) · Seasonal electricity storage	· Decentralised heating · Low-temperature heat · Car

The mobilisation of capital is crucial for the entire value chain of natural gas-free technologies such as heat pumps, heating networks and insulation renovation. This covers all phases: from production and implementation through to installation, operation and disposal. The value chain is characterised by a wide range of participants, including suppliers, product manufacturers, construction companies, installation specialists and end users.

Most manufacturers of insulation materials, windows and doors are micro, small and medium-sized enterprises (SMEs). Although the market for heat pumps is also partly characterised by SMEs, a market consolidation can currently be observed (see also Chapter 2).

Large companies are also relevant for technologies in the field of heating networks, such as solar thermal and geothermal systems and large heat pumps.

We are therefore focusing our analysis on the demand side. On the production side, a strong dynamic can already be observed, as can be seen in the example of heat pump production (see text box *Heat pump ramp-up*). The development of large heat pumps is also progressing rapidly – significant increases in output and temperatures have been observed in the last three years (Ortner et al., 2023). A reliable industrial policy framework and directional certainty are required for this to be consistently transferred to all relevant sectors – especially mechanical and plant engineering.

Heat pump ramp-up

The BMWK announced a heat pump campaign in 2023 with the aim of installing 500,000 heat pumps per year from 2024 (BMWK, 2023d). The announcements have already translated into real investments on the production side. Viessmann and the Bosch Home Comfort Group are each planning to invest 1 billion euros in expanding their production capacities by 2030 (Bosch, 2023; Viessmann, 2022). Vaillant has even more ambitious goals and wants to invest up to 2 billion euros by 2030 (Vaillant Group, 2023). Stiebel Eltron has also announced plans to expand its production capacities. The company plans to invest 670 million euros by 2027 (Stiebel Eltron, 2023). The trend towards expanding heat pump production is not limited to Germany, but is also finding favour internationally. The Japanese company Daikin Industries, one of the world's leading manufacturers of heat pumps, is planning to invest 840 million euros in existing production facilities in Europe by 2025 (Daikin, 2021).

This momentum must be maintained if the heat pump ramp-up is to be successful. Among other things, the debates surrounding the amendment to the Building Energy Act (GEG) led to applications for heat pumps almost halving in the first half of 2023 compared to the previous year (Tagesschau, 2023). Strategic industrial policy and simplified authorisation procedures coupled with reliable funding structures can support this.

Mobilising institutional stakeholders

Institutional stakeholders such as housing companies, energy service providers and municipal utilities are the key to the efficient allocation of private-sector capital and the scaling of the heat transition.

By analysing the value chains of the three transformation paths of energy-efficient insulation renovation, heat pumps and heating networks in the buildings sector, as well as discussions with stakeholders from the respective areas, we have identified groups of stakeholders and their individual structural and economic obstacles.

Homeowners

The first group of stakeholders are homeowners. These can be both private homeowners and institutional stakeholders. In Germany, the majority of residential units (81.5 %) belong to just under 21 million private homeowners (Figure 7.3) (IW Köln, 2017). These include private landlords and owner-occupiers who live in their own house or flat. Homeowners' associations are also counted as private stakeholders. The remainder (18.5 %) is attributable to institutional homeowners with different legal forms (Figure 7.3) (IW Köln, 2017). The latter mainly own apartment blocks, while most single-family homes are in the hands of private homeowners.

A large proportion of institutionally managed homes (18.5 % of total residential units) are owned by private companies (36 %), local authorities (29 %) or cooperatives (27 %) (BMWSB, 2022). A smaller proportion of homes are also attributable to the federal and state governments (4 %) and non-profit organisations (4 %).

In total, there are around 69,000 institutional homeowners in Germany. While private homeowners own an average of 1.7 residential units, one institutional owner owns an average of 114 residential units. In this way, institutional homeowners bundle a larger number of homes and can thus generate investment and scaling dynamics. This leverage is reinforced by a high level of market concentration among private housing companies. Of the almost 3 million homes owned by private companies, a good third belong to the seven largest property companies (Savills, 2019).

"18.5 % of homes are owned by institutional homeowners."

Energy supply companies

The second group includes companies that are active in the gas, electricity and district heating industries. At the end of 2022, there were 2,294 energy supply companies in Germany, of which 700 were gas distribution network operators, 1,038 were gas suppliers and 465 were district heating network operators (companies can be active in several business areas) (BDEW, 2023a). In these business areas, which are critical for the technology transition, the majority of companies are municipal utilities. In this report we define them as energy supply companies with municipal participation and place them at the centre of our analysis, as they play a key role in the (municipal) heating industry and politics through their gas business and the district heating networks.

"Among the large municipal utilities, 60 % are organised as limited companies and 40 % as public limited companies with mostly municipal ownership."

The approximately 1,000 municipal utilities in Germany enjoy a high level of trust among citizens and are therefore well placed to play a pioneering role in the heating transition (Beier et al., 2020). Municipal utilities are fundamentally heterogeneous and differ in terms of

their business models, number of end customers and the regionality of their offerings. Most of them are organised in municipal cross-associations, some of which are cross-financed with other business areas (e. g. profits from the energy business offset losses in public transport) (Schrems & Eulgem, 2022). Municipal utilities are also organised differently in terms of their legal form. An analysis of the 77 largest municipal utilities has shown that around 60 % of these are organised as GmbHs and 40 % as AGs. Of the 77 municipal utilities, around 70 % are municipally owned with shares of over 50 %. Market concentration is very high at regional level, as the largest municipal utilities provide a significant proportion of the total energy supply and district heating supply. It is therefore worth focusing in particular on municipal utilities in cities with over 100,000 inhabitants, as these have the largest supply areas.

Energy service providers

The third group is energy service providers, who will play an important role in the future energy industry thanks to their customer-orientated service offering. This report focuses on the providers of heating services. These include services such as heat supply contracting, heating rental or leasing and the supply chain model for heating systems. In the case of a heating service, the property owner transfers the tasks of heat supply and the associated investment costs to a professional service provider (Verbraucherzentrale, 2022). Its expenses are paid off via monthly instalments over several years, in the best case on a cost-neutral basis from the savings on heating costs for the property owner (BfEE, 2023).

Households are offered the opportunity to replace their fossil-fuelled heating system with a renewable solution, such as a heat pump, as part of a full service that includes all installation and maintenance steps. For energy services, new companies such as cleantech start-ups can dynamise the market with innovative products; in the same way, municipal utilities can also focus more on energy service products to support their customers in the energy transition and at the same time build sustainable business areas.

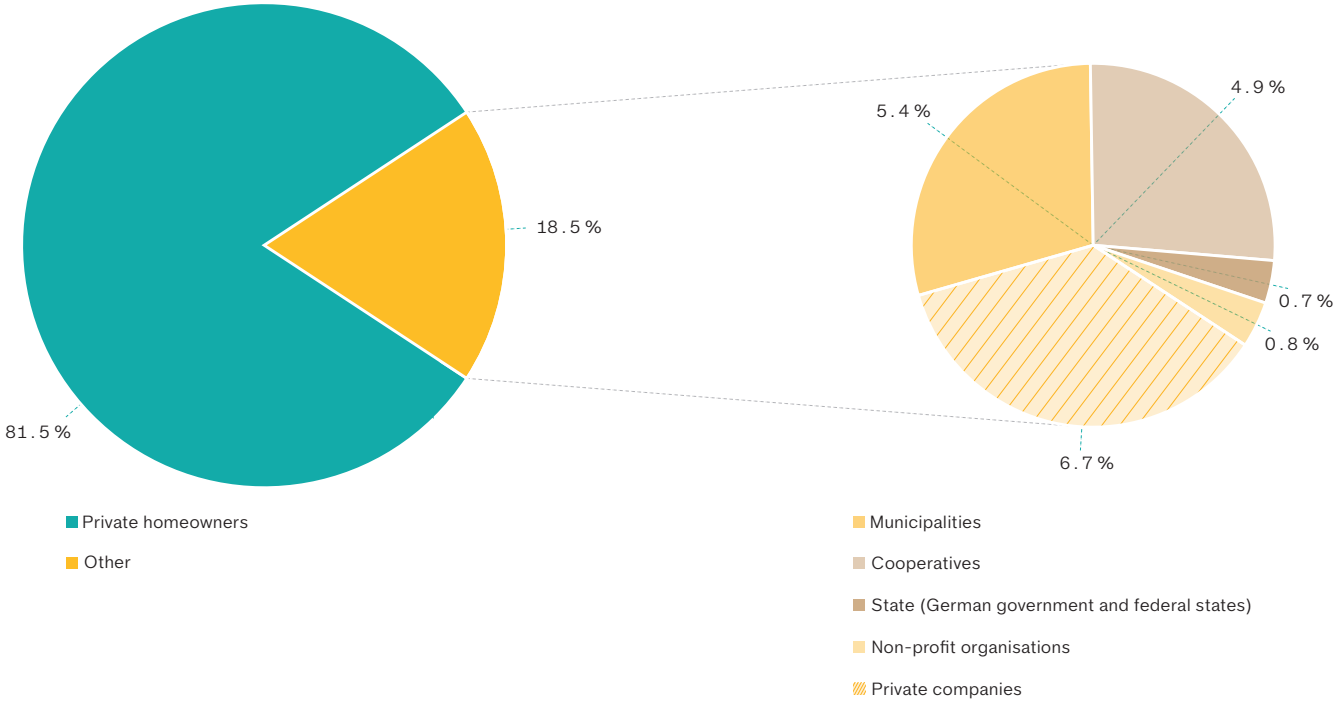


Figure 7.3: Proportions of homes in Germany by ownership type and legal form (IW Cologne, 2017; BMWSB, 2022).

Non-profit-orientated operation of heating networks

In addition to the stakeholders mentioned, there are also options for the legal restructuring of the heat supply. This includes the non-profit-orientated operation of the heat supply (local and district heating). One example of this is the heating legislation in Denmark, where the non-profit principle applies to the entire public heating supply and therefore also to the heating suppliers themselves. Utility services may not be used for indirect taxation (by municipalities) or indirect subsidisation of citizens (Danish Energy Agency, 2015). According to the *Danish Heat Supply Act*, the Danish district heating supply is therefore not profit-orientated but cost-covering and is thereby predominantly provided by municipal companies or cooperatives (Bürger, 2022; Köhler et al., 2023). This form of organisation offers the advantage that heating networks with lower yield profiles can also be expanded.

Craft sector

The craft sector plays a central role in the implementation phase and comprises around 30 trades, 490,000 companies and over 3 million employees. Of these trades, 18 in particular are decisive for the implementation of the measures mentioned, including electrical engineers/installers, heating engineers / well builders and chimney sweeps. Other trades such as roofers, glaziers and carpenters are also important for the energy-efficient renovation of buildings (ZDH, 2023b). The craft sector plays a key role in advising, designing and implementing technology and infrastructure measures on site. It is crucial that the supply of qualified tradespeople keeps pace with rising demand – otherwise many projects may be significantly delayed (Römer & Salzgeber, 2023).

Savings potential and investment needs vary

The greatest natural gas savings potential and investment needs lie with private homeowners, while municipal utilities face high concentrated costs.

Private homeowners, institutional property owners and energy supply companies will have to invest different amounts in their transformation projects in order to manage the technology transition and thus achieve climate neutrality in the buildings sector by 2045 (Figure 7.4). The BMWK's background paper Building Strategy Climate Neutrality 2045 shows the additional investments up to 2045 (Prognos et al., 2022). At 259 billion euros, the largest share is for the conversion of decentralised heat generation from natural gas and oil heating systems, e. g., to heat pumps, or for connecting buildings to district heating, followed by investments for the energy-efficient renovation of the building insulation at 120 billion euros. These two items must be borne by private and institutional homeowners. The third major investment item for the heat transition is the expansion, conversion and decarbonisation of heating networks. Energy supply companies will have to mobilise 7.1 billion euros to expand their heating networks, 13 billion euros to convert to low-temperature grids and 82.8 billion euros to add 103.5 GW of large heat pumps at an average cost of 800 euros/kW (Ahrendts et al., 2023; Biesl et al., 2023). Estimates are heavily dependent on assumptions. Ortner et al. (2023), for example, indicate a significantly lower volume of large heat pumps and AGFW (2020) assumes conversion costs for heating networks of around 30 billion euros by 2030 alone.

The potential for reducing natural gas consumption and the associated additional investments are shown in Figure 7.5. Private homeowners have the largest aggregated consumption and the highest additional costs overall, but are also by far the largest stakeholder group in terms of numbers. On average, each owner accounts for 0.01 GWh and 15,000 euros.[1] The gas consumption per housing company is 0.68 GWh with a higher additional investment of 1 million euros per stakeholder. Energy suppliers, the smallest group of stakeholders in terms of numbers, have a disproportionately high natural gas consumption of 67 GWh for heat generation in heating networks. At the same time, individual companies are burdened with particularly high costs – an average of 102.9 million euros per stakeholder for the transition of their heating network. Costs depend very much on regional circumstances. Biel et al. (2023) estimate investment needs of up to 120 million euros for an energy supply company for the conversion of heating networks alone.

1 The costs are not representative, but only serve to compare the stakeholders, as the calculation of the mean values also includes stakeholders who have already made investments.

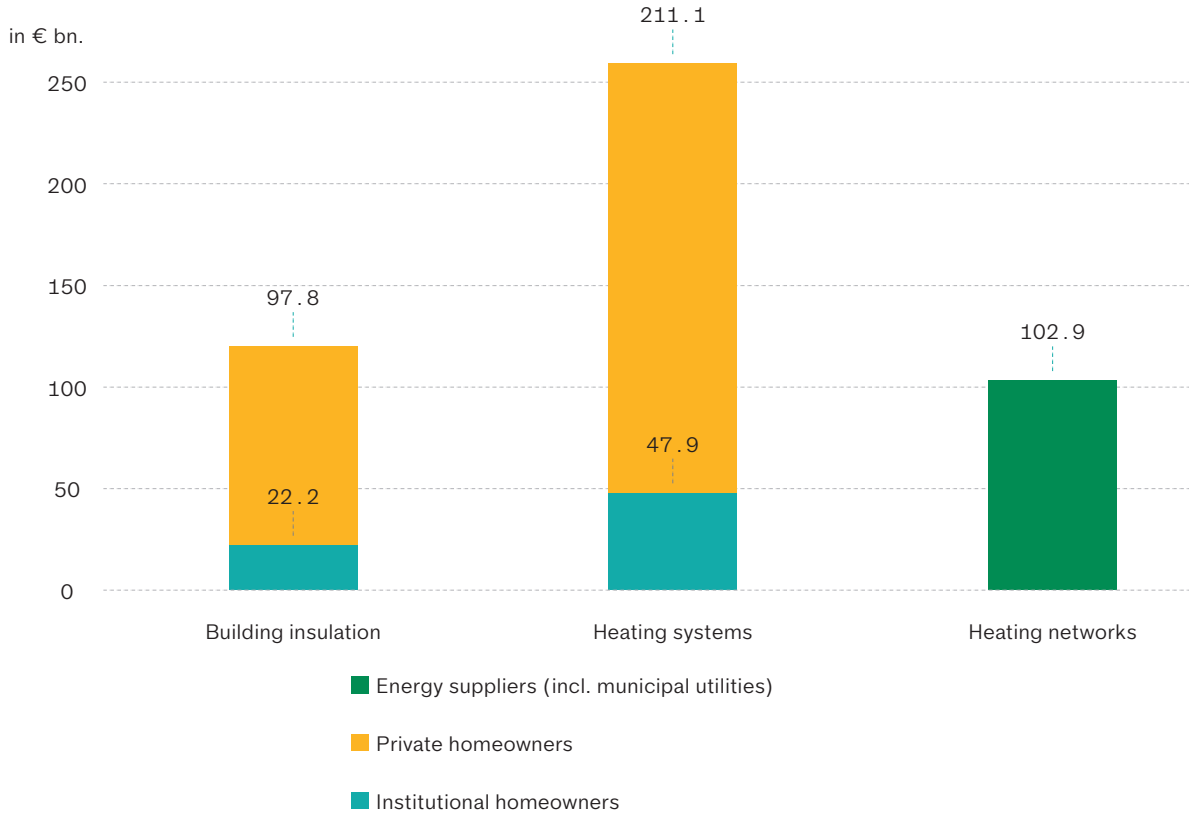


Figure 7.4: Additional investment volumes for a climate-neutral building stock in 2045 by technology and stakeholder (Ahrendts et al., 2023; Biesl et al., 2023; BMWSB, 2022; Prognos et al., 2022).

Depending on the situation, up to 500 million euros can be added for large heat pumps in particularly large grids (Ahrendts et al., 2023). The high concentrated costs made municipal utilities one of the key stakeholders in the heating industry that must be supported in the transformation.

Obstacle analysis

Each of the stakeholders involved faces its own investment challenges. In order to analyse these obstacles, we consulted a number of studies and held discussions with stakeholders. Table 7.2 presents a detailed overview of the barriers to investment for both institutional stakeholders and private homeowners, specifically in relation to heat transition measures for the three key technologies: heat pumps, energy-efficient insulation renovation and heating networks. We focus on factors that are directly related to investments.

In the following sections, the central obstacles are broken down and discussed specifically for each stakeholder. We focus on the obstacles that are currently making investment in the three key technologies particularly difficult. However, it is important to emphasise that many of these barriers are cross-sectoral challenges and can therefore also apply to other stakeholders that are not explicitly mentioned here.

Table 7.2: Overview of the barriers to investment faced by stakeholders in the heat transition in the buildings sector (own presentation)

Stakeholder	Structural obstacles	Economic obstacles
Housing companies	· **Bureaucratic obstacles** (including sound insulation and fire protection requirements, specifications from development plans such as the required use of certain façade materials) · **Landlord-tenant dilemma** with many missing incentives	· **Deteriorating credit conditions** · **Current challenges** (increase in construction costs and interest rates) lead to unprofitability for some housing companies · **Insufficient apportionment options** from housing companies' perspective · **High and short-term return expectations** in the case of listed companies
Energy supply companies	· **Lack of framework conditions** for sustainable investments · Current **regulation** safeguards existing business models · Cross-financing of other public tasks of the municipality · **Financial situation of the municipalities**	· **Large proportion of turnover from fossil fuel business** · **High investment costs** when switching to green technologies · **No access** to large volumes of capital · **Bad risk profile** due to gas grids as stranded assets · **Initially unprofitable investment in heating networks**
Energy service providers	· **Bureaucratic obstacles** (e. g. limited transfer of subsidies to end customers; regulation tailored to established companies (e. g. EnWG)) · Lack of experience and networks among new market participants (start-ups) · Uncertainty in the supply chains	· **Missing supply of venture capital** · **High initial investment** · **High capital intensity of the business model** · **High balance sheet liabilities** · **Uncertain electricity price trends** · Rapid return expectations of investors · No guaranteed sales markets
Private homeowners	· **Insufficient use of information and counselling services** · Uncertainties due to information diffusion in the public debate · **Different willingness** to take out loans · **Perceived complexity of funding applications** · **Incentive deficit for older homeowners** in energy-related investments · **Landlord-tenant dilemma** leads to different priorities for owner-occupiers and landlords · **More difficult coordination and decision-making** in homeowners' association	· Aversion to loans with long terms · **Insufficient access to loans** in the case of a low credit rating · Lower property value due to location dependency increases equity requirements · **Uncertainty about cost-saving effects** through energy efficiency measures · Illiquidity and high capital costs of renewable heat supply enable loan requirements · **Foreign capital aversion** even with creditworthiness

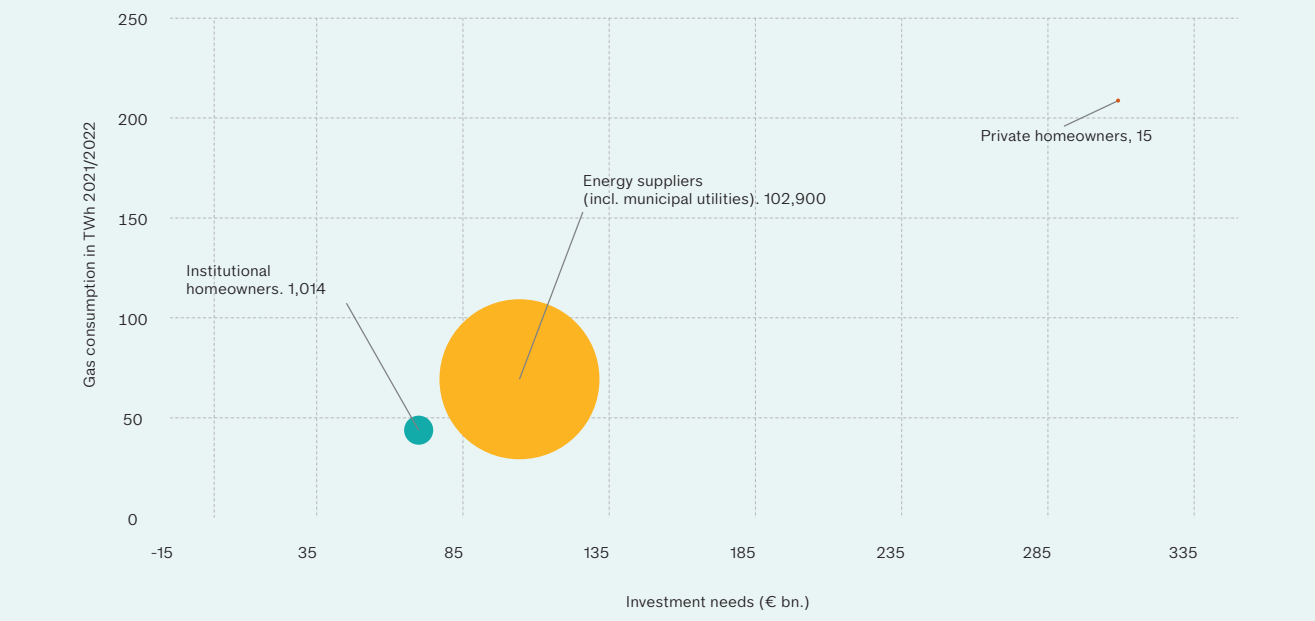


Figure 7.5: Additional investment volume (x, billion euros) and gas consumption (y, TWh/a) by stakeholder and indicative average costs per stakeholder (size of the circles in thousand euros) (Bantle & Wiersich, 2022; Beier et al., 2020; BMWSB, 2022; Prognos et al., 2022).[2]

2 Average costs only provide an indicative picture, as they are calculated from the total number of stakeholders and units, including those who have already invested.

Two brakes on housing companies

Deteriorating credit conditions and bureaucratic obstacles are putting housing companies under pressure.

Regulatory framework and bureaucratic obstacles

On the one hand housing companies are confronted with bureaucratic obstacles. Long waiting times for building permits (GDW, 2023) and the need to fulfil municipal requirements and federal and state regulations, such as noise and fire protection guidelines, lead to delays and additional costs (ARGE, 2023). It is only through legislative amendments such as the Building Energy Act (GEG) and the Heat Planning Act that a legal framework is now being created that sets out a binding path for such investments.

Capitalisation and deteriorating credit conditions

Earlier economic conditions and the lack of clear regulatory requirements meant that housing companies invested only slightly in alternative heating systems such as heat pumps. The initial investment costs for heat pumps are higher compared to gas heating systems and the installation costs in apartment blocks are often considerable (Bürger et al., 2022).

"Rising interest and construction costs are putting both small and large housing companies under increasing pressure."

The amendment to the GEG promises to change this relationship. Housing companies have extensive experience and the corresponding structures to make substantial investments. Nevertheless, investment conditions have deteriorated recently, preventing large economies of scale from being achieved by housing companies.

Rising interest and construction costs are putting both small and large housing companies under increasing pressure (ARGE, 2023; BBSR, 2021). As a result, many SMEs are unable to make the necessary investments without support measures. In the case of large, listed housing companies, a window for investment seems to have been missed: before the interest rate turnaround, some of them made high dividend distributions instead of investments (Gerrard et al., 2023).

The volume of investment in existing properties is heavily dependent on the interest rate situation on the financial markets (BBSR, 2017), with equity capitalisation being a decisive factor for access to loans. Equity capitalisation is a key indicator of structural solvency and the ability to overcome new financial challenges (BBSR, 2021; GDW, 2013). The right ratio between equity and debt capital ensures that risks such as insolvency are minimised and has a significant influence on creditworthiness (GDW, 2019).

Overall, the equity base of the housing companies is balanced. The industry average shows an equity ratio of just over 40 % (Theurl, 2023). Cooperatives stand out here, with an above-average equity ratio of around 47 %. The latter are characterised in particular by planning security and a long-term perspective.

In 2017, the average return on equity for municipal housing companies was around 5 %, and for around 70 % of companies it was over 2 % (BBSR, 2021). More important, however, is the return on assets, which according to industry experts averages 2.8 %. The return on assets can be used as a threshold for taking out new loans. With a key interest rate of over 4.5 %, profitable investments are therefore only possible on average if the investment results in significant cost savings or increases in income.

"There is scope for investment at housing companies with a high equity base and high return on assets."

There is scope for investment, especially for companies with a good equity base and a high return on assets. The lack of an adequate equity base can make it even more difficult for housing companies to access capital. Equity-rich housing companies have lower interest expenses than comparable equity-poor housing companies. They therefore achieve the profitability of an investment earlier. Increases in interest rates thus have a much more negative impact on companies with low equity than on those with high equity. Negative return on equity, low equity ratios and excessive dependence on external financing harbour the risk of over-indebtedness and could ultimately lead to insolvency (Lohse, 2006).

High return expectations of listed housing companies

The expected return on capital depends heavily on the ownership structure of the housing companies. Large listed housing companies such as TAG, Vonovia, Grand City Properties and LEG are characterised by a strong capital market orientation. They are criticised for not investing enough because of investors' return expectations. The opportunity to fully utilise the potential for additional investment, especially in natural gas-free heating systems, was missed during the low-interest phase. In 2021 listed companies siphoned off an average of 41 % of rental income (Figure 7.6), compared with just 32 % in 2016 (Gerrard et al., 2023).

In the meantime market conditions have changed. There were several rating downgrades for listed housing companies in the fourth quarter of 2022. This was due to the weakening economic environment in the property segment, increased financing costs and a 10 % decline in property valuations. Downgrades and loss of investment grade ratings increase financing costs and impair access to capital (Daube & Krivenkov, 2023). Vonovia, Germany's largest housing company, announced a complete halt to new construction projects at the beginning of 2023 (Süddeutsche Zeitung, 2023).

"In 2023 it is estimated that only 38 % of investment costs were spent on modernisation by housing companies."

Modernisation investments on the decline

Listed housing companies have preferred to invest in modernisation measures such as energy-efficient insulation renovation because, unlike maintenance investments, the costs can be passed on to tenants on a large scale. The new interest rate situation inhibits these investments or increases the pressure on rents in the case of modernisations. For housing companies as a whole, a shift towards more maintenance and fewer modernisation measures can be observed due to the higher interest rates, which weakens the investment momentum for natural gas independence. While 44 % of investments were spent on modernisation in 2021, this figure is expected to be just 38 % in 2023. In contrast the proportion of investments in maintenance measures rose from 56 % to 62 % (GDW, 2023). This also affects investments in natural gas-free heating systems such as heat pumps, which also count towards modernisation.

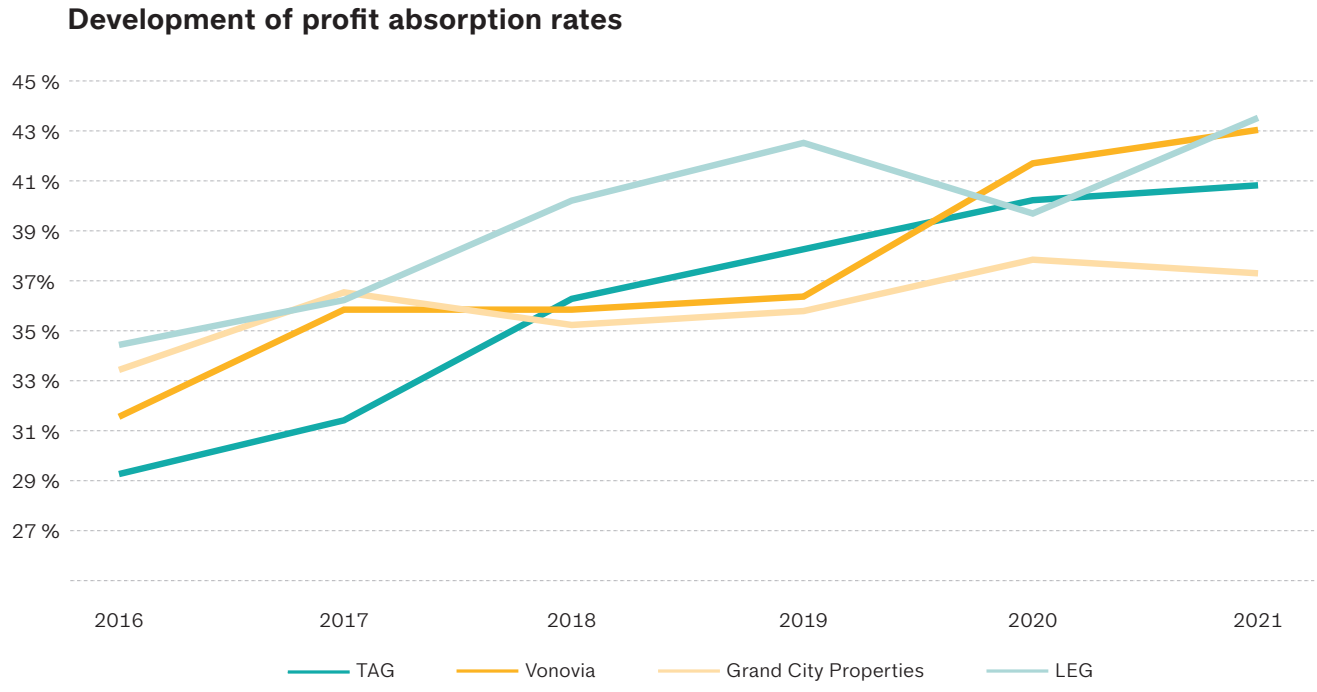


Figure 7.6: Development of the absorption rates of listed housing companies before the interest rate turnaround. Own presentation based on Gerrard et al., (2023).

Landlord-tenant dilemma

According to Section 559 of the German Civil Code (BGB), homeowners have the option of passing on up to 8 % of the modernisation costs incurred for the home to the tenant's annual rent. In the event of a rent increase, the monthly rent may not increase by more than three euros per square metre of living space within six years. If the monthly rent before the increase is less than seven euros per square metre of living space, an increase of no more than two euros per square metre of living space is permitted (Federal Office of Justice, 2023a). Public subsidies currently utilised must also be deducted from the total costs and thus reduce the apportionable costs (Federal Office of Justice, 2023b). This presents politicians and landlords with a well-known dilemma. According to industry statements, the limited passing on of investment costs is increasingly a barrier to additional modernisation in view of rising construction and interest costs. In contrast, in the past there has often been a mismatch between the savings in heating costs and the amount of the modernisation levy if the modernisation does not lead to a comparable reduction in operating expenditure and tenants therefore pay more in net terms (BBSR, 2017). This is particularly a problem if the modernisation measures do not lead to immediate cost savings. For a detailed discussion of the topic, please refer to the relevant literature (Henger et al., 2021, 2023).[3]

3 An analysis of possible solutions to the landlord-tenant dilemma can be found in Henger et al. (2023). Henger et al. (2021) provide an overview of reform options for the modernisation levy as part of the Ariadne project.

Municipal utilities independent of natural gas

Municipal utilities must now develop new business models in order to compensate for sharp declines in revenue from the gas business and secure their future competitiveness. Municipal utilities play a central role in the energy supply landscape, particularly in the context of the municipal heating transition. They have high market shares in the heating and gas supply sector with shares of 88 % of the heating business and 60 % of the gas business in the end customer sector (VKU, 2023b). As gas network operators and suppliers, they are largely responsible for the implementation of sustainable energy concepts. Above all, they have to bear the majority of the 103 billion in additional investment costs for heating networks. However, the phasing out of the gas business is having a significant impact on access to the capital required for this, as our analysis of 77 large municipal utilities (cities with over 100,000 inhabitants) shows.

"25 % of the total turnover of large municipal utilities comes from the gas business."

Gas business: an obsolescent model

The 77 large municipal utilities are heavily dependent on the gas business. All of them sell gas and, with very few exceptions, also own a gas distribution network, the operation of which is outsourced to a subsidiary or sister company due to unbundling regulations. If the energy supplier and grid operator are viewed as one company, income from the gas business accounts for around

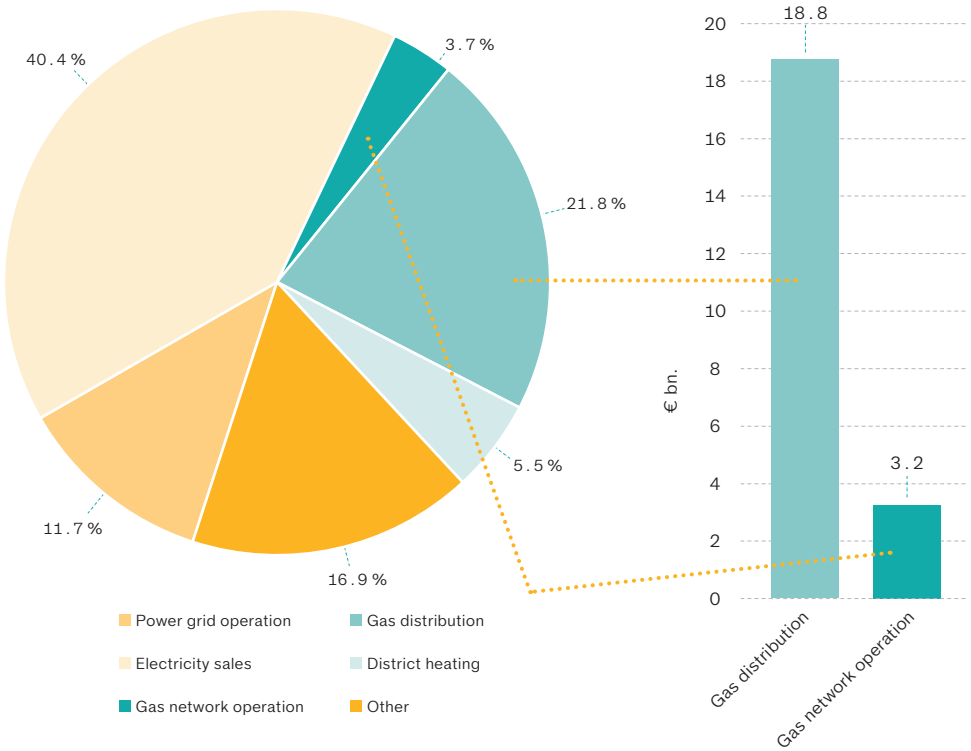


Figure 7.7: Sales composition by business area for municipal utilities in cities with over 100,000 inhabitants (left), total sales in the gas business in 2021 (right). Analysis of the annual reports of municipal utilities from the 77 largest cities in Germany. Own survey.

a quarter of its total turnover on average (Figure 7.7). In absolute figures, the gas sales of the large municipal utilities generate total annual revenues of 18.8 billion euros, while revenues from gas network operation amount to 3.2 billion euros. District heating currently only accounts for 5.5 % of total sales. Six of the 77 municipal utilities do not have their own heating network. Other data shows that grid operation and the sale of gas and electricity also contribute most to the turnover of small and medium-sized municipal utilities (Der Neue Kämmerer, 2019).

Creditworthiness

If around a quarter of future income is lost, this is not a good starting point for access to capital. In contrast the large municipal utilities have a good average equity ratio (31 %). Overall, the data on creditworthiness is inadequate. Figure 7.8 provides an indication and shows the ratio of leverage to EBITDA – but is from 2015. If the value is up to three, the financial situation can be described as adequate, while the strategic room for manoeuvre may be limited if the ratio is significantly higher than three. It is clear that in the past, up until 2015, the vast majority of municipal utilities (77 %) were in a good financial position to meet the transformation challenges (Der Neue Kämmerer, 2017).

Financial situation of the municipalities

In addition, financial support from cities, districts and municipalities plays a decisive role in the credit rating. In 2015 more than half (55 %) of the largest municipal homeowners were still in a budget deficit or a budget protection concept (Figure 7.8). Due to the high burden on public budgets in recent years, it can be assumed that this situation has not fundamentally changed. As part of the energy price crisis, many municipalities and municipal utilities came under high economic pressure (DStGB, 2022b), and it is to be expected that the financing deficits of municipalities will increase in the coming years (BMF, 2022; KfW, 2023d). This could lead to uncertainties with regard to the risk profile of the municipal utilities. The survey results also show that more indebted municipal utilities have to transfer a larger proportion of their profits (Der Neue Kämmerer, 2017).

New business models and infrastructure investments

The key question for municipal utilities is how they can compensate for the loss of income. Municipal utilities are therefore faced with the need to adapt their business models to the changing market conditions. The predicted decline in gas sales and the simultaneous need for investment require a fundamental reorganisation of business models. The decline in the development of new business areas, which fell from 60 % to 40 % between 2021 and 2022, is worrying (BDEW & EY, 2022). In addition, a 2019 study shows that only a small number of municipal utilities had confidence in the regulatory framework for investments (Der Neue Kämmerer, 2019).

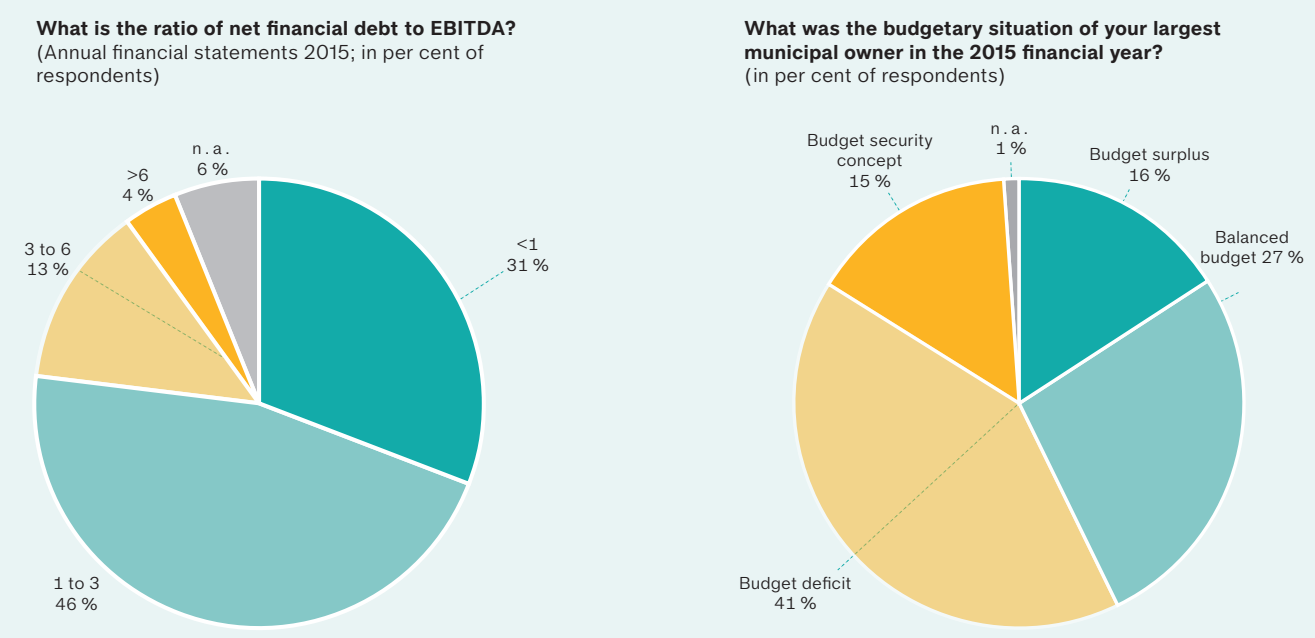


Figure 7.8: Debt ratios of municipal utilities (left) and budget situation of municipal homeowners (right). (Der Neue Kämmerer, 2017).

However, the energy crisis resulting from the Russian war of aggression against Ukraine has triggered a positive dynamic: according to an EY survey, 64 % of municipal utilities are responding by creating new heat offerings and 44 % are accelerating the decarbonisation of their heat generation. At the same time, 17 % are still investing in preparing their gas grids for a potential switch to hydrogen despite a high level of uncertainty (BDEW & EY, 2023b).

Credit terms for heating network projects

Heating networks offer an opportunity to develop new business models (Ortner & Pehnt, 2022). The financing of investments is of central importance. In principle, heating networks are interesting for infrastructure investments due to the high credit volume, but municipal utilities face a double challenge with regard to their creditworthiness. On the one hand they are burdened by their gas grids, which are becoming increasingly unprofitable or stranded assets – their use by gas customers is expected to decline faster than the gas grids can be depreciated (Agora Energiewende, 2023). As long as amortisation lags behind, there is no room on the balance sheet for more sustainable assets, nor can a reduction in the balance sheet have a positive effect on the equity ratio.

"The funding gap for heating networks is around 12 billion euros."

On the other hand, revenue development from the new heating networks is uncertain. Investments in network expansion do not pay for themselves in the first few years, as a period of 10–20 years usually passes after the pipes have been laid until the targeted heat consumers have written off the heat generation systems they have been using up to that point and are ready to switch over. This period must be bridged financially (Biesl et al., 2023).

Funding gap for heating networks

In the case of municipal utilities, the discrepancy between available funding and actual demand is particularly serious. Currently, only around 3.3 billion euros is earmarked for BEW funding, including commitments (see appendix). In contrast, the total funding requirement up to 2045 is at least 11.3–15.6 billion euros, assuming conservative investment levels of 20 billion euros for heating networks (Biesl et al., 2023). This results in a total funding volume of 3.9–5.4 billion euros by 2030 for the conversion and expansion of heating grids, spread evenly over the years, which will enable investments totalling 7 billion euros.

If we follow Pehnt et al. (2020) and assume an investment subsidy for large heat pumps of 40 %, the 3.6 billion euros investment per year assumed by Ahrendts et al. (2023, ~29 billion euros by 2030) results in a necessary funding volume of 11.5 billion euros by 2030 for heat pumps and consequently, including heating networks, a total of 15.4–16.9 billion euros by 2030. Operating costs are not included in these subsidy assumptions.

Deviations from Pehnt et al. (2020) result from higher assumptions regarding the newly installed annual capacity of large heat pumps and deviating assumptions regarding the conversion of heating networks to low temperature. This puts the funding gap at at least 12 billion by 2030.

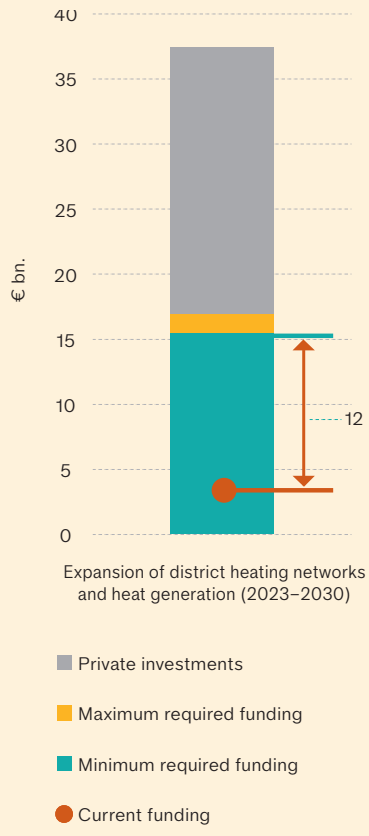


Figure 7.9: Funding gap for investment subsidies for the expansion and decarbonisation of heating networks through large heat pumps by 2030. Without operational expenditure support. Data from the German government (2023e), Bundestag (2023), Biesl et al. (2023).

Despite the collateral provided by municipalities, it can therefore be assumed that the financing conditions for municipal utilities will deteriorate and access to credit will become more difficult. This is made even more difficult by the deteriorating budgetary situation of local authorities in the wake of the energy price crisis and the worsening financial situation of municipal utilities, in particular their liquidity (DStGB, 2022a). These developments, together with rising interest rates, threaten to make access to loans and the associated investments in transformation and infrastructure even more difficult, especially for highly indebted municipalities (Brand & Salzgeber, 2023).

Unharnessed potential of the energy service providers

The current political framework and high liabilities reduce the potential of energy service providers to play a major role in the heat transition.

Energy service providers play a crucial role in decentralised heat supply and make a significant contribution to accelerating transformation projects. In this report we focus on companies that act as contractors or one-stop shops for heating systems. These not only offer process efficiency gains in the planning and implementation of the investment, but also an important dynamic for the heat transition through competition and innovation.

The scaling of energy service providers is proving to be a decisive factor in driving gas independence forward. The bundled and pooled financing service, in particular through the establishment of one-stop shop solutions, enables transformation projects to be implemented more quickly. This approach makes it possible to transfer the operational management of heating systems to energy service providers, as they not only have digitalisation skills, but also the necessary expertise to exploit optimisation potential in the decentralised heat supply and reduce transaction costs.

Structural challenges

A significant obstacle for energy service providers is a high level of regulation, which is often tailored to existing structures. This orientation continues to favour the dominant position of established companies in the heating market, which makes it considerably more difficult for new energy service providers to enter the market and hinders the scaling of their innovative business models. The distinction between companies already active in the energy supply sector and new market entrants is of great importance. The latter are confronted with high barriers to market entry in the energy industry, which are based on complex regulations such as the Energy Industry Act (EnWG) and the Heat Supply Ordinance (WärmeLV) as well as strict supply obligations. However, the requirement for cost neutrality in the Heat Supply Ordinance for buildings with central heating also represents an obstacle to investment in new systems for established energy suppliers (Seefeldt et al., 2021).

High balance sheet liabilities

The business model of energy service providers is very capital-intensive. Service providers take out large loans for the purchase of heat pumps, which they offer to customers for leasing. This practice increases the liabilities in the balance sheets, while equity remains unchanged. The increasing liabilities are leading to a continuous deterioration in access to capital. This fundamentally calls into question the sustainability of this business model.

Limited access to funding

Subsidies are a decisive lever for enabling energy service providers to offer favourable products aimed at low-income households. At the same time subsidies can improve the debt ratio of energy service providers.

"Service providers can only apply for a basic subsidy of 30 % in the BEG."

According to the Federal Funding for Efficient Buildings (BEG) guidelines, service providers as 'landlords' can currently only claim a basic subsidy of 30 % (maximum 9,000 euros) for the replacement of heating systems (BMWK, 2023f). In contrast, owner-occupiers are entitled to a subsidy of up to 70 % (up to 21,000 euros), depending on their income situation. This reduces the competitiveness of energy services compared to purchasing. This primarily affects low-income households, which would benefit from capital extension and process simplification by the energy service providers as a one-stop shop.

Exemplary additional cost estimate from limited access to funding

Energy service providers who pass on the subsidy to customers can apply for up to 12,000 euros less in subsidies than a comparable customer who buys the product themselves, according to the current Federal Funding for Efficient Buildings (BEG) guidelines. The difference depends on the customer's access to the speed bonus and entitlement to special support due to low income.

Assuming a heating system has a service life of 20 years (BWP, 2014), this means additional monthly costs of at least 50 euros plus interest and surcharges. This is 25 % of the discount, assuming a rental price of around 200 euros per month for renewable heating (Hamacher, 2023).

Uncertain electricity price trends

Whether the electrification of the heating system is worthwhile depends on the price of electricity. Price fluctuations on the spot markets can be significant and unpredictable. At the same time projections are associated with a high degree of uncertainty. If service providers offer leasing models that include the operating expenditure as well as the heating technology, this can result in high price mark-ups.

Heat electricity tariffs

Studies show that around half of the energy suppliers analysed offer heat electricity tariffs (EUPD Research, 2023). In 2022 the heat pump electricity price averaged 26 cents/kWh, compared to ten cents/kWh for natural gas, with the tax and levy burden for electricity twice as high as for fossil fuels (BWP, 2023b). In general, it can be assumed that heat pumps are more economical at the current investment costs if the ratio of electricity to gas price is below 2.5 (dena, 2023).

Access to venture capital

The high investment costs deter potential investors, especially venture capital. Scaling and market entry are therefore difficult. Access to venture capital is one of the biggest challenges for start-ups in the energy services market. Although there are some climate venture capital funds, the supply of venture capital in the EU is low compared to other countries (Fink, 2020). Venture investors tend to favour solutions that are less capital-intensive. This is in contrast to the high investment costs and risk associated with innovative projects in the energy market.

Structural challenges

A significant obstacle for energy service providers is the existing regulatory landscape, which is tailored to the existing stakeholders. This orientation favours the dominant position of established companies in the heating market, which makes it considerably more difficult for new energy service providers to enter the market and hinders the scaling of their innovative business models. The distinction between companies already active in the energy supply sector and new market entrants is of great importance. The latter are faced with high barriers to market entry in the energy industry. These include certifications as an energy supplier or complex regulations such as the Energy Industry Act (EnWG) and the Heat Supply Ordinance (WärmeLV), which require a high level of detailed knowledge.

Heat Supply Ordinance

The Heat Supply Ordinance is a cross-cutting issue that affects energy service providers and established energy suppliers as well as housing companies and small landlords. The requirement for cost neutrality in the Heat Supply Ordinance for buildings with central heating when switching to other heat supply systems is key (Seefeldt et al., 2021).

Capital access of private homeowners

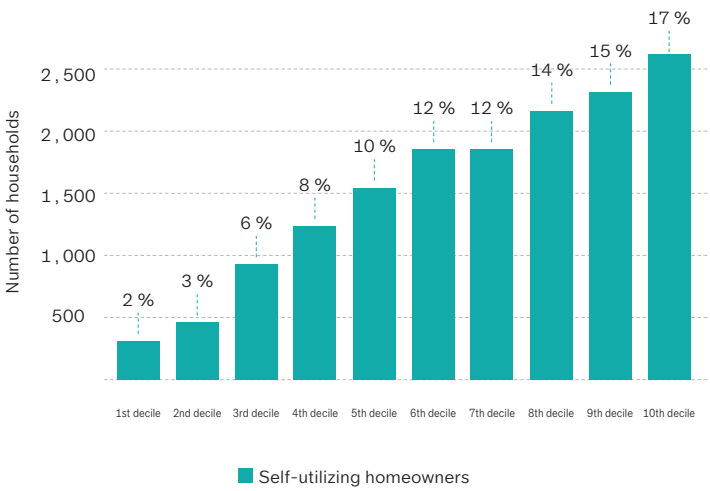
15–30 % of private homeowners have problems accessing capital.

According to a KfW study from 2023, the majority of private homeowners surveyed stated that they could envisage energy-efficient renovation measures, although around 40 % of homeowners stated that they could not afford these investments, over 10 % more than in 2021 (Römer & Salzgeber, 2023). These figures are also in line with estimates that assume that around 15–30 % of private homeowners could have difficulties financing measures for the heat transition (DENEFF, 2023).

"40 % of homeowners state that they cannot afford to invest."

Of the 2.7 million homeowners over the age of 80 (16 %), many represent a special case under the new GEG. The financial burden for this group could be significant. A considerable proportion of 1.5 million low-income homeowners (lower three income deciles) live in older buildings in need of renovation (Römer & Salzgeber, 2023; Schumacher et al., 2022). At the same time fossil fuels are often used in precisely these older and poorly insulated houses (Römer & Salzgeber, 2023). The financial resources for switching to a renewable heating system or energy-efficient renovation are limited in this group, which could lead to a further delay in urgently needed modernisation (Figure 7.10). According to studies, almost 40 % of the German population were unable to cope with unexpected financial expenses in 2020 (Toleikyte et al., 2023). A study by KfW shows that 68 % of the homeowners surveyed from the lowest income group will not be able to afford renovation measures in 2023, a significant increase of 31 % compared to 37 % in 2021 (Römer & Salzgeber, 2023).

Income situation of homeowner households



Debt burden of homeowner households (shares rounded)

Figure 7.10: Income situation (left) and debt burden (right) of homeowners (DENEFF, 2023).

Homeowners' associations

These challenges also extend to homeowners' associations, which own almost 12 % of homes in Germany. Due to the large number of stakeholders in the decision-making process for an investment, an additional coordination problem arises. The need for a coordinated approach leads to delays and uncertainties when investing in energy-related measures. Since 2020, structural changes, such as energy-efficient renovations, no longer need to be approved unanimously. However, a simple majority is still required and, in practice, those outvoted can oppose the measures (Federal Law Gazette, 2020). A lack of coordination within the homeowners' associations can lead to opportunities for the implementation of gas-independent technologies not being optimally utilised. This may mean that gas-fired floor heating systems, for example, are not replaced by new renewable heating systems.

Fostering investment readiness

Lack of utilisation of advisory and funding services coupled with an aversion to long-term loans inhibit private investment.

The basic willingness to borrow is a key prerequisite for investing in natural gas-free heating systems. However, the group of private homeowners is extremely heterogeneous. Diversity among private homeowners is crucial for the willingness to invest. Owner-occupiers are more inclined to invest in view of long-term utilisation prospects. However, older homeowners are often reluctant to carry out renovations and leave these decisions to their descendants (Grashof, 2023; Stieß et al., 2010).

Funding gap for heating replacement and insulation renovation

Private homeowners and housing companies must provide a total of 379 billion euros in additional investment. It is crucial that investments are made in natural gas-free alternatives at the time of reinvestment in order to avoid the creation of stranded assets and high costs due to the internalisation of environmental costs (CO_2 prices).

Although renewable heating alternatives are already the economic option for many building types (Pehnt et al., 2023), they incur significantly higher capital costs than natural gas heating systems. Therefore, in addition to stretching the cost of capital through energy services, reducing the cost of capital is a key starting point for mobilising private capital.

Currently, the BEG subsidy is 30–70 % and the renovation subsidy is 15–20 % of the total costs (not the additional costs). According to Prognos (2022), total annual climate investments amount to 60–65 billion euros. For the period 2023–2027, this would correspond to an investment volume of 300–325 billion euros. According to the German government's financial plan (as of Nov. 2023), 75 billion euros in funding is expected in the KTF for the same period, which corresponds to 23–30 % of total investment. We therefore assume that existing funding programmes are currently sufficient should they be continued beyond 2027 until that time.

Insufficient utilisation of support services

Among homeowners with long-term utilisation intentions, a number of factors speak against investment. Although they are often not fundamentally opposed to modernisation, they show little interest or willingness to actively inform themselves, as they are satisfied with the current condition of their home and perceive the renovation as an additional burden (Stieß et al., 2010). In addition, new heating systems are often accompanied by a change in handling and are therefore perceived as an uncertainty factor (Engelmann et al., 2021). They often only consider a possible investment when it becomes necessary due to equipment failure or a regulatory requirement (Albrecht et al., 2010).

Due to the lack of interest and the short time available for action, information and advice services such as renovation roadmaps (KfW, 2023c) or advice from consumer advice centres (Verbraucherzentrale, 2023) are often not taken up sufficiently (Stieß et al., 2010). However, a positive trend can be observed in this respect: while around a quarter of homeowners still showed a low willingness to provide information in 2021, this figure fell to 15 % in 2023 as a result of the energy crisis (Römer & Salzgeber, 2023).

This problem also extends to the perceived complexity of funding applications. The complexity of the application process, which involves various contact points such as KfW, BAFA and energy consultants, leads to delays and uncertainty regarding possible financial support. The variety of funding bodies at federal, state and municipal level and the different funding lines (heat pump, renovation) make orientation, application and decision-making difficult (Engelmann et al., 2021).

A lack of information and the complexity of the subsidy processes lead to avoidable confusion about the added value of heating replacement and energy-efficient renovation and the costs of delaying the investment. This has a direct impact on the willingness of private homeowners to invest and requires targeted simplification and improved communication with regard to funding opportunities and advisory services.

Landlords compared to owner-occupiers

A defect in the heating system is also usually the trigger for renovation measures for landlords. In addition, economic motives are more pronounced than in the case of owner-occupation (Engelmann et al., 2021). The landlord-tenant dilemma can be seen here in a similar way to the housing companies. Nevertheless, landlords can benefit from energy-efficient renovations in the long term, as they can lead to an increase in the value of the property and a long-term improvement in rentability (Thöne et al., 2019).

Long amortisation periods

Investments with amortisation periods of more than two years are only considered by a minority (27 %) of consumers (McKinsey, 2008). However, the average operating life of heating systems is 20–30 years. This long period of time until amortisation often leads to investments being rejected prematurely, as the savings do not materialise immediately. The decision-making process is often based solely on the investment costs and neglects the ongoing operating costs and emerging factors such as rising CO_2 prices. In addition, there are high perceived uncertainties regarding the cost-saving effects and the long-term benefits of energy-efficient renovation measures, particularly in comparison to the directly perceptible investment costs (Jenny et al., 2012). Owners tend to prefer more favourable measures with rather short-term returns over those with high investment costs and slow but higher returns (Albrecht et al., 2010). As a result of such challenges, irrational decisions are made, such as the increased purchase of oil and gas heating systems, even though natural gas-free technologies are actually more advantageous.

"In general, investments with amortisation periods of more than two years are only considered by 27 % of citizens."

Aversion to loans

In addition, private homeowners can tend to be averse to borrowing, even if they are creditworthy. According to studies, 53 % of respondents say that their decision not to renovate, modernise or convert is because they do not want to take out a loan (Durth, 2017). Private homeowners tend to be reluctant to take out loans for high investment costs, even if the profitability of the investment measures is present and perceived (Albrecht et al., 2010; Gigli, 2008). Debt aversion is particularly true for homeowners with lower incomes (Albrecht et al., 2010).

Shortage of skilled labour in the craft sector as a cross-sectional challenge

The craft sector faces major challenges in securing and mobilising skilled labour – further measures to mobilise skilled labour are necessary.

The demand for skilled labour in the craft sector is increasing significantly for the necessary conversion of technologies and infrastructures, which presents the craft sector with new challenges in terms of securing and mobilising skilled labour, also in view of the already significant skills gap in the craft sector.

According to industry estimates, the number of heating installers will have to double by 2050 (EHI, 2021) in order to achieve the climate targets for heating replacements. According to IG Metall and trade associations, there is a shortage of up to 190,000 skilled workers, particularly in the area of energy-efficient renovation of 19.2 million residential buildings (ZVEH, 2022). In 2022 a skills gap of around 31,500 employees was identified in the fields of sanitary, heating and air conditioning technology and building electrics – with only 20 suitably qualified job seekers for every 100 vacancies nationwide (Malin & Köppen, 2023). We estimate that the skills gap could triple to 95,400 skilled workers by 2026 (Energy Independence Council, 2023). This estimate is also compatible with the forecasts of the Zentralverband des Deutschen Handwerks, which speaks of 60,000 additional skilled workers needed for heating replacements by 2030 (ZDH, 2023a). Similar estimates are also available from the electrical trade (Birk, 2022). The main reason for this is the expected higher demand for natural gas-free technologies, for the installation of which more highly qualified and additional skilled labour is required, while at the same time demographic change is taking place.

"The skilled labour gap could triple by 2026."

To install these heating systems, many of the skilled workers who installed 598,000 gas heating systems in 2022 will need to be retrained and given further training. The shortage of skilled labour in the craft sector is also becoming increasingly apparent in people's everyday lives when implementing investment measures; the shortage of skilled labour is already a significant and growing obstacle to investment. According to a KfW study, 9 % of homeowners in 2021 stated that a lack of craft sector capacity prevented the implementation of measures; by 2023 this figure had tripled to 27 % (Römer & Salzgeber, 2023).

In some trades the number of trainees has risen again, but this is too low to cover the increasing demand for additional tradespeople – especially in light of the succession situation in many craft businesses (Schwartz & Leifels, 2022). Despite the essential importance of the craft sector, the attractiveness of skilled trades is declining; the shortage of skilled labour is particularly significant in the climate-relevant HVAC and electrical installation sectors (Mischler, 2017).

7.2 Transition towards natural gas-free industry

German industry is in a good position to invest in natural gas-free technologies. As described in Chapter 2, Germany is internationally competitive as a business location, primarily due to its good innovation and research infrastructure and well-trained labour force. At the same time German companies have secure access to financial products.

Compared to the buildings sector, industry has more areas of application in which natural gas must be substituted. One reason for this is that almost all industrial sectors rely on this energy source and it is used in different technologies depending on the requirements of the process. As a carbon derivative, natural gas also serves as a raw material base for products in basic chemistry, for example, or as a starting material for the production of hydrogen in ammonia, silicon or aluminium production and in refineries (Hüther et al., 2023).

Overarching conclusions

Six conclusions can be drawn for the mobilisation of investments in German industry's independence from natural gas:

1. **Develop customised measures:** Small and medium-sized enterprises (SMEs) and large companies face different challenges, which differ depending on company size, sector and technology. In order to achieve an investment dynamic that accelerates rather than delays investments, an approach is needed that does justice to this broad spectrum of problems.
2. **Solve cross-sectional tasks:** Common problems such as high financing costs, lack of infrastructure access and the reform of grid fees must be tackled quickly. They form the basis for a competitive and successful transition to natural gas-free technologies.
3. **Place stronger focus on SMEs:** The mobilisation of investments by SMEs offers great potential for natural gas substitution. The hurdles are low, as natural gas-free technologies with a high level of technological maturity and low economic and structural hurdles (see Table 7.3) are used. Especially in combination with the low natural gas avoidance costs, a great deal of momentum can be generated here with few resources. To this end existing funding instruments must be further developed and made accessible to SMEs in particular.
4. **Place responsibility on industries:** The food industry, paper industry, cement and lime industry and basic chemicals account for 67 % of industrial natural gas demand, which can be substituted with 9.5 billion euros in plant investments.
5. **Promote pioneers:** Promoting pioneers, both large companies and SMEs, is a crucial step in gaining experience with natural gas-free technologies, further developing processes and improving the risk profile of transition investments.
6. **Initiate learning processes:** Companies that are currently unable to switch their production processes to natural gas-free technologies due to structural or economic obstacles can learn from pioneers. Sharing experiences and best practices can serve as an important mechanism to reduce risk perceptions and support other companies on the path to natural gas independence.

Findings from the analysis of the industrial sector

These conclusions are based on ten findings that we derive on the following pages.

1. **Electrification of process heat and focused use of hydrogen** – The substitution of natural gas in industry means the greatest possible electrification of process heat and the focused use of hydrogen in basic chemicals and steel production.
2. **High degree of maturity of substitution technologies** – The technologies for substituting natural gas in industry have a high degree of technical maturity and can be used beyond pilot projects.
3. **Plant engineering as a competitive advantage** – Germany is a leader in plant engineering and is therefore particularly well positioned to play a leading role in the switch to natural gas-free industrial processes.
4. **Timing of investments is crucial** – Industrial plants have long lifetimes, which is why the timing of (re) investments is crucial. Extra costs can be avoided if investment windows can be utilised in line with the renewal cycles.
5. **Overlooked industries** – Industries with low market concentration can substitute a third of natural gas consumption with low investment volumes; they can usually be addressed via cross-sectional technologies.
6. **Manageable investment needs** – Compared with investment requirements in buildings and energy costs, investments in systems for natural gas-free process heat are low, but in the typical logic of the sector they require rapid amortisation.
7. **Different starting conditions** – Depending on their size, location and specific energy requirements, companies face different challenges when it comes to the transformation.
8. **OpEx beats CapEx** – A large proportion of the total cost of ownership of green industrial plants is attributable to OpEx, with only a small proportion attributable to CapEx.
9. **Three company types in the industrial transition** – Based on their obstacles and the associated status of natural gas substitution, companies can be differentiated into pioneers, followers and participants. This differentiation makes it possible to prioritise stakeholders where investment and innovation cycles can be accelerated.

As mentioned in the introduction, we are focusing on mobilising demand for natural gas-free technologies. It is important to emphasise that upstream bottlenecks can occur in the value chains if too many companies invest at the same time. As the heat pump ramp-up shows, rapid adjustments to production capacities can be expected if there is politically driven investment and planning security for these technologies. **The following discussion therefore requires a clear industrial policy prioritisation of the sectors that provide natural gas-free technologies and systems (e. g. large heat pumps, industrial furnaces, electrode boilers).**

Electrification of process heat and focused use of hydrogen

The substitution of natural gas in industry means the electrification of process heat and the focused use of hydrogen in basic chemicals and steel production.

There are basically two technological options for replacing natural gas as an energy source in the industrial sector, which also enable climate neutrality in the long term: electrification and the use of green gases, above all hydrogen. For processes with temperature requirements below 500°C, electrification is generally the most efficient and economically sensible measure. Natural gas that is used as a material must be substituted by a CO_2-neutral raw material. Hydrogen is generally suitable as a reducing agent and as a raw material base for ammonia and methanol (Energiekrise solidarisch bewältigen, neue Realität gestalten, 2022; Luderer et al., 2021; Samadi, 2022).

The two energy-related fields of application for natural gas are the provision of process heat in industrial furnaces and the generation of steam and hot water (see Figure 7.11). They account for 90 TWh/a and 95 TWh/a of consumption respectively. In addition, 30 TWh/a are generated for material utilisation (Luderer et al., 2022).

High degree of maturity of substitution technologies

The technologies for substituting natural gas in industry have a high degree of technical maturity and can be used beyond pilot projects.

Some technologies are cross-sector technologies that can be used across all industries, such as electric and electrode boilers, which are suitable for replacing natural gas-fuelled steam generation in various industries. Other technologies are industry-specific, such as electric furnaces in the glass industry or electric arc furnaces and direct reduction installations (DRI) in steel production. Table 7.3 provides an overview of all technologies that are relevant for the substitution of natural gas in industry – broken down by sector and the natural gas-based technology they are replacing (IN4climate.NRW, 2021). We have already listed technology-specific barriers here. In the following sections and Table 7.5, these are supplemented by stakeholder-specific barriers for industrial companies.

The technology readiness level (TRL) is a scale for systematically assessing the development of new technologies. The nine levels of the TRL scale provide information on the market maturity of the technology (BLE, 2021). With regard to the technologies described, the electric steam cracker, for example, is at 5–6 on the scale (Luderer et al., 2021), which means it is at the experimental development stage, including the development of prototypes and use in pilot projects.
In comparison, electric and electrode boilers already have level 9 (Luderer et al., 2021) and are therefore ready for market use (BLE, 2021).

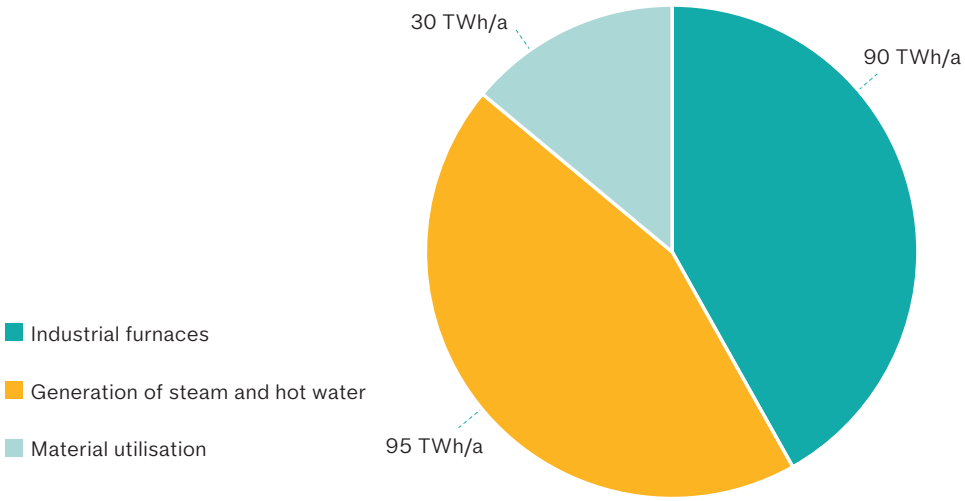


Figure 7.11: Natural gas consumption of the application areas in the industrial sector (Luderer et al., 2022).

Table 7.3: Overview of the substitution technologies considered in industry, technological degree of maturity, areas of use as well as business and structural barriers [4]

Substitution technology	Technological readiness level (TRL) [1–9][5]	Natural gas technology	Use in industries	Used in		Business obstacles					Structural obstacles		
				SMEs	Large companies	High initial investment	Uncertain operational expenditure	High conversion costs	Uncertain demand	International competitive pressure	Necessary infrastructure	Complex bureaucracy	Lack of willingness to innovate
Large heat pumps	9	Natural gas CHP / natural gas boiler	Cross-industry	X	X	X	X	X			X		X
Electric & electrode boilers	9		Paper industry, food & tobacco, basic chemicals	X	X		X						
Deep geothermal energy	8–9		Cross-industry	X	X	X		X				X	X
Solar thermal energy	2–9		Cross-industry	X	X	X		X				X	X
Energy efficiency in process heat	market-ready	/	All sectors	X	X	X							X
Electric melting tanks	6–8	Natural gas-fired furnaces	Glass & ceramics	X	X		X	X			X		
Electric industrial ovens: infrared & plasma	Infrared: market-ready Plasma: 3	Natural gas-fired oven	Infrared: paper industry; plasma: iron & steel, aluminium	X	X		X				X	X	
Electric arc furnaces	market-ready	Natural gas-fired furnace, blast furnace converter route	Iron & steel	X	X	X	X				X		X
Hydrogen-based direct reduction units (H_2 DRI)	5–7	Blast furnace converter route (coal), natural gas-based DRI	Iron & steel		X	X	X		X	X	X	X	
Electric steam crackers	5–6	Natural gas-based steam crackers	Basic chemicals		X	X	X	X			X	X	
Systems for ammonia and methanol synthesis and the MTO process	7–9	Natural gas as a raw material basis for hydrogen and thus methanol, ethylene and ammonia	Basic chemicals		X		X	X	X	X	X	X	

4 Based on Luderer et al. (2021), Heumann & Huenges (2017), Giovannetti et al. (2018), Agora Energiewende (2020) and interviews with experts (list in the appendix); the most recent source was always used.

5 Stages 1–2 basic research, 2–4 industrial research, 5–8 experimental development, 9 transition to market maturity.

Plant engineering as a competitive advantage

Germany is particularly well positioned to play a pioneering role in the switch to natural gas-free industrial processes.

Each of the technologies has its specific suppliers from the German mechanical and plant engineering industry. The energy-intensive industries and mechanical and plant engineering are deeply interlinked (Agora Energiewende, 2020). The technologies are customised with regard to the specific requirements of the respective projects. These are usually not individual systems, but rather the integration of technologies into an overall industrial production system.
The German mechanical and plant engineering sector, which is primarily characterised by specialised SMEs, comprises more than 6,600 companies and over one million employees (BMWK, 2023h).
The industry has outstanding innovation performance and international competitiveness. It is therefore ideally positioned to complete the conversion of industrial plants and this opens up great opportunities for the sector's long-term competitiveness and technological leadership (Agora Energiewende, 2020).

Timing of investments is crucial

Industrial plants have long amortisation periods, which is why the timing of (re)investments is crucial.

The technologies described in Table 7.3 are used in the industries described there and are replaced in the course of very long investment cycles. Ground-breaking investment decisions are now being made for the coming decades. Industrial systems can have lifetimes of up to 70 years. By 2030, 30–50 % of steel, chemical and cement industry plants will have to be reinvested (Hauser et al., 2022). These investment decisions also influence the long-term international competitiveness of German industry (Energiekrise solidarisch bewältigen, neue Realität gestalten, 2022). Continuing to reinvest in conventional industrial plants does not make sense under the current framework conditions of European emissions trading (ETS 1). According to current resolutions, CO_2 emissions will no longer be available in European trade towards the end of the 2030s for energy-intensive sectors (European Council, 2023). At the same time the CO_2 price in the EU ETS 1 is not yet sufficiently high, and the development of the future CO_2 price is not sufficiently certain, so companies are reluctant to invest in the new technologies. Despite uncertain framework conditions, industry today faces the challenge of setting the course for a green and competitive plant fleet and utilising investment windows to adapt to the changing regulatory framework through ambitious and far-reaching changes to industrial production systems and value chains (Luderer et al., 2021).

Industrial companies make long-term investment decisions based on the investment costs and operational expenditure of available technology systems. Switching processes entails considerable transformation costs and risks, which can result in a potential reduction in profits and a major business risk. These arise from the additional costs of the new technologies for investments (CapEx) and plant operation (OpEx) (Luderer et al., 2021). Under current CO_2 prices, the OpEx of natural gas-free technologies is generally higher than that of conventional technologies (Hauser et al., 2022). The switch in production will also have a selective impact on the infrastructure, such as the expansion of electricity grid connections, which will be adapted to the requirements of the new technologies in line with the switch in production.

Overlooked industries

Industries with low market concentration can substitute one third of natural gas consumption with low investment volumes.

The analysis of the market structure shows that SMEs and large companies play an important role across all sectors (see Table 7.4). A handful of large companies are decisive for a high proportion of sales, as the largest companies generate between 58–80 % of total sales depending on the industry (Heidorn & Weche, 2021). The SME sector consists of micro, small and medium-sized enterprises (Destatis, 2023d). Large companies are active in all sectors, but play a particularly important role in basic chemicals, iron and steel, and non-ferrous metals foundries. Micro and small companies dominate the food and tobacco and cement and lime industries, with market shares of 58 % and 79 % respectively. Medium-sized companies are the largest group in basic chemicals, non-ferrous metals and foundries, the paper industry, glass and ceramics, metalworking and iron and steel.

Table 7.4: Market structure and concentration of the sectors analysed (Destatis, 2023e)

Industries	Company size			Corporate concentration
	Micro & small companies	Medium-sized companies	Large companies	CR6
Paper industry	31 %	54 %	15 %	57 %
Cement and lime industry	79 %	19 %	2 %	57 %
Metalworking	34 %	58 %	8 %	58 %
Food & tobacco	58 %	33 %	9 %	63 %
Non-ferrous metals, foundries	27 %	49 %	24 %	67 %
Iron & steel	32 %	38 %	31 %	68 %
Glass & ceramics	34 %	53 %	14 %	72 %
Basic chemicals	36 %	45 %	20 %	80 %

We use the Herfindahl-Hirschman Index (HHI)[6] and the market share of the six companies with the highest turnover (CR6) to determine the concentration of interests or concentration of stakeholders. The sector with the highest concentration is basic chemicals with an HHI of 2,359 and thus over 2,000, which means that 80 % of the market is divided between the six largest companies. Glass and ceramics, iron and steel and non-ferrous metals and foundries are in the midfield (67–72 %). The different company sizes and market structures entail different requirements for legislation, which are explained further in this chapter.

Manageable investment needs

Compared with investment requirements in buildings and energy costs, investments in systems for natural gas-free process heat are low, but in the typical logic of the sector they require rapid amortisation.

The substitution of natural gas takes place in three areas: the generation of process heat (in all sectors), materially in the production of ammonia, methanol and olefins (basic chemicals) and in hydrogen-based direct reduction plants (steel production).

For the calculation of investment requirements, the costs for systems required to substitute natural gas in the processes are estimated. Fleiter et al. (2023) quantify investments for the electrification of natural gas-powered industry reference processes.

We extrapolate this to the total natural gas consumption of the sectors. We also use the targets for green chemical and steel production capacities in Germany and their specific investment costs for decarbonisation to calculate the investment volumes for the material substitution of natural gas and for green crude steel production (German Environment Agency, 2023).

The total investment volume for the substitution of natural gas in industry amounts to around 44 billion euros. The breakdown by application area is shown in Figure 7.12. The substitution of natural gas in process heat accounts for the largest investment requirement at 30 billion euros. However, the investments are spread across various plants in almost all sectors. Around 12.5 billion euros will be spent on the construction of DRI and electric arc furnaces as replacement investments for the blast furnaces that will be written off by 2030 (explanation in the text box: *Future of steel*). 1.6 billion euros must be invested in plants for ammonia and methanol synthesis and the methanol-to-olefins process in order to substitute natural gas in the basic chemicals industry.

The investments shown solely relate to the plants themselves and do not include any necessary infrastructure expansions (electricity grid connections, transformers) or the demolition of existing plants. In its study, KfW quantifies additional investments for a climate-neutral industry in 2050 and shows a value of 462 billion euros. The difference to the investment requirements shown in this study can be explained on the one hand by the focus on plant costs and on the other hand by the focus on natural gas-intensive sectors (basic chemicals, non-ferrous metals and foundries, paper industry, glass and ceramics, metalworking and iron and steel). Furthermore, our study does not consider the development of hydrogen production capacities and further DRI capacities in Germany after 2032.

6 The HHI measures concentration as the sum of the squared market shares of the companies multiplied by a factor of 10,000. It therefore has a value ranging from no concentration (0) to monopoly (10,000). Values between 1,000–2,000 are generally considered harmless and less than 1,000 as low concentration (Effenberger et al., 2020; Monopolies Commission, 2022).

Future of steel? Investing where it makes sense.

The 2020s will show whether Germany will lock in high CO_2 emissions for decades to come with the risk of stranded assets, or whether it will succeed in taking the path towards sustainable steel production. Replacement investments are due for 18.7 Mt/a (~77 %) of production capacity in Germany by 2030 (Agora Industrie, 2023). This offers the potential to switch to natural gas-free technologies and avoid reinvestment in blast furnaces. 3.9 Mt/a can be replaced by increasing secondary steel production.

1.7 % of natural gas is used in the steel and iron industry and the energy source only accounts for 12 % of the sector's final energy consumption (Fraunhofer ISI, 2022). Nevertheless, the complete substitution of natural gas in steel processes is particularly complex, as the utilisation of new technologies is largely dependent on the availability of hydrogen. Iron ore is reduced to iron in blast furnaces, which are currently fuelled by coal. The substitution technology is direct reduction installations (DRI), which can be operated with natural gas or hydrogen. Natural gas is not used in the blast furnaces. However, for technical reasons, the natural gas-fuelled system components can only be replaced in combination with the rest of the system.

This means that the industry's demand for natural gas could even increase for a short time and it must be ensured – through focussed use in no-regret applications – that green hydrogen is available for DRI plants in the near future (Hauser et al., 2022).

The production of crude steel from iron and steel scrap can be electrified using electric arc furnaces, which currently also use a small proportion of natural gas. However, complete electrification is possible in the future.

Completely natural gas-free crude steel production can therefore only be achieved by using green hydrogen. It is not absolutely necessary for the DRI to take place within Germany. Germany could switch from importing iron ore to importing iron, which would have a negligible effect on Germany's import dependency.

The energy-intensive step would then take place in countries that have favourable conditions for hydrogen production due to the high availability of renewable energies, such as Brazil, Australia and South Africa (Agora Industry & Wuppertal Institute, 2023).

In response to the climate protection agreements, German steel manufacturers have already announced that they will switch to DRI as part of the first wave of replacement investments (by 2030) (Agora Industrie, 2023). These include in particular Salzgitter, Thyssen in Duisburg, Arcelor Bremen, Arcelor Eisenhüttenstadt and Saarstahl. It can be assumed that the second wave of replacement investments will also take place in Germany. This means that investments for 16.8 Mt/a capacity of DRI plants and electric arc furnaces are pending, which, with specific investment costs of 745 euros/tonne production capacity (Hauser et al., 2022), amount to 12.5 billion euros.

To estimate our investment requirements, we assume that no new DRI plants will be built in Germany from 2032 and that imports of green iron, in the form of hot briquetted iron (HBI), will be used to ensure competitiveness in the steel industry. This would keep 96 % of jobs in Germany and at the same time save 16 % of the production costs of crude steel, which could secure the competitiveness of the green steel industry and its customer industries in Germany (Agora Industry & Wuppertal Institute, 2023). It should be noted that the outsourcing of parts of the value chain is ultimately a political and strategic decision that only serves as an assumption for estimating cost requirements.

With regard to the goal of becoming independent of natural gas, it is important that the steel processing processes be electrified, as they are currently mainly based on natural gas. Electric systems are available for substitution, some of which can also be implemented in combination with hydrogen heating. A complete conversion of the 19 TWh of natural gas utilisation in these processes would require plant investments of 10.64 billion euros (Fleiter et al., 2023). This means that the investment needs for the steel industry amount to 23.1 billion euros.

Future of steel? Investing where it makes sense.

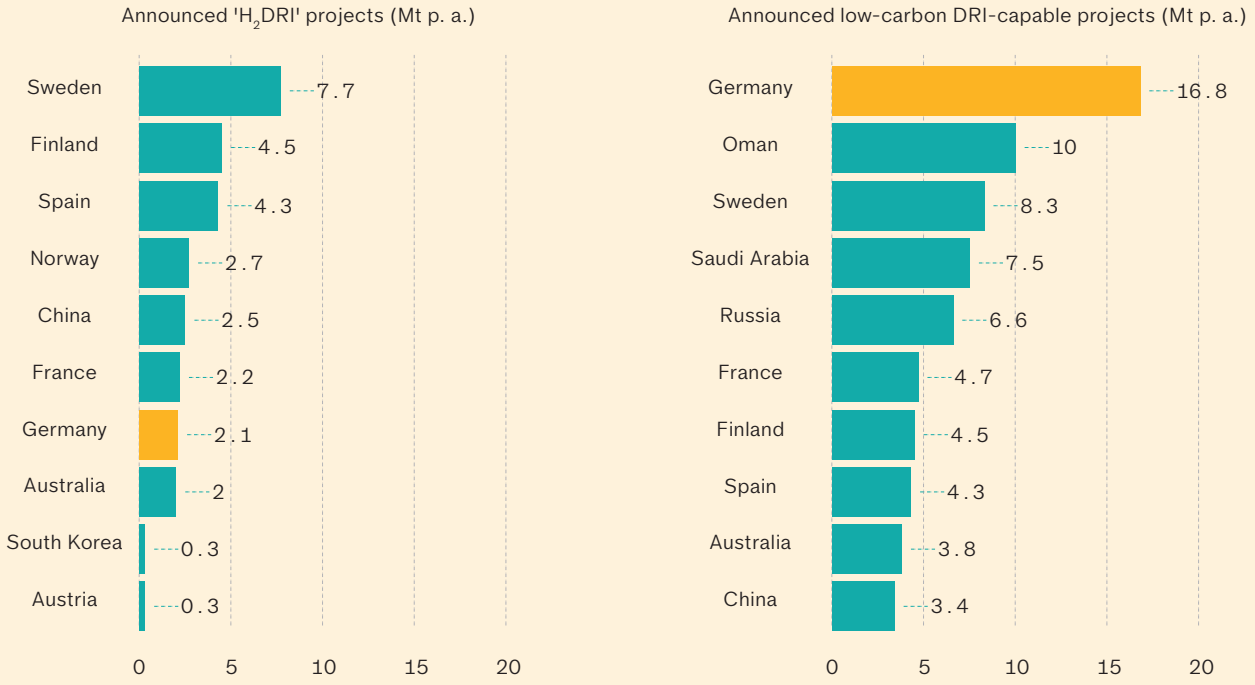


Figure 7.13: Globally announced investments in DRI of iron ore with hydrogen (H_2) or natural gas by 2030. Own presentation based on Agora Industrie (2023).

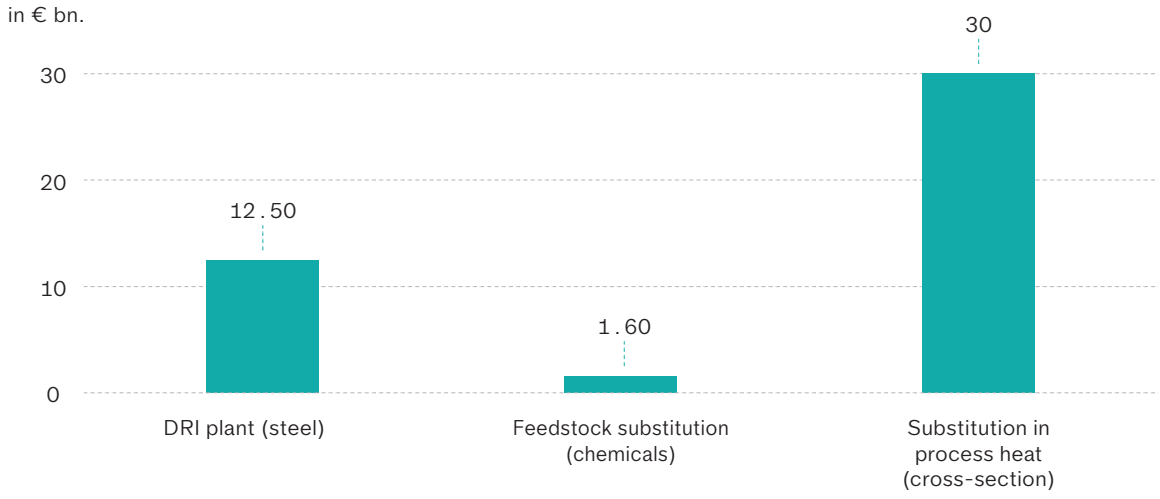


Figure 7.12: Investment volume for the substitution of natural gas in German industry by field of application and (sector) in billion euros (Agora Industrie, 2023; Fleiter et al., 2023; Fraunhofer ISI, 2022; Fraunhofer ISI et al., 2022; Hauser et al., 2022).

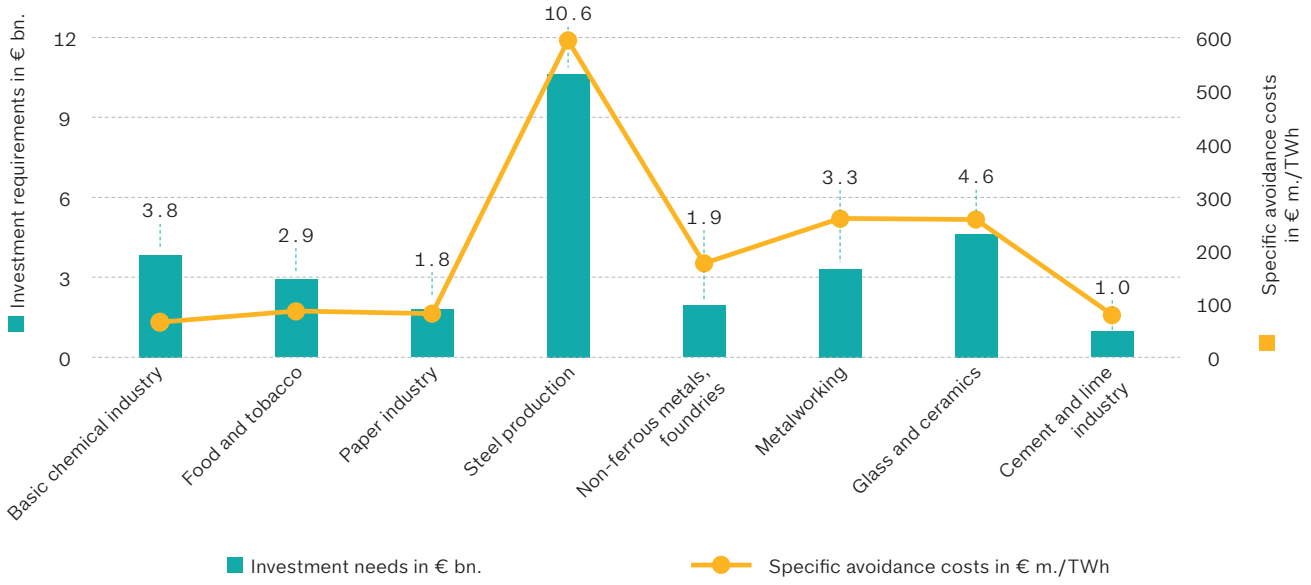


Figure 7.14: Investment requirements for the substitution of natural gas through electrification of process heat generation in billion euros and avoidance costs by sector in million euros. Own calculations. See Figure 7.12 for data basis.

Focus on process heat

55 % of natural gas consumption in industry is used to generate process heat. The costs for the complete changeover amount to around 30 billion euros.[7] Various technologies are used for this purpose, which are introduced in Table 7.3. In the basic chemicals industry, this involves the provision of steam, while the food and tobacco sector and the paper industry use heat in drying processes. Higher process temperatures are required in other sectors – in different furnaces in the glass and ceramics industry as well as non-ferrous metals and foundries; mainly in rolling processes in the steel industry; different furnaces are used for forming and hardening in metalworking; and in the cement and lime industry, the area concerned is the burning of lime and cement. The investment needs for these sectors can be quantified on the basis of the technologies required to electrify the processes, their specific investment costs and the natural gas consumption. Figure 7.14 shows the investment requirements for natural gas substitution and the avoidance costs as a division of the investments by the annual natural gas consumption of the sectors.

The most efficient savings are made in the basic chemicals sector, where 72 million euros is generated per TWh of natural gas consumption for the plants used to electrify the processes. The other sectors (food and tobacco/food industry, paper industry, cement and lime industry) with a process heat requirement at a lower temperature level also have avoidance costs of less than 100 million euros/TWh. The food industry, paper industry, cement and lime industry and basic chemicals together account for 67 % of industrial natural gas demand, which can be substituted with 9.5 billion euros in plant investments.

Large investments are needed to replace natural gas in the rolling processes of the steel industry. The 17.9 TWh in 2021 could be substituted with 10.6 billion euros in investments in electrically heated rollers (595 million euros/TWh). Figure 7.15 shows the different abatement costs based on market concentration (CR6, explained in Table 7.4). Almost a third of the opportunities for substituting natural gas lie in sectors with low market concentrations and low investment costs. These include the paper industry, the cement and lime industry, metalworking and food and tobacco.

7 The data is based on the UBA study CO_2-neutral Process Heat (UBA, 2023), which analyses the conversion of the industrial plant fleet for process heat generation in the above-mentioned sectors. The calculation framework refers to the replacement of the furnace or steam generator with the same production capacity. Other necessary adjustments such as the demolition of the existing plant and the expansion of the infrastructure within the company and in the supply grid (transformers and power grid connections) are not taken into account.

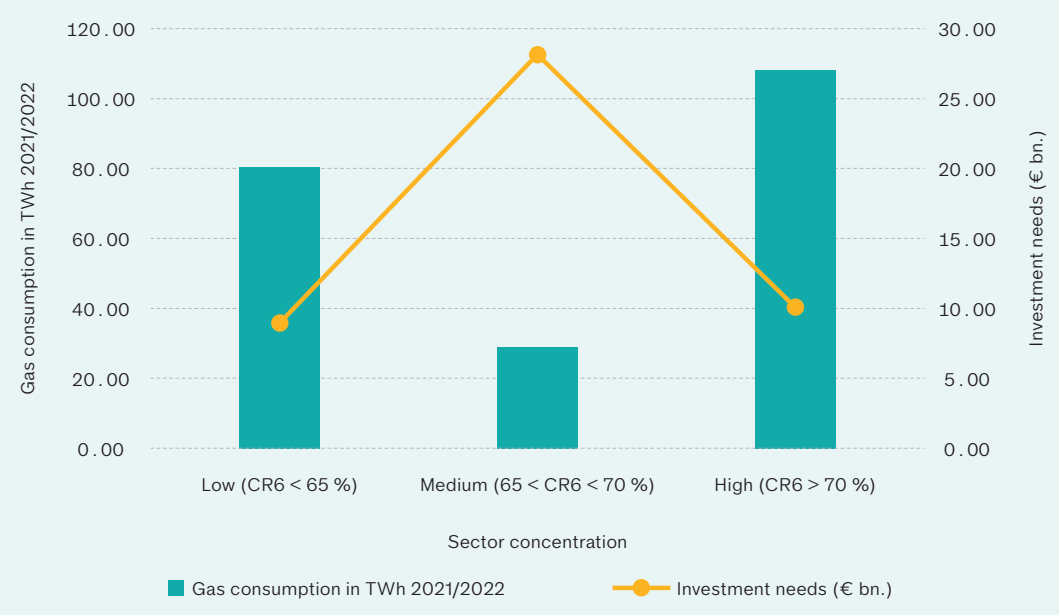


Figure 7.15: Gas consumption and investments by sector concentration. Own calculations. For data basis, see Table 7.4 and Figure 7.12.

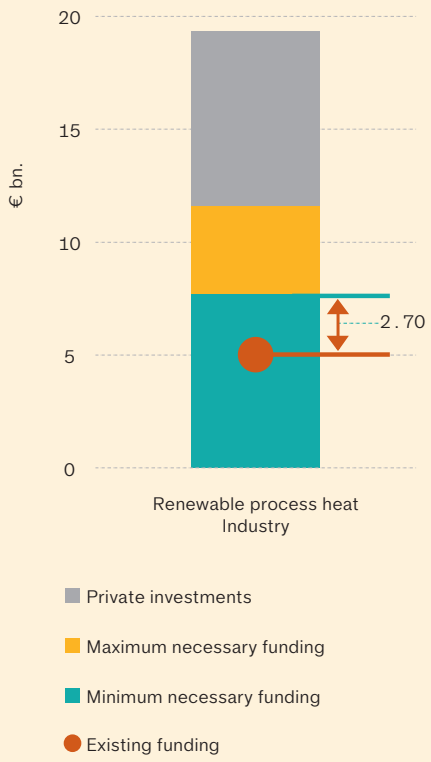


Figure 7.16: Funding gap for the electrification of process heat in industry in comparison with current commitments and necessary investments. Own calculations based on data from Bundestag (2023a, 2023b) and Agora Industrie, (2023), Fleiter et al. (2023), Fraunhofer ISI (2022), Fraunhofer ISI et al. (2022); Hauser et al. (2022).

Funding gap in industry for process heat

In industry, the funding gap for the upcoming capital costs of 20 billion euros for renewable process heat is relatively small, around 3–7 billion euros. The subsidies provided for in the climate protection agreements and the associated investments by the steel industry are not included in the calculation, as they cannot be easily estimated due to their OpEx share. The gap is calculated assuming an investment subsidy of 40–60 % in accordance with the BAFA's *Energy and Resource Efficiency* programme. We make the conservative assumption that already allocated KTF subsidies totalling around 5 billion euros will be used exclusively for the substitution of natural gas.

If one compares the total investments required to decarbonise industry (which go beyond pure natural gas substitution) according to Burret et al. (2021) with the planned subsidies, the existing subsidy amounts including declarations of commitment according to the budget section of 22 billion euros indicate a substantial subsidy share (62 %) by 2030 (Burret et al., 2021).

The greater challenge, however, will be the total additional investment in the decarbonisation of industry of 462 billion euros beyond 2030 (Burret et al., 2021). This also includes significant infrastructure investments, such as for the hydrogen network. In contrast, only 40 billion euros is available for the entire industry from the budget (including commitments), which corresponds to a share of only 8.6 %.

An important aspect to consider is that the main problem in industry is not so much the one-off investment costs (CapEx), but the ongoing operational expenditure (OpEx). For a comprehensive assessment, the subsidies would have to be compared with the additional operational expenditure incurred when substituting natural gas over the entire life cycle of the plant (see *OpEx beats CapEx* chapter). For this reason no conclusive assessment is made at this point.

Different starting conditions

Depending on their size, location and specific energy requirements, companies face different challenges when it comes to the transformation.

In the following, we will see that companies face very different starting conditions. Independence from natural gas will succeed if the investment dynamic is built up gradually until it encompasses German industry as a whole – especially small and medium-sized enterprises. To achieve this, each company must be able to move forward at its own pace. In Table 7.5, we have summarised the structural and economic obstacles based on industry studies and stakeholder interviews. It serves as a supplement to Table 7.3. The obstacles that are currently making investment in natural gas-free production processes particularly difficult are discussed in more detail below.

Risk aversion of SMEs

Decision-makers at SMEs in particular are more sensitive to risks. The effect of the high financing costs is amplified by a possible reduction in income. A low level of technological maturity or a lack of application examples of the technology also influence the decision. SMEs fear production disruption and losses if they move away from best practice.

Large companies: more opportunities with higher expectations

In contrast large companies are prepared to take higher risks and are capable of large investment volumes. The focus is primarily on profitability and the impact on profit expectations. Large companies are under greater pressure in terms of profitability, not least due to their frequent stock market listing. In addition, the decision-making chains in large companies are often lengthy, which inhibits agility in the market. Steep hierarchies and long decision-making processes often prevent innovative ideas from reaching the management level. The process chains in large companies are often still strongly focused on conventional products. This limits the scope for economic adjustments.

Wanted: access to infrastructure and funding

Financing and risk only play a role once the structural preconditions for investment have been met through the corresponding infrastructure. These are often not existing – be it in terms of electricity grid connections or the availability of hydrogen. In particular, the expansion of grid connections for large consumers (steam crackers or electric arc furnaces) poses special challenges and waiting times. Even with good will, investments are then not possible.

Lengthy approval procedures for subsidies, complex EU state aid regulations and regional heterogeneity in the regulatory system have a similar effect. Overall, many of the existing instruments are only suitable for individual pilot projects or are focused on individual industries (climate protection contracts) due to the volume of funding. Instruments for scaling the technologies are rare. The step from pilot project to mass application is too seldom successful.

In addition, SMEs are less well represented in political networks and are therefore less able to communicate their interests. Large companies tend to have easier access to funding and political networks.

Table 7.5: Investment barriers for industrial companies

Stakeholders	Structural obstacles	Business obstacles
SMEs and large companies	· **Insufficient infrastructure** (e. g. electricity grid connection, availability of hydrogen, connection to hydrogen grid) · Attitude of **sticking with the tried and tested** → few innovations · **Risk aversion of SMEs** · **Bureaucratic obstacles** (e. g. EU state aid law; complex & lengthy authorisation procedures) · Structure of grid fees obstructs the path to flexible electrification · Electricity as an energy source currently bears a significantly higher burden of the transition than gas · Expectations of a short amortisation period (esp: energy efficiency measures are only considered 'close to the market' if they amortise within three years)	· **Unprofitability (high CapEx/OpEx)** · Production changeover harbours major **business risk and possible profit reduction** due to switch to new technologies · Large proportion of turnover with **fossil business models** · Insufficient knowledge/uncertainty about opportunities for 'green' premiums due to lack of standardisation of green products · **Harder access** to large volumes of capital · Little financial room for manoeuvre for investments and lean periods · **Restricted access and lack of information** on pilot projects and funding · **Lack of personnel for transformation planning**

Investing after the interest rate turnaround

If future income and risks can be mapped, SMEs are generally well positioned to take out the necessary loans (KfW, 2023b). This is also reflected in the low loan rejection rate among SMEs (Figure 7.17). The same applies to large companies that are experienced in acquiring capital due to their size.

Financing conditions have in the past played a decisive role in debt sustainability. The interest expenses of SMEs, which peaked at 53 billion euros in 2009, totalled 26 billion euros in each of the last few years (KfW, 2023b). However, it is likely that this volume will increase significantly in the coming years, as interest rates for corporate loans have risen noticeably with the turnaround in interest rates. Increased interest expenses are already expected for the current year 2023, meaning that the debt sustainability of some companies is likely to be put to a tougher test (KfW, 2023b).
The mobilisation of investments is not a problem across the board (KfW, 2023b). Nevertheless, increased financing costs can act as a deterrent.

Figure 7.17: Loan rejection rate among SMEs (KfW, 2023b).

OpEx beats CapEx

A large proportion of the total cost of ownership of green industrial plants is attributable to OpEx, with only a small proportion attributable to CapEx.

In the initial project development phase, companies must secure the financial requirements from equity and then finance investment costs from borrowed capital (first two phases of Figure 7.18). The prerequisite is that the profitability of the investment can be refinanced through revenue surpluses. The level of OpEx therefore plays a decisive role.

Energy costs only make up a small proportion of total costs for most companies. Even before the conflict in Ukraine began in 2021, around a third (34 %) of SMEs had energy costs that accounted for no more than 2 % of their total turnover. This figure has risen until spring 2023: at that time, 42 % of SMEs had energy costs that did not exceed 2 % of their total turnover, which corresponds to around 1.6 million companies. For just under a third of SMEs, energy costs were between 2 and 5 % of turnover and for a fifth between 5 and 10 %. The proportion of SMEs for which energy costs accounted for more than 10 % of turnover has fallen from 16 % to 7 % (KfW, 2023a).

"In basic chemicals and the food and tobacco industries, no OpEx increases are expected as a result of electrification."

Nevertheless, OpEx is the dominant component of the total cost of ownership over the entire service life of many technologies, particularly in the case of process heat generation. Table 7.6 shows the ratio for some of the sectors using assumed energy and CO_2 prices as an example (Fleiter et al., 2023). In most sectors the OpEx are higher than those of the natural gas-fuelled reference technology.[8] No additional OpEx costs are expected in the basic chemicals and food and tobacco sectors; in fact, cost savings can even be realised in the basic chemicals sector.

8 The OpEx of the reference technology were calculated assuming EUR 75/t CO_2 and are based on Fleiter et al. (2023).

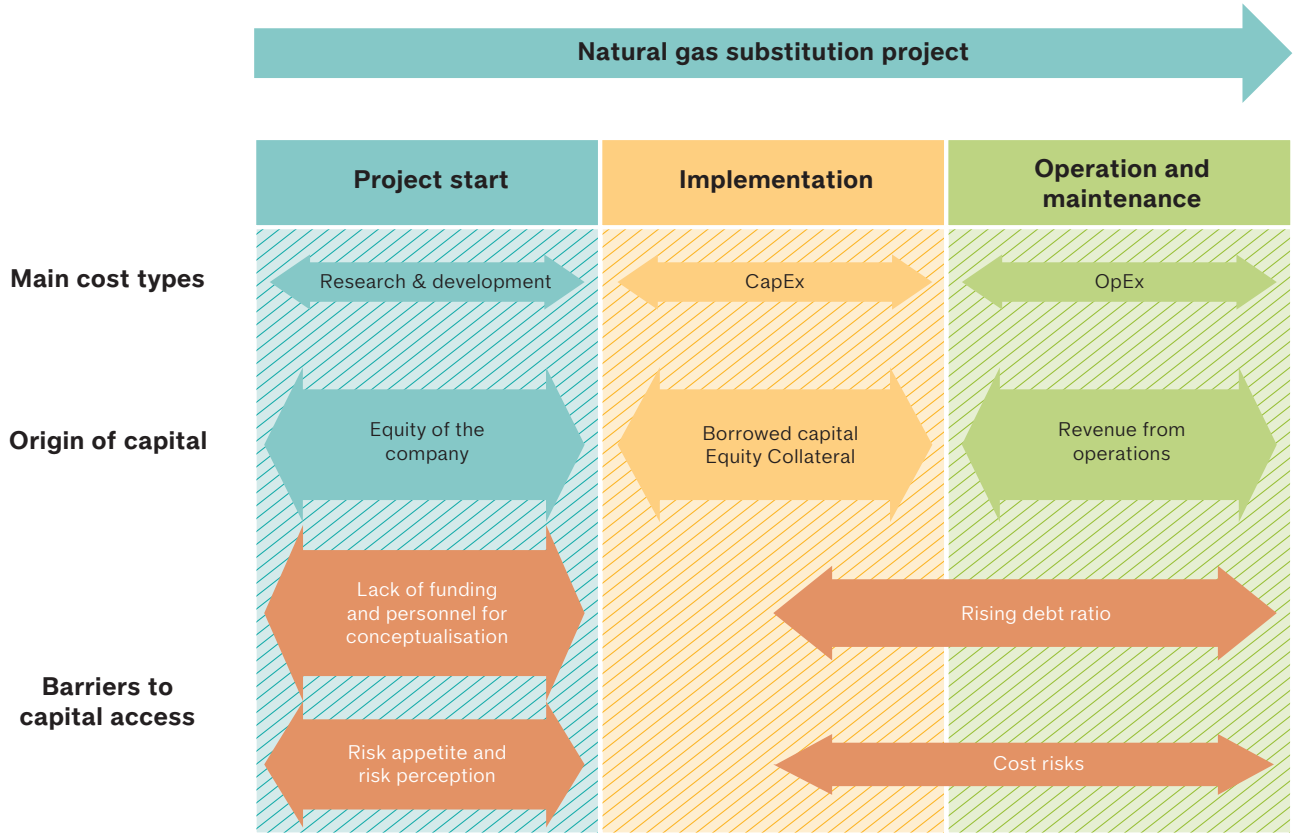


Figure 7.18: Funding by project phase. Own presentation based on UNEP (2008).

"In many industries, the OpEx cost differences for electrification are many times higher than the associated CapEx."

In contrast, the additional costs of electrification in the other sectors exceed CapEx many times over. These will only become competitive through increases in CO_2 prices or a reduction in electricity prices. However, for a full assessment of the impact on competitiveness, the additional costs would still have to be set in relation to the total costs. Uncertainties in their calculation, particularly due to fluctuating electricity prices, are not yet factored in, which further influence profitability and risk perception. The German government's climate protection agreements for energy-intensive industries offer a partial way out.

Green lead markets as a way out?

If cars were made exclusively from green steel, this would mean higher costs for cars of around 300–700 euros (depending on size and weight) (BMWK, 2022b). Companies theoretically have the option of financing these cost increases through 'green premiums'. However, the development of markets for green products is a lengthy process that requires, above all, reliable and standardised definitions and accounting rules that can be used to secure green premiums. This uncertainty, which still exists today, is depressing the profitability expectations of investments. Green markets therefore only offer a medium-term solution. At the same time they are only relevant for certain industries and market segments that can activate the willingness to pay for the additional costs of the end products. Nevertheless, green lead markets can have a supporting effect, particularly when driven by a government procurement policy, in order to accelerate the conversion of production processes (BMWK, 2022b). However, 'green premiums' do not promote broad social access to new technologies and therefore also reach their market limits.

Table 7.6: Comparison of OpEx (energy & CO_2 costs) of the reference technology and electrification for representative example processes as well as CapEx for electrification based on Fleitner et al. (2023). Costs are not discounted. Assumption natural gas price 40 euros/MWh and electricity 90 euros/MWh

Energy and CO_2 costs in billion euros/year	Example process	Reference	Electrification				
Industry		Natural gas (40 euros/MWh)	Electricity (90 euros/MWh)	OpEx difference over service life	OpEx over service life	CapEx	Ratio: OpEx/CapEx
Basic chemicals	Steam supply	7.65	7.52	–2.51	150.43	3.82	39
Food & tobacco	Milk powder production	2.78	2.78	-	55.56	2.92	19
Paper industry	Paper drying	2.90	4.19	25.78	83.78	1.78	47
Iron & steel	Heat treatment Flat/long steel	2.66	4.77	21.08	47.67	10.64	4
Cement and lime industry	Continuous lime burning	3.61	6.82	32.07	68.16	0.96	71
Assumption:	75 euros/t CO_2						

Three company types in the industry transition

Based on their obstacles and the associated status of transformation, companies can be differentiated into pioneers, followers and observers.

The previous overview of obstacles has shown that companies can be categorised into three categories based on business and structural obstacles. This categorisation enables the incentive systems to be adapted in a targeted manner, as the needs and challenges vary depending on the type of stakeholder (Table 7.5).

1. **Potential pioneers as innovation trailblazers:** Companies that already fulfil the business and structural requirements for a transformation are categorised as potential pioneers. These stakeholders need incentives to start or continue the transformation process. To ensure that their investment has an impact on the economy as a whole, it is crucial to create incentives and structures so that pioneers can share their knowledge with potential followers.
2. **Possible followers on the path to transformation:** Companies in the category of potential followers can map the transformation from a business perspective and are prepared to invest, but face structural obstacles. It is crucial for these stakeholders to learn from pioneers and prepare intensively for the transformation. Incentive systems should aim to pave the way for these companies and support them in overcoming structural challenges.
3. **Observers as potential bearers:** Observers are companies that are not yet actively transforming for structural or business reasons. Targeted and low-threshold support programmes can help to bring about a mindshift, especially if financial reasons or risk considerations have so far prevented a changeover. If there are structural obstacles, knowledge sharing and cooperation with pioneers can serve as an incentive to prepare and develop a customised transformation plan. This enables observers to be prepared as soon as the structural conditions for a successful transformation are in place.

Figure 7.19 contains various strategies and instruments that are already being implemented or discussed. It becomes clear that investment decisions not only depend on actual profitability or structural factors, but above all on the perception of risk. Misperceptions can cause the actual and perceived risk to diverge.

7.3 Finance as enabler of natural gas independence

Above all, investments in natural gas independence require trust. Financial companies, and banks in particular, play a key role in building trust when they make targeted use of their expertise in risk management.

For a successful redirection of capital flows into natural gas-free technologies – around EUR 482 billion in the buildings sector by 2045 (see Chapter 7.1) and around EUR 44 billion in the industrial sector (see Chapter 7.2), not only capital borrowers but also capital providers (commercial banks, investment banks and investment funds) must opt for financing.

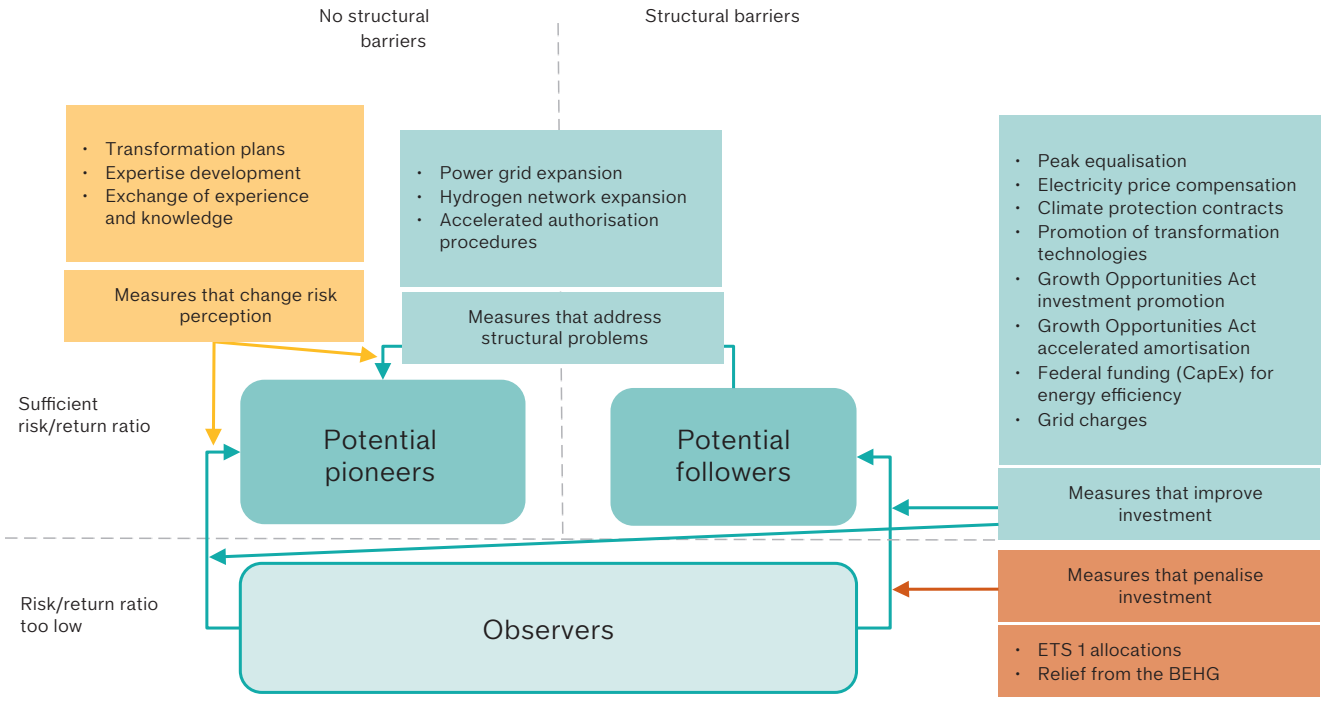


Figure 7.19: The industry lock-in: company types categorised according to obstacles and opportunities for overcoming structural and economic obstacles as well as changes in risk perception. Own presentation.

Expected returns and risks, the risk profile of the borrower and the investment volume influence the interest of investors and which financial instruments are suitable. Expected returns, risks, the borrower's risk profile, and the investment volume all influence investor interest and determine the suitability of various financial instruments. Our analysis of how financial organisations can become enablers of change results in five key findings, which are explained in more detail in the following sections:

Conclusions for the financial sector

1. **Finance structural change** – Targeted and accelerated financing of natural gas independence requires a precise linkage of capital supply and demand.
2. **Invest between profitability and risk** – Where risks, a lack of planning certainty and low expected returns put the brakes on investments in natural gas independence, reliable regulation, changes in risk perception, public investment and risk assumption enable the crowding-in of private capital.
3. **Bundle loans and expenses** – In order to reduce high lending costs, financing solutions are needed that effectively bundle loans.
4. **Rethink the role of banks and map transition risks** – In the future, banks will become transition partners for corporate and private customers by identifying and addressing transition risks. Financing instruments must be based on standardised and binding objectives and ongoing impact analyses in order to minimise transition risks in the medium term and rule them out in the long term.
5. **Clear, supportive and ambitious standards** – A reliable data basis and clear categorisation of investments in gas independence in the context of the EU taxonomy strengthens the flow of capital into economic structural change. In contrast a patchy EU taxonomy that does not clearly cover the industry's investments (44 billion euros) in natural gas independence promotes uncertainty.

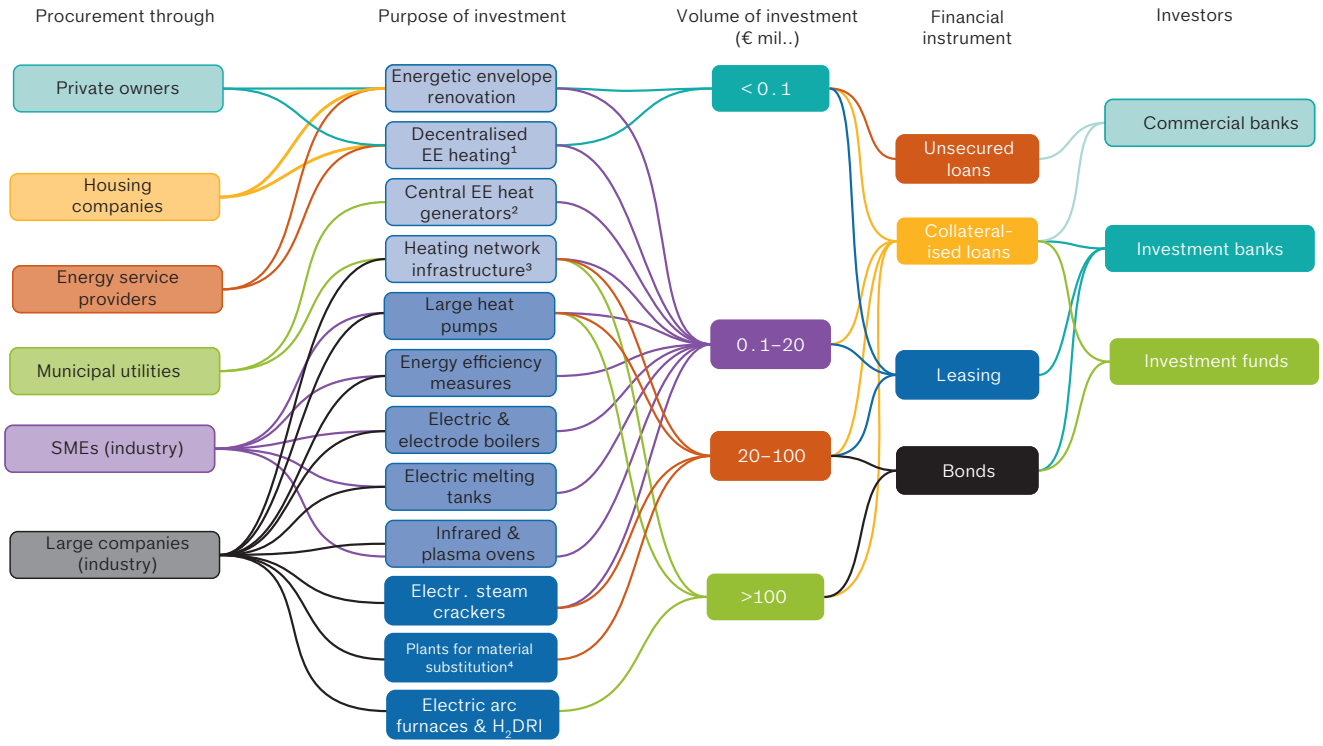
Financing structural change

Targeted and accelerated financing of natural gas independence requires a precise linkage of capital supply and demand. The diversity of borrowers requires a diverse range of financing options that are tailored to their specific needs. Figure 7.20 provides an illustrative overview of the allocation of borrowers, detailing what is invested in, the volumes involved, and the instruments and financial companies used to provide the capital. These cover all direct financing, regardless of whether it relates to the purchase or provision of a product. Capital flows directly from the bank to the project developer or the buyer of the product.[9]

For buildings we assume that the majority will be financed either from internal funds (e. g. from reserves or profits), through a leasing model or via loans (Whitehouse et al., 2020). Small and medium-sized enterprises (SMEs) also finance themselves primarily through equity or loans, 80 % of which are less than 100,000 euros (KfW, 2023e). Bonds or project-related investments are considered in a few cases for large companies or large infrastructure projects.

The debt capital comes either from commercial banks, investment banks or investment funds. German and European capital market regulations and laws define which providers are eligible for which investments. While UCITS are securities funds, alternative investment funds (AIFM) can also invest in real assets. They are subject to specific regulations that limit the volume and types of permissible investment assets (e. g. funds, tangible assets such as real estate, shares in infrastructure project companies, uncertificated receivables, loans, etc.) (see text box *Example European Long-Term Investment Funds*).

9 Depending on their size, loans or bonds are resold on the capital market (secondary access to capital), which can increase the volume of available primary capital.



[1] Heat pumps, biomass, geothermal energy, solar thermal energy
[2] Large solar thermal systems, deep geothermal energy, biomass CHP
[3] Pipelines, civil engineering measures, compressor stations
[4] Plants for ammonia and methanol synthesis and the methanol-to-olefines process

Figure 7.20: Illustrative Senkey diagram for matching capital demand (left) and private capital supply (right). Links between borrowers, technologies, financing volumes, financial instruments and lenders are illustrative and show possible capital flows based on expert judgements. The volume and types of authorised investment assets of funds are subject to the regulations of UCITS[10], EU AIF[11] and the KAGB.[12]

10 According to the European Union (2023a)
11 According to the European Union (2021).
12 According to KAGB (2023).

Example European Long-Term Investment Funds

European Long-Term Investment Funds (ELTIF) are closely related to the AIFM Directive (2011/61/EU) and are by definition EU AIFs. They are managed by alternative investment fund managers authorised under the Directive. ELTIFs can invest in illiquid assets with fixed repayment periods and a long-term economic profile via loans, debt or equity instruments. These include, in particular, tangible assets from energy infrastructure such as energy grids, projects to adapt to climate change or to mitigate the consequences of climate change. In principle, ELTIFs can be opened to private investors regardless of a minimum investment amount or a minimum portfolio value. In this case there are restrictions in terms of diversification, i. e., for example, only a certain percentage can be invested in individual infrastructure projects or SMEs (with a capitalisation of up to 1.5 billion euros).

Depending on the borrower, different financial companies and instruments are suitable:

- → **Private homeowners** are often faced with the challenge of raising the initial investment for measures such as a heat pump or insulation renovation. They primarily cover the expenses using their own available funds or through loans. State-subsidised loans and grants, such as those offered by KfW and BAFA, are a crucial addition. These financing options often offer lower interest rates and easier repayment terms. Energy services and leasing models are also available, where a service provider assumes the investment costs and, depending on the product, also the operation and maintenance of the heat generation system and these are paid off over several years.
- → **Housing companies**, whether small or large, need financing models that enable them to realise major energy-efficient insulation renovations or the installation of renewable heating systems in their portfolios. In addition to traditional bank loans, specialised real estate funds and public subsidies are also relevant here. For larger housing companies in particular, green bonds can also be an interesting option for raising capital.
- → **Municipal utilities** are facing major infrastructure investments. In addition to state subsidies and traditional bank loans, special infrastructure funds can also be important for large-scale projects. These can help to raise the capital required for large-scale investments such as the construction of heating networks or the installation of large heat pumps. However, this is only an option for investments with a corresponding return – this is not the case for heating networks in the first few years.
- → **SMEs** in the energy sector need flexible financing solutions. In addition to traditional bank loans, government funding programmes and specialised loan programmes for SMEs can also play a role here.
- → **Large companies** have access to a wide range of financing instruments. In addition to large corporate loans and syndicated loans, capital market products such as corporate bonds and equity issues are particularly important for them. These make it possible to mobilise considerable sums for large-scale projects such as the switch to renewable energies or the construction of major infrastructure projects.

Investing between profitability and risk

Where risks, a lack of collateral and low income slow down investments, reliable regulation, a change in risk perception, public financing and risk assumption enable the crowding-in of private capital. Five factors play a special role in risk and return assessments and the subsequent investment decision:

Untypical investments – Investments in the transformation of the business model are not typical in the financial sector. They are not clearly regarded as major new infrastructure or property projects, but rather as the transformation of existing assets. They do not generate any additional (financial) returns in the short term that would attract investors or equity providers. This perception reduces the interest of investors, especially investment funds, as investments offer less financial attractiveness or security than traditional large-scale projects.

Expectation certainty present? A strong headwind for investments comes from the often lacking expectation certainty (see Chapter 6). This includes regulatory uncertainties regarding the validity periods of minimum standards, subsidies and reporting expectations. There are also technical uncertainties, as investments are often made in processes and technologies that are less tried and tested than alternatives fuelled by natural gas. Most of the technologies are ready for the market, but as significant development progress has been made in recent years, they are not yet widely known.

Risk too concentrated? Uncertainties regarding the availability and reliability of technologies play an even greater role because investors generally do not want to take a concentrated risk on a specific company or a specific technology. Since natural gas independence concerns a few specific technologies, there is easily the danger of a cluster risk if one of these technologies fails.

High debt ratios – Energy service providers need investors who are prepared to accept high debt ratios and risks (see Chapter 7.1). High capital costs are financed through debt and lead to declining credit ratings. This deterioration in turn has a negative impact on the lending banks, as it increases the risk of their assets. Instruments such as leasing models can provide a remedy.

"In order to achieve profitability, public capital is needed in some cases."

Lack of profitability – In principle, only profitable investments (positive present value, see Chapter 6) are considered by private investors. To achieve profitability, public capital is required in some cases (e.g. heating networks), which is provided by the German government via the Federal Office for Economic Affairs and Export Control (BAFA) or the Kreditanstalt für Wiederaufbau (KfW) and by the federal states via state offices or state banks. It is not necessary to make the full investment, but rather to finance the difference required for profitability. In addition to the pure cost consideration, transaction costs, learning costs and other indirect costs are also involved here.

Bundling loans and expenses

In order to reduce high transaction costs, financing solutions that effectively bundle loans are needed. Investments by private customers and small companies are associated with high initial costs. The difficulty lies in the fact that each individual investment is small for the bank, usually less than 50,000 euros, which entails significant administrative costs for identifying, verifying and processing loans. For SMEs, 80 % of loans are also below a volume of 100,000 euros, with the average being 100,000 euros (KfW, 2023b). Without appropriate standardisation and digitalisation for automation, banks are therefore less willing to invest resources in credit checks, as the returns are low compared to other investment opportunities. Bundling investments can offer a solution, making them appealing not only to commercial banks but also to other investors.

Rethinking the role of banks and mapping transition risks

In the future banks will accompany the transition for corporate and private customers by identifying and addressing transition risks. Financing instruments must be based on standardised objectives and ongoing impact analyses in order to map transition risks.

Transition expertise in demand

The effects of sustainable finance regulation mean a significant change from a past-orientated to a future-orientated assessment of borrowers. It is no longer sufficient to assess creditworthiness solely on the basis of the current business model and past cash flows and debt. Rather, credit risks arise from the future viability of business models and the associated specific investments in transformations that are necessary. This requires the development of new skills that go beyond financial knowledge and also include technical expertise. One example of this is DZ Bank's sustainability reporting (DZ Bank Group, 2022). This not only lists loans for green technologies, but also provides insights into the CO_2 intensity of borrowers such as steel companies or car manufacturers. To date, rating agencies, whose assessments are a key basis for lending, have not sufficiently taken these risks into account (Ciummo et al., 2022), which means that market decisions are still distorted. Despite the existence of emissions trading systems, the external costs of climate change are only factored into investment decisions to a limited extent.

"Banks will become facilitators of the transition in the future by identifying and addressing transition risks."

Inconsistent transition plans of the CSRD

This is due to inconsistent and variably ambitious transition plans mandated by the Corporate Sustainability Reporting Directive (CSRD) and Corporate Sustainability Due Diligence Directive (CSDD). These make it difficult to assess the transition risks and build up the corresponding competences of financial companies. Data from 2022 from CDP (a non-profit organisation that operates the global environmental information system for investors, companies, cities, states and regions) shows that of almost 1,500 mostly listed companies headquartered in Europe, 49 % have submitted a transition plan to climate neutrality (Sokolowski et al., 2023). However, only 0.5 % of these companies have covered all 21 CDP indicators and therefore have a transition plan of sufficient scope. Only 5 % have reported on two-thirds or more of the indicators as well as emission reduction targets that are aligned with the 1.5°C target.

Transition plan

To gain insight into a transition plan, we recommend reviewing the Heidelberg Cement Transition Plan (Heidelberg Materials, 2023).

Clear, supportive and ambitious sustainable finance standards

In order to increase the flow of capital into economic structural change, a reliable data basis and a clear classification of investments in natural gas independence in the context of the EU taxonomy are required. Conversely, an incomplete EU taxonomy that does not comprehensively address the industry's investments in achieving natural gas independence, totaling 44 billion euros, fosters uncertainty.

EU taxonomy

The EU taxonomy is an important lever for channelling investments into sustainable business activities. Their steering effect arises from the fact that investments by financial companies can be recognised as part of the Green Asset Ratio (GAR). Although financial companies are not yet subject to any minimum quotas for the GAR, the classification enables continuous monitoring of whether financial companies are mapping and addressing transition and climate risks. Reputational risks, credit ratings from rating agencies or the ECB's capital requirements for banks can have a steering effect on lending, for example.

Incomplete coverage of investments in natural gas-free technologies

Overall, 8 % of the total investment in gas independence (44 billion euros) is not clearly considered to be taxonomy-aligned – this mainly affects industry (see Figure 7.21 and Table 7.7). 29 billion euros can be categorised as taxonomy-aligned in compliance with threshold values after the investment. 16 billion euros cannot be recognised under the EU taxonomy due to the lack of taxonomy-eligibility of the economic activities.

"16 billion euros of investments in industry are not taxonomy-eligible."

The reason for this is that on the supply side the taxonomy defines which technologies are considered green. These include the production of renewable energy technologies (solar, wind, etc. – activities 3.1), energy-efficient building equipment (3.5) and low-carbon technologies (3.6 – not climate-neutral). This also applies to the generation of renewable heat (geothermal energy, solar thermal energy, waste plants, etc. – measures 4.15–4.25) and the associated expansion of heating networks (4.14) as well as the installation and operation of electric heat pumps (4.16). The problem is that both the generation of electricity from natural gas and the generation of heat fall under the criteria under certain conditions.

The use of technologies in the industrial sector, on the other hand, is assessed on the basis of cross-sector threshold values for CO_2 intensity. For the sectors with high natural gas consumption, threshold values are set for iron and steel production (activity area 3.9) and the manufacture of chemical products (organic raw materials and chemicals, soda, ammonia, nitric acid, plastics – activity areas 3.14–3.17). There is a technology-specific threshold value for electric arc furnaces, as an existing blast furnace for iron smelting can only be replaced in combination with an electric arc furnace. Threshold values for DRI plants are therefore not defined.

Although the production of low-carbon technologies (electric and electrode boilers, electric melting furnaces, electric steam crackers, infrared and plasma furnaces, electric arc furnaces and industrial furnaces) falls under the category of *production of low-carbon technologies* (3.6) and is considered taxonomy-eligible, there are no evaluation criteria for many industries that use these technologies and they are not considered taxonomy-eligible. This primarily affects the paper, food and beverage, glass and metal processing industries. As a result, investors can only classify their investments as taxonomy-aligned if they are related to taxonomy-eligible activities.

In addition, the final state of the process is decisive for activities that fall under the existing evaluation criteria. When electrifying individual components in the manufacturing process using the existing electricity mix, there is a risk that the process will still fall below the threshold value. Investments in these technologies can only be considered taxonomy-aligned if they are part of a CapEx plan that is expected to achieve taxonomy-alignmentt within five years (European Commission, 2021).

Reassessing the taxonomy-alignment of natural gas activities

In addition, the taxonomy provides positive incentives for investments that increase dependence on natural gas. The eligibility of investments in natural gas-fuelled heat and power generation (activity areas 4.29–4.31) is particularly problematic. Although these investments are linked to strict limits and conditions, including a plan to switch to renewable energy sources by 2035, this regulation remains questionable in its current form.

"In view of the desired independence from natural gas, the categorisation of natural gas as a transitional technology in the EU taxonomy needs to be reassessed."

These regulations were issued at a time when natural gas was still regarded as a transitional technology. However, their inclusion equates natural gas-free and natural gas-based technologies, which leads to false incentives in financing decisions. Natural gas-based technologies that are not listed in the taxonomy are still legal and can continue to receive investment. However, they are not environmentally sustainable and, in the case of natural gas technologies, are not compatible with the EU's emission reduction targets (Platform on Sustainable Finance, 2022).

Current figures show that natural gas technologies are also receiving substantial investment. Between 2021 and 2022, global investment in natural gas increased by 14 % from 131 trillion to 149 trillion dollars (OGJ, 2022). In view of the desired independence from natural gas, the categorisation of natural gas as a transitional technology in the EU taxonomy needs to be reassessed. The expansion of natural gas-free technologies and renewable energies should be prioritised over investments in natural gas.

Lack of information

Although the compatibility of investments with the taxonomy is a necessary prerequisite, it is not sufficient for loans or bonds at financial companies to be recognised as such. Corresponding data must be available to assess the loan with regard to the EU taxonomy. This is often difficult, especially for loans to private individuals and SMEs, even if they are taxonomy-eligible. Depending on the size, private individuals are usually granted unsecured loans of up to 100,000 euros to replace heating systems or carry out energy-efficient renovation – the bank can only classify these loans as taxonomy-aligned if they are utilised for this purpose. Even with secured loans for major energy renovation measures, the decisive factor is what energy standard the building will achieve afterwards or whether savings of at least 30 % can be achieved. This requires information on the previous status and energy consumption.

Furthermore, SMEs not listed on the capital market are not subject to the CSRD reporting obligation. However, the calculation of the GAR in accordance with the EU taxonomy only includes companies that fall within the scope of the CSRD. This puts financial institutions that mainly specialise in loans to SMEs and smaller projects at a disadvantage. This particularly affects banks such as Triodos or GLS Bank, which play a pioneering role in the sector. They cannot include these loans in the GAR for all companies outside the scope of the CSRD – regardless of whether the companies' green activities fall under the EU taxonomy. Even if a company voluntarily discloses its sustainability impact, it does not gain any advantages in the capital market. The reason for the exclusion of SMEs was also the additional implementation effort of the CSRD. However, there are feasible solutions for this, such as implementing streamlined reporting requirements.

Table 7.7: Taxonomy-eligibility of CapEx investments in selected technologies to accelerate natural gas independence. Own presentation based on expert discussions and European Parliament and the Council (2020)

Taxonomy compatibility	Technologies with eligible CapEx	Economic activities (EU taxonomy)	Total investment volume
Compatible	Thermal insulation and renovation, heat pumps, heating networks and connections, RE heat generators in the heating network, large heat pumps, solar thermal systems for process heat, deep geothermal energy for process heat, energy efficiency measures in industry, services related to the energy performance of buildings	Renovation of existing buildings (7.2), installation, maintenance and repair of renewable energy technologies (7.16), installation and operation of electric heat pumps (4.16), district heating/ cooling distribution (4.15), installation, maintenance and repair of renewable energy technologies (7.16), combined heat, cooling and power generation from solar energy and 10 other activities (4.15–4.25), installation and operation of electric heat pumps (4.16), manufacture of energy efficiency equipment for buildings (3.5), manufacture of renewable energy technologies (3.1), manufacture of other low-carbon technologies (3.6)	482 billion euros
taxonomy-eligible, compatibility depends on reaching the limit values	Electric and electrode boilers, electric melting tanks, electric steam crackers, electric arc furnaces, infrared and plasma furnaces, DRI plants for steel production in combination with an electric arc furnace, electrolysers	Combined heat, cooling and power generation from solar energy (4.17), combined heat, cooling and power generation from solar thermal energy (4.21), combined heat, cooling and power generation from geothermal energy (4.18), combined heat, cooling and power generation from geothermal energy (4.22), manufacture of hydrogen (4.10), manufacture of equipment for the production and use of hydrogen (3.2), manufacture of low-carbon technologies (3.6)	29 billion euros
Not taxonomy-eligible	All investments	Manufacture of paper and paper products, manufacture of food products, manufacture of glass and glass products, metalworking	16 billion euros

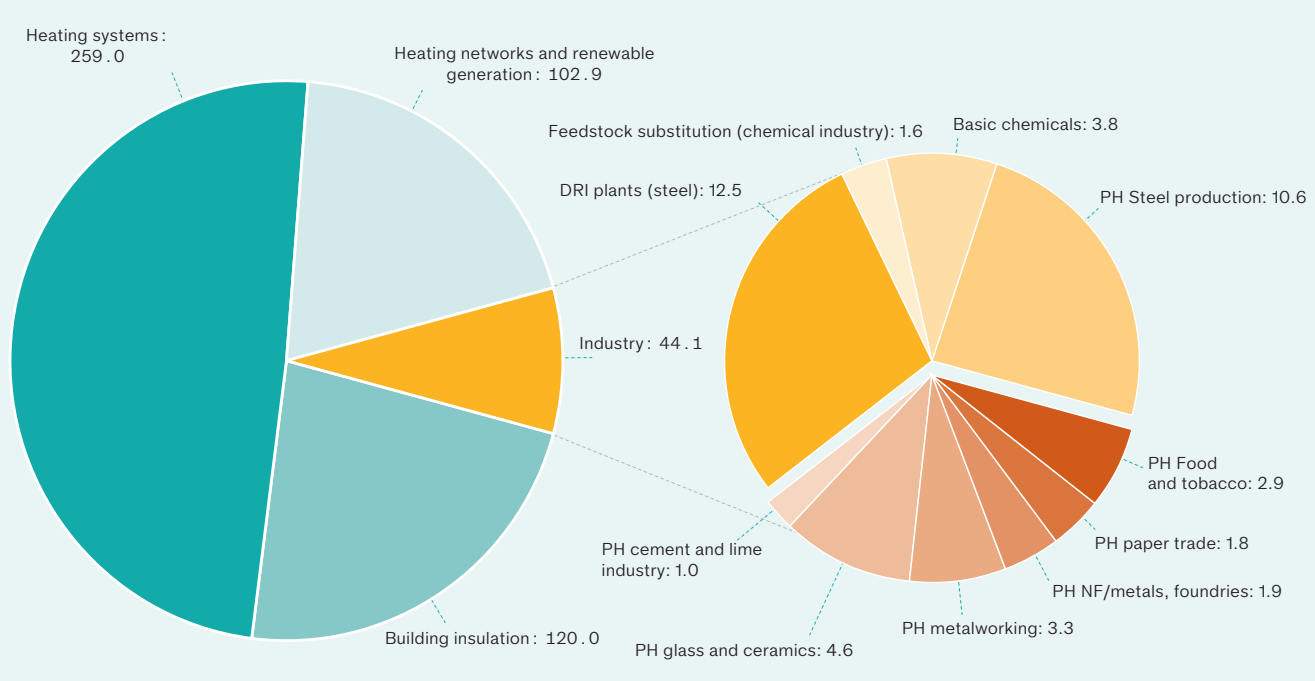


Figure 7.21: Taxonomy-eligibility and alignment of the necessary investments (in billions of euros) in industry and buildings to substitute natural gas. PH = process heat. Green = taxonomy-aligned, yellow = taxonomy-eligible (91 %), compliance dependent on fulfilment of limit values (7 %), red = not taxonomy-eligible (3 %). Own calculations based on data from Figure 7.4 and Figure 7.12. See appendix for details.

Ten proposals for natural gas independence

8. Act: Ten proposals for natural gas independence

2022 marked a turning point geopolitically and in terms of energy policy. Although the immediate effects of the energy crisis have been mitigated in the short term, these successes should not obscure the need for a fundamental reassessment of German and European energy policy.

Initial situation. The EU and Germany have successfully decoupled themselves from lower Russian natural gas supplies in the short term by importing 66 % more LNG into the EU between 2021 and 2022 and reducing consumption. In the long term, the import dependency on LNG will afflict the economy and society with new price uncertainties, inflation risks, geopolitical dependencies and growing transition and climate risks. Prioritising independence from natural gas has the potential to mitigate these risks. Germany can benefit significantly from a leading role in the field of key green technologies and thus contribute to strengthening domestic value creation and the European economy (see Chapter 2).

Investments. The technologies that will lead Germany out of its dependence on natural gas have already been tried and tested in all areas of application (see Chapter 4). A wave of investment is now needed to replace natural gas in the heating supply of buildings, to electrify industrial process heat and to utilise scarce hydrogen capacities specifically for material substitution and direct reduction processes.

Political framework. A clear, ambitious and targeted policy framework is required to redirect capital flows to natural gas-free technologies – an estimated 482 billion euros in additional investment in the building sector and around 44 billion euros in total investment in industry by 2045 for plant replacement. This should motivate key stakeholders to invest and effectively close existing gaps in the structure of legal requirements, targets and instruments (see Chapter 3).

Efficiency. In the area of tension between short-term affordability, long-term competitiveness and social acceptance, supplementing emissions trading with targeted subsidies creates an environment for private investment that generates both economically efficient and socially effective investment dynamics through economies of scale and shared learning (see Chapter 6).

Key stakeholders. For the separation from natural gas to succeed, the actions of relevant key stakeholders must be effectively interlinked. This is achieved through ten measures.

→ **Buildings sector:** A scaling programme for heating contracting, an enabling package for the municipal heat transition and practice checks mobilise institutional stakeholders (housing companies, municipal utilities and energy service providers) to accelerate the investment dynamic, generate economies of scale and participate in the further development of the legal framework. A Heating-for-all programme ensures access to a natural gas-free heating supply even for homeowners with poor credit ratings. The skilled labour offensive promotes the training of the necessary skilled workers.

→ **Industrial sector:** An Industry transition accelerator platform mobilises pioneering companies to lead the way in the electrification of process heat and create confidence in the change through experience. These pioneers show the way to effectively prevent transition and climate risks and inspire other companies.

→ **Financial sector:** The focus of sustainable finance regulation on the structural change associated with independence from natural gas makes banks and institutional investors companions of this change. They use their expertise in risk management to identify transition risks and strengthen confidence in investments.

→ **Systemic:** A commission for natural gas independence, targeted public financing and temporary green TLTROs (targeted long-term refinancing transactions by banks) have a broad impact and support the structural and economic framework conditions for accelerating Germany's natural gas independence.

Obstacles. Structural or economic conditions are still preventing the economy and society from jointly embarking on the path to a natural gas-free future. Our ten proposals create a framework in which key stakeholders decide to invest in natural gas independence. Table 8.1 and Figure 8.1 provide an overview of the proposals and show which stakeholders the proposals are aimed at and which obstacles they overcome.

Focus on private investment. Many of the proposals promote the mobilisation of private investment in natural gas independence even without public funding. This applies in particular to the measures of the natural gas commission (1), pillars 1–4 of the municipal heat transition enabling package (2), the heating contracting scaling programme (3), the practice checks for the heat transition (4), the functioning of the Industry transition accelerator platform (IBP, 7), the further development of the sustainable finance regulation (8) and the temporary green TLTROs (10).

Public funding. Public funding plays a role when investments are not profitable in the short to medium term but are necessary in the long term (such as investments in green heating networks), risk profiles prevent access to capital (vulnerable homeowners), wage incentives are too low or retraining costs are too high (skilled labour in the craft sector) or short-term cost disadvantages arise that are only offset in the long term when CO_2 prices are high (IBP investment funding). Options for creating the necessary room for manoeuvre in the budget are summarised under the proposal Targeted public funding (9).

Strengthen iterative learning and adaptability beyond CO_2 prices, regulation and funding

Feedback mechanisms. The recommendations deliberately extend the range of measures beyond regulation, CO_2 prices and subsidies. It is about creating an environment that promotes trust, initiating processes and establishing feedback mechanisms that spark a dynamic that makes Germany's independence from natural gas a reality.

Adaptability. The solution for the buildings and industrial sector to move away from natural gas will take time. A learning framework that enables iteration and adaptation is crucial for success. Risk profiles and profitability are core aspects of investments, but looking at them alone is not enough. The demand for and supply of capital must be harmonised and crucial information must reach the right stakeholders at the right time. Processes and structures are needed in which all stakeholders learn together over the coming years of structural change, exchange experience and continuously adapt the structural and legal framework conditions based on these findings. The following proposals are to be understood in this context and are intended to pave the way for innovative solutions.

Ten proposals for natural gas independence

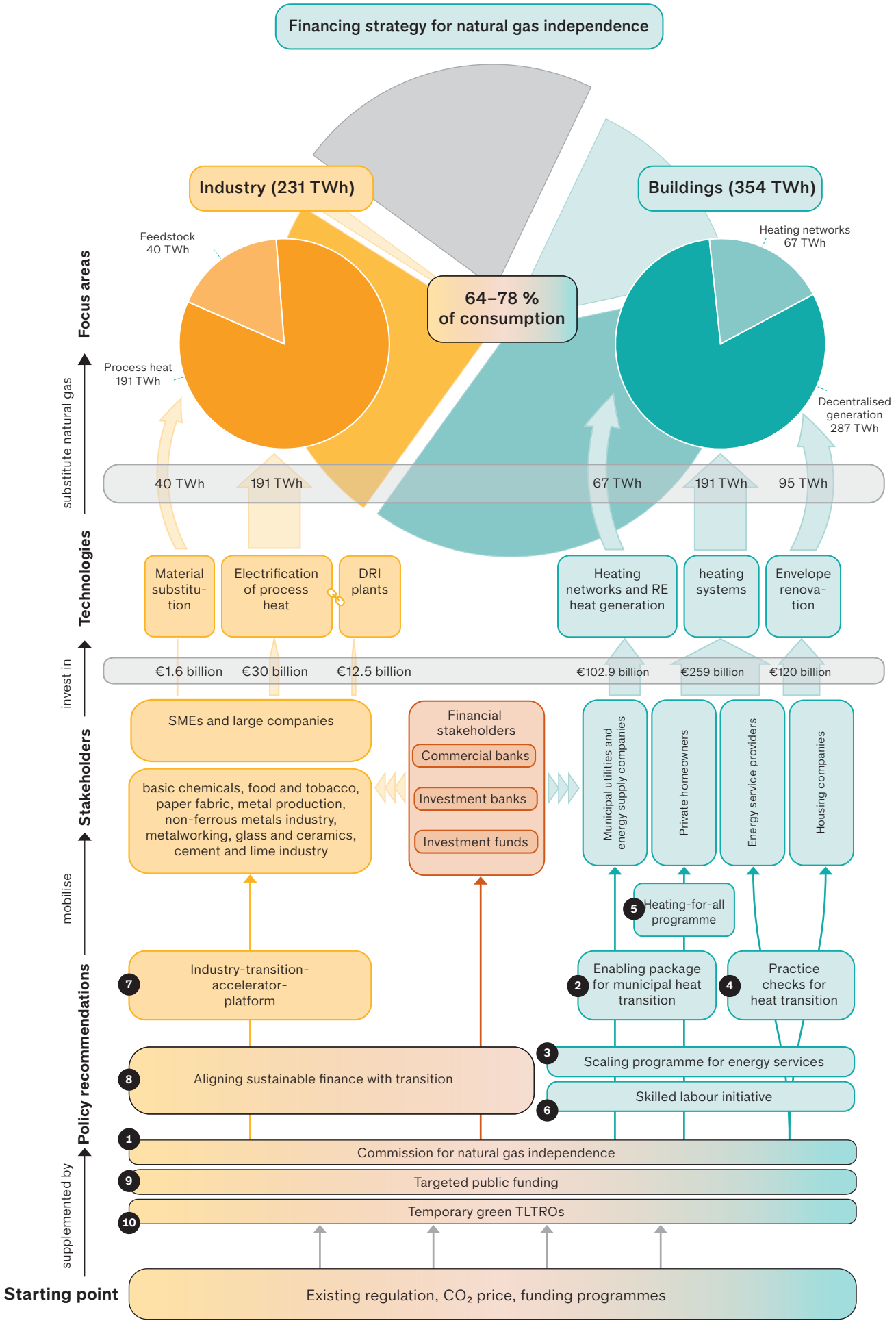


Figure 8.1: Financing strategy for natural gas independence – overview of stakeholders, policy recommendations, technologies and focus areas including investment volumes and natural gas reduction potential.

Table 8.1: Assignment of measures to selected obstacles of housing companies, homeowners, municipal utilities, energy service providers, industrial companies and financial institutions. Own presentation.

		Commission for natural gas independence	Enabling package for the municipal heat transition	Scaling programme for heating contracting	Practice checks for the heat transition	Heating-for-all programme for vulnerable homeowners	Skilled labour offensive for the heat transition	Industry transition accelerator platform	Targeted public funding	Align sustainable finance with transition	Temporary green TLTROs
Housing companies and homeowners	Bureaucratic obstacles for housing companies	■	■		■						
	Worse credit conditions for housing companies								■		■
	Lack of willingness to invest		■	■		■			■		
	Aversion to loans with long terms			■							
	Low credit rating			■		■			■		■
	Shortage of skilled labour			■			■				
Municipal utilities	Financial situation of the municipalities		■						■		
	Business model dependent on gas business		■	■							
	Unprofitable investments in heating networks	■	■						■		
	Gas grids as stranded assets	■	■	■							
Energy service providers	Limited access to funding			■							
	Regulation tailored to established companies	■	■		■						
	Capital intensity of the business model			■							
	Uncertain electricity price trends			■							
	Shortage of skilled labour						■				
Industrial companies	Status quo bias of SMEs							■			
	Long amortisation										■
	Lack of information on funding and pilots							■			■
	Unprofitability (high CapEx/OpEx)							■	■		■
	Caution towards new technologies							■		■	
	Lack of personnel for transformation planning							■	■	■	
Financial companies	Matching capital supply and demand			■		■		■			
	Atypical investments							■	■	■	
	Expectation certainty	■				■				■	
	Cluster risks							■			
	Capital intensity of energy service providers			■							
	Lack of return on investment	■							■		
	High lending costs			■							
	Assessment of transition risks									■	
	Lack of taxonomy-alignment			■						■	
	Distorted capital markets									■	■

Ten proposals for natural gas independence

Some restrictions

Focus on financing. The obstacles that are directly related to financing issues and have an impact on the matching of capital demand and supply were selected. To this end we have chosen a (microeconomic) stakeholder focus and restricted ourselves to the buildings and industrial sectors. This does not deny that there are numerous other challenges that play a role in the transition to a natural gas-free future.

Electricity sector. The electricity sector was excluded, as a corresponding investment dynamic can already be observed here and it plays a negligible role in overall natural gas consumption. However, the electrification strategy results in important interactions between the measures proposed here and the electricity market design, including via combined heat and power generation. Electricity is still subject to higher taxes, levies and surcharges than natural gas. For a natural gas-free future, there have therefore long been calls for ways to reduce electricity costs and for a reform of grid fees. Our measures should be seen as complementary to these demands.

Infrastructure. Secondly, with regard to the further development of network infrastructures (electricity, heat, gas, hydrogen), the focus was placed on investments in heating networks, which significantly reduces the investment volumes in industry mentioned here. Due to the complexity and the number of stakeholders and interest groups involved, we recommend discussing related issues of integrated network development, such as changes to concession law, the Gas Network Charges Ordinance, the Incentive Regulation Ordinance, the Network Development Plan, the Energy Industry Act or the Hydrogen Network Charges Ordinance, in the designated natural gas commission.

Technology offering. The effectiveness of the proposals put forward here therefore requires a clear industrial policy prioritisation of the sectors that provide technologies and systems (e. g. large heat pumps, industrial furnaces, electrode boilers). This includes the German mechanical and plant engineering sector in particular. Our study focuses on the mobilisation of demand for natural gas-free technologies, both for industry and buildings, and not on their supply. This can lead to bottlenecks upstream in the value chains if too many companies invest at the same time. As the heat pump ramp-up shows, rapid adjustments to production capacities can be expected if there is politically driven investment and planning security for these technologies.

Industrial policy. Our proposals are intended to complement the German industrial strategy. They focus on selected sectors with relevant potential for saving natural gas and sector- and company-specific obstacles. Apart from the resulting recommendations on the prioritisation of sectors and technologies, overarching systemic issues of industrial development in Germany and Europe, its future viability and strategic priorities are not addressed. This also includes related discussions, such as the establishment of green lead markets, which we have only mentioned in passing.

Europe. These measures are limited to Germany and are the responsibility of the German government, with the exception of temporary green TLTROs and the adaptation of the sustainable finance regulation. However, energy, industrial and housing policy are now largely coordinated at European level. We do not cover issues such as the effects of the measures on the European gas market in the event of accelerated independence from natural gas in Germany, associated geostrategic considerations or effects on the European internal market.

1. Commission for natural gas independence

A commission for the institutionalisation of natural gas independence

Natural gas flows through Germany via an extensive gas network with 555,000 km of distribution network and 40,000 km of transmission network (BMWK, 2023l). Accompanying the transformation of this infrastructure requires well-founded decisions that must be both economically viable and socially acceptable. We therefore propose the establishment of a natural gas commission. The commission provides a structured framework for the continuous dialogue between stakeholders on issues relating to natural gas independence in Germany. It brings together experts from different interest groups and specialist areas to continuously evaluate existing measures and accelerate Germany's independence from natural gas.

Objective of the commission

→ Identification of a realistic and socially acceptable **path to natural gas independence**that is compatible with the German government's climate targets, taking into account the German government's system development strategy (BMWK, 2023j) for planning security for investments.

→ Development **of a strategy for the decommissioning of gas networks or their transformation**, including regulations for supply obligations and amortisation conditions as well as concepts for conversion.

→ Proposal of **measures to mobilise investment in natural gas-free technologies**.

→ Coordination of various stakeholders as well as continuous **evaluation and further development of measures to reduce German natural gas consumption**. The aim is to jointly develop binding agreements that are secured with corresponding regulatory adjustments and financing commitments.

Organisation and composition

→ The objectives and mandate of the commission are defined in advance by the German government and independent and cross-party cooperation is ensured within the mandate.

→ The commission is made up of experts and representatives of interest groups. Experts cover the various sectors of natural gas substitution (buildings, industry, energy industry, financial sector) and combine macroeconomic, financial and technical expertise.

→ The line-up is deliberately balanced and independent moderation is ensured. Conflicts of interest are handled transparently and in a way that creates trust.

→ Based on existing studies, the commission discusses stakeholder- and sector-specific as well as systemic barriers to the mobilisation of investments in natural gas substitution technologies.

→ In particular, it identifies unresolved issues relating to the decommissioning of the gas grid infrastructure. These include, in particular, legal adjustments to the basic suppliers' supply obligations, regulations in concession agreements, the apportionment of grid fees and the amortisation periods for grid operators (Agora Energiewende, 2023). This relates in particular to concession law, the Gas Network Charges Ordinance, the Incentive Regulation Ordinance, the Network Development Plan, the Energy Industry Act and the Hydrogen Network Charges Ordinance.

→ It makes proposals on how the decommissioning of the natural gas supply can be integrated into future-orientated network and heat planning in order to create both supply options for consumers and new business areas for energy companies.

Implementation

The first step would be an appointment decision by the German government and a nomination procedure by the coalition parties with the BMWK as the responsible ministry in charge.

2. Enabling package for the municipal heat transition

In order to achieve the goals of the Building Energy Act (GEG), it is essential that municipal heat planning is implemented quickly. This requires a coordinated approach that takes into account the diversity of local conditions, especially as the challenges in small and medium-sized municipalities differ significantly from those in large cities (DStGB, 2023). The enabling package includes measures that apply to both residential and non-residential buildings. The following aspects play a key role here:

→ **Strengthening the adaptability of legislation** and optimising the flow of information between municipalities, federal states and the German government in order to enable effective cooperation at national and municipal level (Beer et al., 2017; Coalition for Urban Transitions., 2019).

→ **The establishment of effective municipal coordination** which takes into account municipal stakeholders such as municipal utilities, housing companies, energy service providers, the craft/construction sector and commercial banks as well as the interaction between public and private players – it can have an accelerating effect on implementation (Hüncke et al., 2022).

→ **Empowering stakeholders to fulfil their roles responsibly.** Municipal utilities and private energy suppliers in particular need support in adapting their business models and redefining their roles in the structure of municipal stakeholders (KWW, 2023). In addition, the provision of specialist staff and adequate funding volumes and guarantees for decarbonisation and the expansion of heating networks is essential for municipalities and energy suppliers in order to meet new requirements.

→ **The synergetic view of planning, financing and implementation.** The role of municipal utilities, housing companies, energy service providers, the craft/construction sector and commercial banks must be taken into account as early as the planning stage in order to prevent obstacles to implementation.

Objective of the municipal heat transition enabling package

Five pillars of the enabling package

The interaction of the following measures is illustrated in Figure 8.2.

1. Provision of municipal heat transition teams (MHTTs) for the municipalities
With the support of the MHTTs, all municipalities (especially small municipalities) can effectively implement their municipal heating plans. MHTTs promote the understanding of the heat transition as a joint project. In dialogue with local stakeholders, they develop ideas for the complex challenges, mobilise support and prevent resistance during implementation.

→ **Three functions of the MHTTs:**
1) Expert support for local capacities in planning.
2) Organisation of participation processes with local stakeholders (municipal utilities, housing companies, energy service providers, craft/construction sector, commercial banks).
3) Support in the implementation of heat planning.

→ **Financing:** Provision of funds for personnel capacities of the teams from state or federal budgets, depending on the financial situation of the municipality.

→ **Staff recruitment:** Possibility of recruitment through the municipality, but hiring via the Kompetenzzentrum Kommunale Wärmewende (KWW) in order to create better remuneration and an effective interface to the German government and funding offers.

2. Organisation of MHTT dialogues at federal level:
These dialogues improve the flow of information between the municipality and the German government. Through their role, MHTTs uncover implementation difficulties among the actors involved (housing companies, energy supply companies, energy service providers, homeowners) that can only be solved through state or federal legislation. They communicate these to the legislator in order to enable an efficient adaptation of the legal framework.

→ **Implementation:** The KWW organises regular stakeholder dialogues with members of the MHTTs. At these events municipal success factors and legal hurdles for the heating transition are discussed and ideas for improvements are collected to be incorporated into future legislative processes.

3. Initiation of regular exchange and learning programmes of the MHTTs at state level
These programmes enable municipalities to anticipate challenges, avoid mistakes and speed up implementation. Common state legislation ensures comparability.

→ **Implementation:** State level (e. g. state energy agencies) organises formats in which MHTTs of the state identify challenges and share solutions and ideas. These events serve to exchange knowledge and experience.

→ **Integration into existing structures:** Utilisation of state energy agencies for economic efficiency, low bureaucratic effort and region-specific knowledge.

→ **Access to funding and advice:** The formats also serve as a platform for accessing funding (e. g. ERDF, state funding).

4. Hosting of innovation clusters for municipal utilities and energy suppliers at state level:
Municipal utilities and energy supply companies develop innovative business models to reposition themselves as all-round suppliers independent of the gas business, including new heating services and offers such as wall boxes for electric cars.

→ **Implementation:** States and districts award prizes for innovative business models, such as the Energy Transition Award (Energy Transition Award, 2023).

→ **Innovation cluster:** Management staff from award-winning municipal utilities come together with innovation managers from other municipal utilities and share solutions and ideas in organised formats.

5. Increase and dynamisation of federal funding for efficient heating networks
A large part of the necessary investment in the decarbonisation of heating networks and heat generation is currently not profitable. These investments were estimated at around 103 billion euros in Chapter 7.

→ **Further develop the federal funding for efficient heating networks:** The current funding of around 3 billion euros should be seen as a first step. Future budget planning should take into account increases in the programmes *Subsidies for the operation of decarbonised heating infrastructures* and *Transformation of heating networks*. In addition, energy suppliers should be able to apply for personnel capacities for the strategic further development of business models (see also proposal → Targeted public funding).

→ **Dynamic subsidy:** When expanding the heating network, a subsidy based on the connection density actually achieved would be helpful – the more building homeowners connect, the lower the subsidy would be. A KfW programme with interest-free loans would be suitable for this purpose, with repayments only becoming due when the economic efficiency of the network increases as a result of more connections.

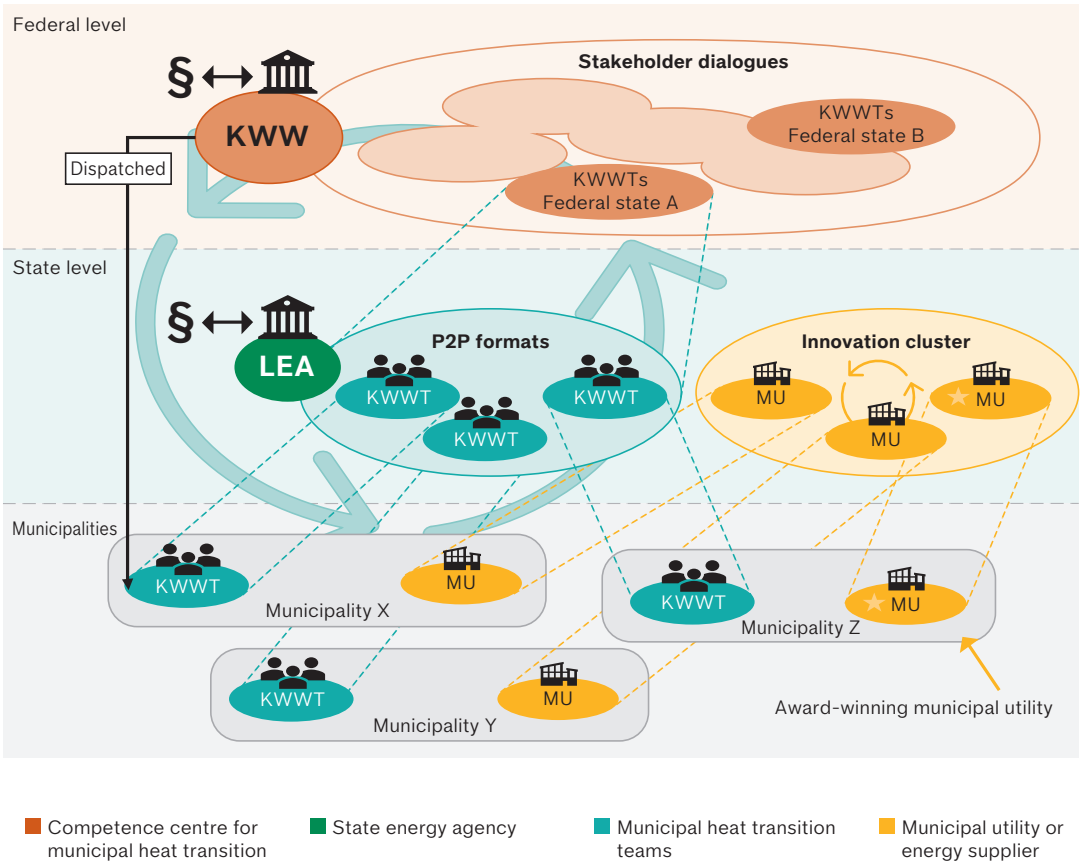


Figure 8.2: Illustrative presentation of the municipal heat transition enabling programme, in particular the interaction between the German government, federal states and municipalities and the role of municipal heat transition teams (MHTTs) as well as municipal utilities and energy suppliers.

3. Scaling programme for heating contracting

Heating contracting is a key lever for mobilising investment in renewable heating technologies. It generates a fourfold dividend.

1. **Efficient financing** by reducing transaction costs for building homeowners through energy services (one-stop shop solution, bundled knowledge about funding applications);
2. **Support for vulnerable homeowners** through the conversion of CapEx into OpEx;
3. Municipal utilities can utilise **heating services as a new business model** and thus compensate for the loss of around 25 % of revenue from the gas business;
4. Private homeowners can support each other **regionally in replacing heating systems** and thus create a collective spirit of optimism.

The main service providers are municipal utilities, energy supply companies and a few energy start-ups. In principle, the models can also be applied to all products with energy savings, including energy-efficient insulation renovation. Challenges in implementation (see Chapter 7.1) are the high capital intensity, which has a negative impact on creditworthiness, as well as reservations about the model. In addition, heating services are primarily offered for single-family homes and not for the broad mass of the housing stock. The scaling programme addresses all these problems. It is true that the energy service increases the total costs for the contract recipient. Nevertheless, heat contracting can act as a catalyst for investment if these are outweighed by the aforementioned advantages.

Aim of the scaling programme

→ **Incentivising building homeowners** to replace their heating systems by outsourcing capital and transaction costs to energy service providers.

→ **Establishing sustainable business models** for municipal utilities and energy service providers by implementing the programmes.

→ Generating greater **acceptance of the measures** through yield sharing.

→ Securing the **creditworthiness of energy service providers** through the establishment of special purpose vehicles.

Functionality: special purpose vehicles for bundling and municipal participation

→ **In order to expand the use of heating services, we propose the establishment of regional special purpose vehicles (SPVs) as stock corporations (SAGs) or cooperatives (eGs).**

→ The SPV would bundle the purchase of renewable heating technologies and the associated borrowing and make the products available as a leasing offer to municipal utilities and other service providers for further conveyance to property homeowners.

→ The special purpose vehicle would legally acquire the products (heat pumps, energy-efficient insulation renovation, etc.), with the product being made available directly to energy service providers such as municipal utilities or other companies. In return, a leasing contract is concluded between SPV and the energy service provider for a certain volume of heat pumps or insulations.

→ Citizens in the region can acquire shares in the SPV and thus participate in profits.

→ The German government should ensure that the SPV can also gain access to federal funding that it passes on to users.

Numerous advantages of bundling

Favourable credit conditions and access to capital

The SPVs could be founded with the participation of KfW, commercial banks with municipal roots, federal states or municipalities. Bundled borrowing protects the service providers' balance sheets from high liabilities. The involvement of KfW and the municipalities ensures the creditworthiness of the SPVs. In addition, the participation of public lenders enables the company to take out loans at favourable interest rates, which also benefits customers. This effect is amplified if the credit volume and eligibility for the EU taxonomy lead to further interest rate advantages.

Creating trust through participation and insurance

Confidence in the heat transition is strengthened through various levers. By cooperating with regional commercial banks, citizens would be able to acquire shares in the SPV and participate in the profits. This makes it possible to keep the added value in the region, strengthens the visibility of the programme and increases acceptance – as the model of regional energy cooperatives shows.

In addition, the combination with an insurance policy that balances out electricity price peaks can help to guarantee a 'secure heat price' (see supplementary instruments) and thus secure savings compared to the fossil heating alternative.

New business models for municipal utilities

Delegating the purchase of heat pumps to a special purpose vehicle reduces the management workload for sales. This facilitates the development of this business segment. Furthermore, the SPV's borrowing protects the balance sheets of the municipal utilities from further liabilities. This gives them more economic room for manoeuvre, as income from the gas business is declining and municipal utilities have to invest in the expansion of district heating at the same time. In principle, it should be examined whether municipal utilities could also acquire shares in the SPV. This would allow them to utilise an institutional relationship with the SPV, which would make it easier to coordinate the development of an energy services programme.

Unprofitable lending is centralised

It is only profitable for banks to grant small loans to replace heating systems if the interest costs are high. These in turn inhibit investment. The bundling and centralisation of credit checks and funding applications relieves the burden on banks and enables favourable credit conditions. Instead of millions of individual loans, a small number of large loans are taken out.

A tried-and-tested and award-winning model

→ Similar models have already been developed and implemented for energy-efficient renovations, including by the Inter American Development Bank (IDB). The concept has been identified by the Global Innovation Lab for Climate Finance as one of the most promising instruments for mobilising private sector investment in renewable technologies (Whitehouse et al., 2020).

→ The German Energy Efficiency Initiative for Businesses (DENEFF) also recently proposed a similar programme for low-threshold financing of investments (DENEFF, 2023).

→ A report by the IEA estimated the European market for energy services at 30 billion euros in 2017, 10 % of which was with guaranteed savings. China and the United States are leading the way. The degree of market development is influenced by the opportunities for energy savings through energy efficiency in different regions and by the policies to promote such investments. Germany is considered the most mature market within the EU, together with France, Austria and the Czech Republic. This could be followed up on (European Commission, 2017).

Instruments: scaling premiums and insurance for support

Scaling premium

We also propose extending the entitlement to the speed bonus and income supplement of the Federal Funding for Efficient Buildings to energy service providers if the customers of the leasing contract fall under the income categories of the BEG, which therefore primarily affects owner-occupiers. In addition, as part of the BEG funding, a premium for energy service providers should be introduced for extending the range of energy services to building types other than detached houses and combined with a scaling premium. This would supplement the demand-side incentives (investment subsidy, speed premium, income supplement) with supply-side incentives.

This could look as follows: The subsidy rate per renewable heating technology leased increases by 0.01 % per GWh for each heat generation forecast by customers within one year – on condition that the provider covers a minimum number of apartment blocks. The customers' heating energy requirements from the previous year would be used for the estimate. The increase would be capped at a maximum of an additional 1.5 % and a total of 10 million euros for the products of a provider. What would only be a small amount of support for individuals becomes economically interesting for the energy service provider due to the economies of scale and would channel investments primarily into larger heat pumps and thus into apartment blocks. Other structures (e. g. depending on the company's sales growth) are also conceivable.

Sample calculation

For example, a provider that leases heat generators with a heat production of 100 GWh would receive an additional 1 % subsidy. With an annual energy production of 10 MWh/heat pump, this would correspond to 10,000 heat pumps sold. Assuming subsidised costs of 30,000 euros per heat pump, the company would receive an additional 3 million euros. If the target of 500,000 heat pumps per year were to be achieved by energy service providers alone (e. g. 20 providers with 25,000 heat pumps each), this would only mean additional costs of 0.2 billion euros.

Insurance

To hedge against fluctuating electricity prices and the associated operating risks, the SPV could offer electricity price insurance for energy service companies in cooperation with an insurance company via the leasing contract. This would further reduce the revenue risk (Whitehouse et al., 2020).

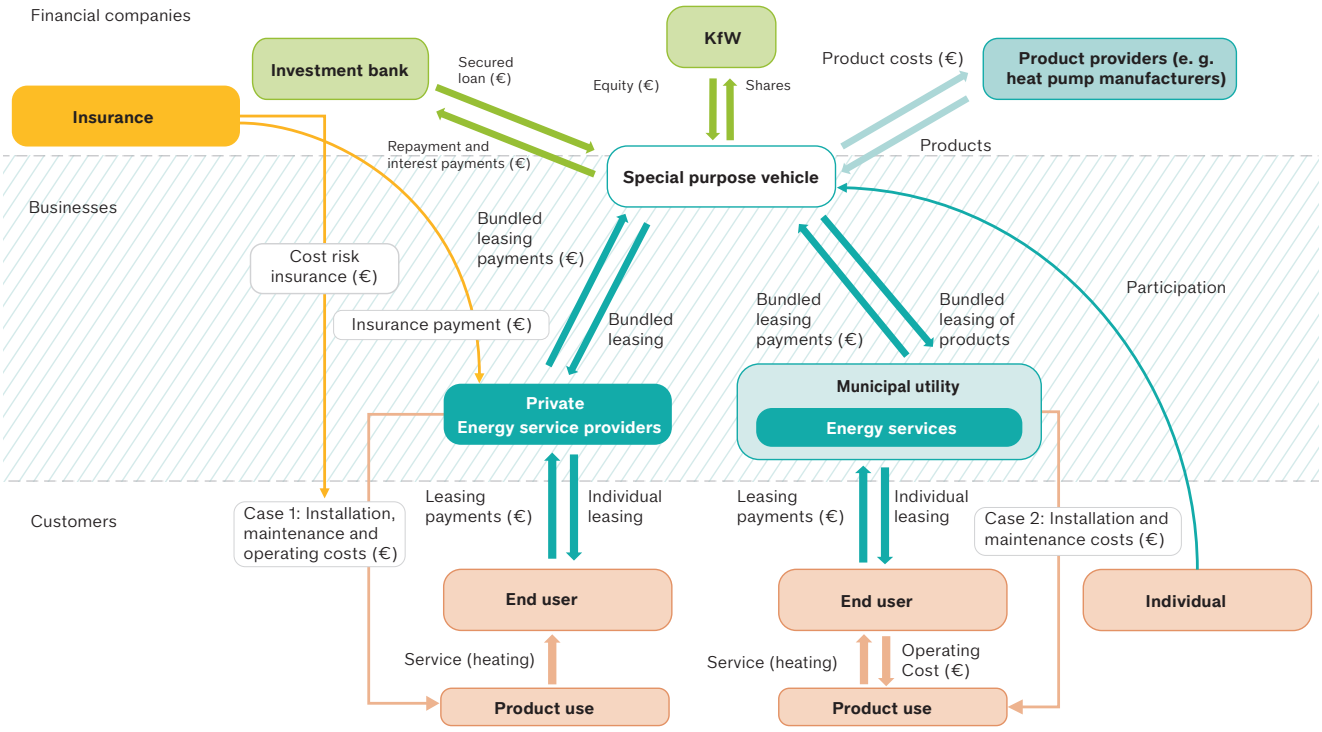


Figure 8.3: Bundling of heating contracting agreements by an investment bank and KfW to secure the capitalisation of municipal utilities and private energy service providers (above) and combination with insurance (below). Own presentation based on Whitehouse et al. (2020).

4. Practice checks for the heat transition

This measure is designed to identify bureaucratic obstacles through targeted participatory conferences and gradually remove them in a heat transition enabling package. The practice checks create a new dynamic that relieves the housing industry and energy service providers of excessive regulation. This will accelerate the transformation to a natural gas-free building stock. The practice checks relate to both residential and non-residential buildings.

Acceleration of insulation renovation, heating system replacement and energy services in the buildings sector

The aim of the practice checks is to accelerate the implementation of energy-efficient insulation renovation, heating system replacement and energy services by reducing inappropriate regulation in the buildings sector. This is achieved through the following steps:

→ Identification of bureaucratic obstacles through participatory conferences with relevant stakeholders.

→ Reduction of the identified obstacles in a heat transition enabling package for a targeted reduction in bureaucracy.

→ Establishment of a mutual learning process to create acceptance and trust in targeted regulation. This forms an essential basis for effective cooperation in the development of further measures.

Functionality

The practice checks offer a space for comprehensive stakeholder participation and thus strengthen acceptance for the change processes (BMWK, 2023n). The process is systematic and open-ended in order to facilitate a mutual learning process. This makes the approach very different from simply communicating decision outcomes (Tacke et al., 2019).

Due to their scaling potential, the key stakeholders include representatives of the housing industry and energy service providers, which include broad-based utilities such as energy groups and municipal utilities, but also specialised energy service providers.

Small and medium-sized housing companies in particular suffer from regulatory obstacles and find it more difficult to achieve economies of scale due to a large number of standards (ARGE, 2023; BMWK, 2023c).

During stakeholder participation, structural barriers are identified that stand in the way of accelerating energy-efficient insulation renovation, heating system replacement and energy services in the buildings sector in order to reduce costs. These can include, for example (see ARGE (2023)):

→ municipal requirements, such as sound insulation and fire protection requirements;

→ regulations from development plans, such as the required use of certain façade materials;

→ technical building regulations/norms and quality standards.

The issue of ownership of the system is also an obstacle to heat supply contracting. As the heating system becomes an integral part of the building when it is installed (Verbraucherzentrale, 2022) and therefore legally belongs to the building owner, this results in more complex financing conditions than is the case with contracting for photovoltaic systems, for example. Owners can refuse to regulate ownership via an easement, which complicates the situation for contracting providers.

Best practice examples

Solar practive check: There are already successful approaches such as the *Solar Practice Check*, which led to Solar Package I. The construction and operation of photovoltaic (PV) systems was made less bureaucratic and the expansion of photovoltaics was accelerated. The legislative package was preceded by an intensive dialogue with the industry as part of a practice check in order to identify and specifically remove obstacles and bureaucratic hurdles. The participating stakeholders included the affected sectors, the federal states and the parliamentary groups. As a result, bureaucratic obstacles in connection with the commissioning of photovoltaic systems on balconies were reduced, among other things (German government, 2023b).

District heating summit: As part of the district heating summit, the signatories committed to organising in-depth workshops on key areas of action such as "price transparency and consumer protection, the integration of renewable energies and waste heat as well as the funding framework for the expansion and transformation of local and district heating" and to agree on joint solutions (District Heating Summit, 2023). Section 556c of the German Civil Code (BGB) and the Heat Supply Ordinance, for example, were identified as key obstacles that play an important role in making it easier for tenants to have affordable and climate-neutral heating and in promoting the increasing supply of heat from renewable energies and waste heat. As a result, there is to be a joint review of how these regulations will be organised in the future (District Heating Summit, 2023).

Possible next steps

Participatory conferences

→ The BMWK and the BMWSB organise participatory conferences with stakeholders from the housing construction industry. Representatives of the housing construction and extension industry, local authorities, energy service providers, state development banks and heat transition competence centres come together to identify regulatory obstacles based on practical cases.

Heat transition enabling package

→ The regulations will then be legally amended as part of a heat transition enabling package. Alternatively, the identified regulatory hurdles can be integrated into existing laws, such as the Act on the Promotion of Climate Protection in Urban and Municipal Development. The latter already allows privileged permissibility for construction projects for renewable energies in Section 35 of the BauGB and the safeguarding of subsequent energy-saving measures for the installation of PV systems in Section 248 of the BauGB.

5. Heating-for-all programme for vulnerable homeowners

At least 11 % (1.5 million) of private homeowners have difficulties financing the replacement of their heating system. In view of this situation, there is an urgent need for financial instruments that can help these homeowners to invest in the replacement of heating systems and the energy-efficient renovation of building insulation.

However, banks are often not in a position to bear the credit risk for such investments, as the creditworthiness of these homeowners is generally insufficient. As a solution to the problem, we propose the establishment of a state deficiency guarantee as part of a Heating-for-all programme.

Objective of the state deficiency guarantee

→ The aim of the state default guarantee is to provide loans for vulnerable households with low incomes and poor credit ratings, e. g., due to their advanced age, who would otherwise have no access to capital.

→ It promotes investment in buildings with poor energy standards and outdated heating technology in order to reduce the demand for natural gas where there is the greatest potential for savings.

How the deficiency guarantee works

→ Owners apply for access to the Heating-for-all programme for an investment – either with their commercial bank or via a specially designed and easily accessible online platform. The heating provider can assist with the application.

→ After the application is submitted, it is checked whether the owner has access to existing KfW loan programmes (promotional loan, supplementary loan) or traditional bank loans and has the necessary creditworthiness. Owners who do not meet the creditworthiness criteria are granted access to the programme.

→ In addition, it will be examined whether the owner has the option of implementation via an energy service provider who bears the investment costs (see scaling programme for heating contracting). If this is not possible, the owner will have access to a loan that ensures that all investments that are not covered by the state subsidy of 30 % to 70 % Federal Funding for Efficient Buildings (BEG) are covered. The loan is combined accordingly with existing BEG funding programmes.

→ In the event of a loan default the public authorities secure the remaining repayments via the bank's KfW, including a guaranteed interest rate.

→ The deficiency guarantee enables favourable interest rates, as the public authorities assume the risk.

Prevention of abuse

→ A default is established if insolvency is proven or if execution was unsuccessful.

→ The loan amount is transferred directly from the bank to the certified company carrying out the energy-related measure (insulation renovation, heating replacement) and is supplemented by an acceptance confirmation from the homeowners to ensure that the funds are used exclusively for the planned investments.

"Further measures with a similar effect can be found at DENEFF (2023)."

6. Skilled labour offensive for the heat transition

There is currently a risk that skilled labour from the slumping construction sector could migrate to other industries. In addition, there is great potential in the sectors affected by structural change to recruit and retrain skilled labour for the professional groups relevant to the heat transition.
The skilled labour offensive for the heat transition picks up on these developments.

Objective of the skilled labour offensive

→ **Recruitment of qualified skilled labour from sectors affected by structural change and from the collapsing construction industry** in order to close the skilled labour gap in finishing trades such as sanitary, heating and air conditioning (HVAC) and building electrics.

→ **Building on existing and proven retraining programmes** in the heating industry and skilled trades, especially finishing trades such as HVAC and building electrics.

Functionality

The skilled labour offensive scales up tried-and-tested retraining programmes, such as Vaillant's retraining programme (KOFA, 2023), in which heating manufacturers offer retraining programmes together with craft businesses. Our skilled labour offensive builds on Vaillant's retraining programme, or similar programmes that have been tried and tested in practice, and complements the German government's development programme for heat pumps (BAFA, 2023), which aims to provide further training for existing skilled labour with a broad-based recruitment and retraining programme.

At the centre of our skilled labour offensive are craft businesses and heating manufacturers, who work together to recruit and retrain skilled labour from other sectors. The companies and heating manufacturers can be supported in this by regional employment agencies. The condition is that the vocational training of the skilled labour from other sectors corresponds to at least 40 % of the school content of the HVAC plant mechanic training programme.

Similar to Vaillant, the retraining programme lasts 4.5 months: three months of further training at school and 1.5 months of practical training in the company. The Vaillant programme includes twelve training occupations, in particular automotive and industrial plant mechanics, electronics technicians and industrial fitters.

We propose extending tried-and-tested retraining programmes, such as Vaillant's, to training occupations of other sectors.

1. **For sectors affected by structural change:** This includes automotive manufacturing, for example. As part of the electrification of transport, skilled labour will also become available in traditional car manufacturing; studies estimate that up to 180,000 jobs could become vacant there by 2030 (Agora Verkehrswende, 2022).
2. **Construction sector:** In the economically collapsing construction sector, between 60,000 skilled workers (Energy Independence Council, 2023) and, according to construction companies, up to 300,000 employees (Uhlenbroich, 2023) are also expected to become redundant within the next two years. Here, retraining measures can channel economic power into building renovation and thus support the construction industry. Here and in other sectors, the skilled labour offensive is creating new opportunities for securing skilled workers and further training in growth sectors, which can make a significant contribution to the investment momentum in natural gas-free technologies.

Heat pump development programme

The heat pump development programme is aimed at the further training of existing skilled labour from the craft sector trades who want to train their skilled workers for work relating to heat pumps. It aims to qualify around 21,000 skilled workers in the field of heat pumps every year and subsidises eligible training courses with 90 % up to a maximum of 250 euros per day and participant; practical qualification measures on site are subsidised with 90 % up to a maximum of 500 euros per day and participant. In total, the maximum funding amount is 90 % and 5,000 euros per participant (BMWK, 2023k).

Implementation

→ All skilled labour whose school content in their previous vocational training was at least 40 % in line with the HVAC plant mechanic training would be qualified for the retraining programme and funding.

→ Like the heat pump development programme, the heat transition skilled labour offensive would be financed by the German government and handled by BAFA. As with the heat pump development programme, BAFA applications are submitted directly by the craft businesses. The skilled labour offensive could be combined with the announced investments in communication, image and young talent campaigns (BMWK, 2023e) in order to create retraining opportunities on site together with municipal heat transition teams and employment offices.

→ The funding should continue until 2030 and the maximum funding amount should be degressively adjusted. Initially, until 2026, a funding rate of 90 % of the training costs with a funding limit of 10,000 euros per employee could be utilised. After that, until 2030, a subsidy rate of 70 % of the training costs with a subsidy limit of 7,000 euros per employee could be utilised. In order to identify the total funding volume, the additional skilled labour requirement of 60,000 skilled workers for heating replacement by 2030 can serve as an eligible cap (ZDH, 2023a). This results in a maximum funding amount of 600 million euros.

Challenges

The Vaillant retraining programme, which can serve as a basis for scaling, is not yet officially recognised. An official vocational qualification with clear training and wage conditions is needed to ensure the quality of the craft sector and to prevent the lateral entry of skilled workers from leading to a deterioration in working conditions in the craft sector.

Discussions are already under way between industry associations, social partners and the relevant ministries; important steps in this direction were initiated at the second heat pump summit. The heat pump development programme is already an important building block in the qualification of skilled workers in the HVAC trade; there is a political will to create new job profiles in order to relieve the burden on the HVAC trade.

7. Industry transition accelerator platform

We propose the establishment of an Industry transition accelerator platform that mobilises investment by lowering the risk perception of companies in the substitution of natural gas, increasing the profitability of investments through investment promotion and empowering companies to undertake transformation planning.

Flanked by incentive programmes and status benefits for participation, the platform offers the potential to initiate investment momentum despite structural obstacles faced by some companies.

Objective: Accelerating the industry transition

→ Establishment of a **hub for knowledge exchange, business cooperation and investment promotion** to accelerate the conversion of large companies and small and medium-sized enterprises (SMEs) to natural gas-free processes.

→ **Reducing the risk perception** of entrepreneurs when investing in unknown technologies.

→ Creation of a central **interface for funding advice** and feedback to legislators.

→ **Scaling of pilot projects** of SMEs and mobilisation of private investment.

Approach: Learning and cooperation accelerate investments

→ **What:** The Industry transition accelerator platform offers processes, consultations and events that enable joint learning. It promotes investment cooperation between companies that invest and those that convert their work processes later. The platform pools expertise on support measures and acts as an interface between companies and politics.

→ **Who:** Companies can operate in three roles on the platform: pioneers, followers and participants (Figure 8.4).

- **Pioneering companies** have already largely reorganised their work processes or are in an advanced transition process. They have valuable knowledge and are committed to sharing their experience with companies that have not yet begun to switch their work processes. In return, they receive tax relief as a *pioneer bonus* and can network with other companies for attractive future collaborations. This gives rise to new financing and cooperation models. At the same time they benefit from joint ventures and can test new technologies in joint pilot projects.
- **Followers** are companies that decide to invest as a result of sharing knowledge with other followers or pioneering companies.
- **Participants** are companies that previously used natural gas-based processes and had not yet initiated a switch when they joined the platform. The aim of the platform is to develop them into followers by offering knowledge transfer, cooperation and targeted support services.

→ **Clusters:** The structure of the platform should include sectoral clusters such as cement and metal processing, paper, glass and chemicals, as well as technology clusters such as direct reduction in steel production or the decarbonisation of furnaces in the glass industry. To simplify access to capital, public and private banks are also invited to join the platform.

Example projects demonstrate the impact

The positive effects of cooperation in the area of knowledge exchange and innovation have already been proven by numerous network offerings – such as the Competence Centre on Climate Change Mitigation in Energy-Intensive Industries (KEI), the platform for industrial transformation IN4climate.NRW in North Rhine-Westphalia, as well as the Energy Efficiency and Climate Protection Networks (IEEKN). The IEEKN have proven their worth by focusing strongly on their networking and cooperation function. Since the end of 2014, 398 networks with 3,319 locations/companies (some companies/locations participate in several networks at the same time) have already been registered. Based on previous experience with existing or already completed energy efficiency networks, the German government anticipates that savings of 9 to 11 TWh of final energy or 5 to 6 million tonnes of GHG emissions can be achieved through a further 300 to 350 networks (BMWK, 2017).

Functionality: competition for cooperation

Figure 8.4 shows the intended sequence of actions of the learning and exchange processes in five steps. It shows how companies, supported by funding, inspire each other.

Table 8.2: Structure of the platform in two phases

Phase 1: Setting up the platform	Phase 2: Investment momentum emerges
· **Identification of participants:** All SMEs and large companies are invited to take part in the platform. There are no special entry barriers. · **Identification of pioneers** → The platform uses suitable measures (tenders, etc.) to identify pioneering companies that are prepared to switch their processes to natural gas-free technologies. Selected companies receive access to subsidies such as tax relief. This aims to ensure that companies share their knowledge and strengthens the profitability of the investment. → Companies that have already received public support for investments in natural gas-free technologies (e. g. climate protection contracts, federal funding for resource and energy efficiency) can also switch to pioneer status and, if necessary, gain access to further funding, whereby double funding must be avoided. In return, they enable other companies to share their experience.	· **Admission:** All companies can join voluntarily and receive a funding consultation. · **Participants** are eligible for funding to create a *transformation concept* with the help of a transformation manager. · **Followers:** Participants can apply for the new investment subsidy to implement natural gas-free technologies. In return, they undertake to share any knowledge that arises. As soon as the investment has begun, a participant moves up to become a follower. · **Supporters** participated in the investment of a follower. Both receive additional subsidies.

Recommendations for offers and added value of the platform

→ **Investment subsidies.** We propose that the German government supplement the existing funding programmes with specific investment subsidies for the electrification of natural gas-based processes. In order for companies to move from participants to followers, effective incentives for investment are needed that are staggered according to the role of the company. Possible instruments include special depreciation allowances, tax relief or investment grants. All companies should have access to the funding instrument; platform participants enjoy advantages. The amount of funding depends on the size of the company and is capped as a percentage. In order to encourage early investment, the maximum subsidy amount and subsidy percentage per year decrease.

→ **Funding advice.** The platform should offer funding advice for its participating companies and human resources to support the preparation of applications.

→ **Transformation manager.** The existing funding opportunities in module 5 of the federal funding programme for energy and resource efficiency should be expanded. In particular, funding should not only be provided for consultancy, but also for the recruitment of qualified personnel for transformation management and the creation of a transformation plan, including personnel costs.[1] Funding volumes and objectives currently limit support to the creation of transformation plans and the initial introduction of implementation processes in climate protection management.

SMEs usually lack the human and financial resources to develop transformation plans and build up the necessary expertise within the company.

→ **Enable regulatory learning.** One expert from the German government should be involved in each of the technology and industry clusters. The structure of the platform enables a coordinated exchange between companies and political decision-makers. This strengthens regulatory learning so that regulations are adapted to the needs of innovative companies.

→ **Promote corporate cooperation.** The platform promotes investment cooperation between companies by developing templates and processes, especially between companies that are structurally unable to transform and those that can. This can include cooperation agreements in which a company benefits from the experience of another company by making an investment contribution. But classic joint ventures are also conceivable.

1 As part of the federal funding programme for energy and resource efficiency in Module 5: *Transformation concepts*, the BMWK provides funding of up to 50,000 euros for consultancy costs in connection with the creation of a transformation concept.

Implementation

We propose that the German government examines whether it is possible to expand the mandate and further develop the IEEKN and KEI into an Industry transition accelerator platform, or whether a new structure needs to be created.

Further development of the IEEKN would build on the latest developments of the programme. From the new 2021 project phase, the range of topics has been expanded from the focus on energy efficiency to include resource efficiency, climate protection and sustainability. Networks now have the option of reporting a CO_2 reduction target in addition to a quantified savings target (BMWK, 2017).

Members of the IEEKN can currently receive a subsidy of up to 80,000 euros (BAFA, n. d.). Only platform member companies will receive this in future. In addition, a learning environment would be established in which companies' risk perceptions could be harmonised and investment dynamics accelerated. The new mandate should contain concrete instruments, staggered according to status, that incentivise investments that go beyond energy efficiency. The mandate should make it possible to mobilise companies for investment, share their existing knowledge and promote cooperation between companies.

In addition, a link with the KEI would likely create synergy effects. The KEI has extensive experience in the development of pilot projects and has been managing the *Decarbonisation in Industry* (KEI, n.d.) funding programme on behalf of the Federal Ministry for Economic Affairs since 2021. This offer could be extended to all funding lines, beyond the energy-intensive industry.

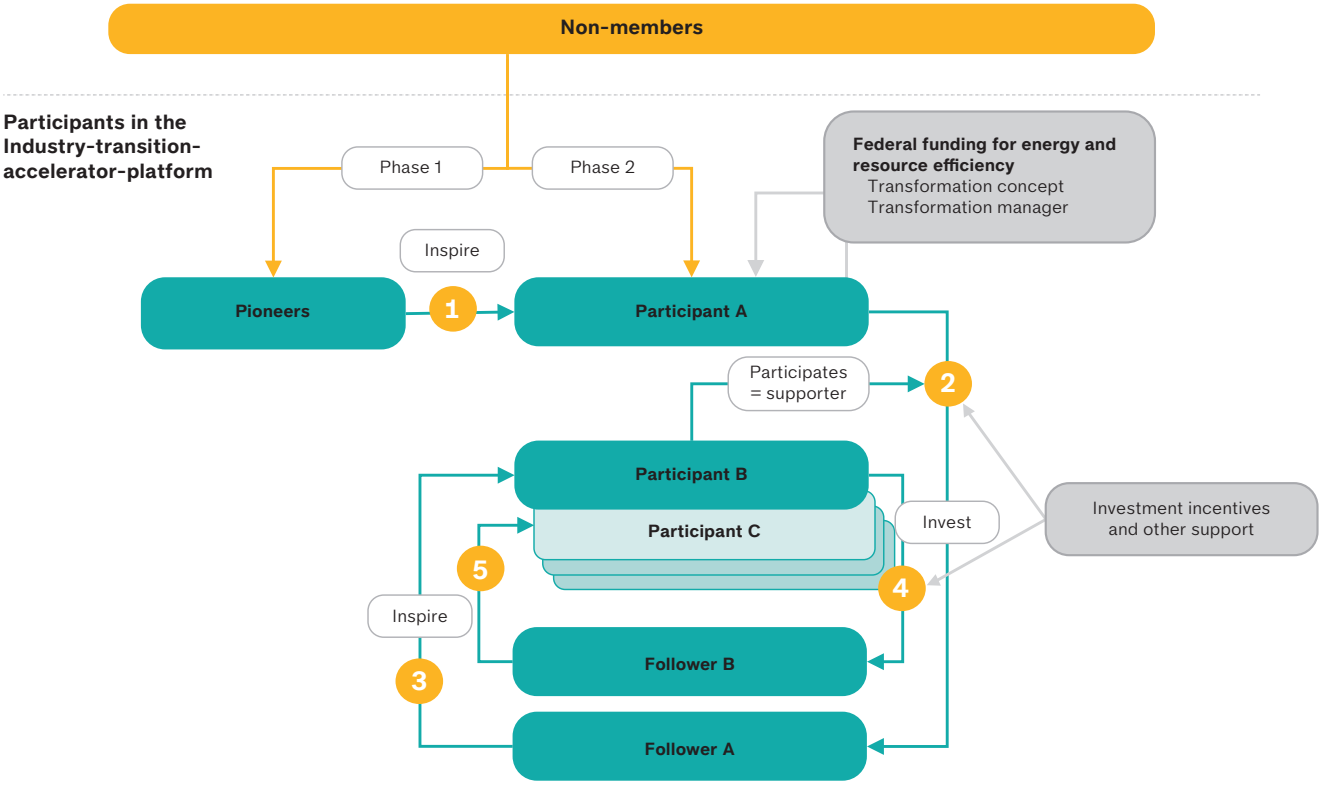


Figure 8.4: Schematic representation of the learning process between companies on the Industry transition accelerator platform. Grey: Funding instruments. Blue: Roles of the platform participants.

8. Aligning sustainable finance with transition

Sustainable finance can help channel capital into natural gas-free technologies. To realise the full potential of this approach, we propose adapting the EU taxonomy, standardising transition plans, improving the calculation of the Green Asset Ratio (GAR) and extending the Corporate Sustainability Reporting Directive (CSRD).

Currently, the EU taxonomy in the industrial sector does not cover 33 % of the investments to be made by industry. For the remaining 67 %, taxonomy-alignment depends on the threshold values of the technical screening criteria being reached. Furthermore, the CSRD does not cover the majority of companies, in particular all non-capital market-orientated small and medium-sized enterprises (SMEs). Inconsistent standards for transition plans also make it more difficult for banks to develop expertise in the risk assessment of transition investments.

Objective of the measures

→ **Enable eligibility:** Investments in gas-free technologies in all sectors should be able to be counted towards the banks' green asset ratio as part of the EU taxonomy.

→ **Develop uniform standards for transition plans** that enable the risk assessment of transformation projects by banks and can serve as future conditions for public funding programmes.

→ **Ensure CSRD coverage:** Companies and sectors that are relevant for gas independence should be covered by the CSRD.

Development of sector-specific standards for transition plans

We recommend that the German government, in cooperation with relevant bodies, develop uniform and sector-specific standards for transition plans that bring together the various reporting obligations under the CSRD, the Minimum Requirements for Risk Management (MaRisk) regulation and the climate protection agreements in one standard.

The European Sustainability Reporting Standards (ESRS) currently only define superficial KPIs for transition plans of companies under the CSRD.

Although this makes the interpretation very flexible, it also means that banks cannot use transition plans for the standardised assessment of transition risks. This means that there is no common language in the financial sector as to which factors influence transition risks and how these are to be assessed. This makes it more difficult to build up expertise in forward-looking risk assessment within the companies, although the transition plans can be particularly helpful for assessing ESG and EU taxonomy-alignment. At the same time there is no equal basis for linking the payment of future public subsidies to transformation commitments.

Develop the EU taxonomy into an instrument for natural gas independence

The EU taxonomy must allow all sectors that make a significant contribution to reducing natural gas consumption as well as investments in electrification to be eligible. The European Commission has announced that it will regularly adapt the technical screening criteria to new developments.

In future adjustments, the following additions are necessary to support investments in German and European gas independence and to further develop the EU taxonomy into a transition instrument:

1. **The inclusion of further sectors in the delegated acts**

These include in particular the following economic activities (NACE categories) (Eurostat, 2008):

- **a.** Manufacture of paper and paper products
- **b.** Manufacture of food products, beverages and tobacco products
- **c.** Manufacture of glass and glass products
- **d.** Metalworking
- **e.** Non-ferrous metals, foundries
- **f.** Processing of stone and earth.

Justification: These categories have not yet been covered. This means that sales and investments, even if they contribute to a renewable production process, cannot be included in the EU taxonomy.

2. The inclusion of electrification activities in the EU taxonomy

Expansion of the scope of coverage of climate-neutral technologies (low-carbon) to include the production of systems and machines that electrify processes fuelled by fossil fuels. In addition, investments (CapEx) in the electrification of processes previously powered by fossil fuels should be included in the list of eligible support activities – regardless of the CO_2 intensity that the company achieves after the investment and thus regardless of the company's electricity mix.

Justification: In most cases electrification is the prerequisite for the substitution of fossil process heat for a climate-neutral production process, which can then be operated with renewable electricity. Nevertheless, investments in, for example, electric industrial furnaces, electric and electrode boilers, electric melting tanks, infrared and plasma furnaces, electric arc furnaces or electric steam crackers are only recognised if the industry is already taxonomy-eligible, as well as if the threshold value of already recognised industries is reached within five years.

3. Examination of whether energy services are adequately recognised in the EU taxonomy

Energy services can make a significant contribution to scaling renewable heating technologies (see Chapter 7.1). However, as companies only generate income from green heat generation through leasing offers to customers, it should be examined whether this income could be offset against the EU taxonomy. In particular, this includes clarifying whether energy services are already sufficiently covered in the economic activities of the EU taxonomy that are relevant to natural gas. In contrast to activities related to the mobility sector, leasing models are not explicitly listed in the relevant activities.

4. The reassessment of the inclusion of natural gas-based electricity and heat generation in the taxonomy-aligned activities and the deletion of technical screening criterion 1b

Before the geopolitical turning point, natural gas was discussed as a transitional technology. In the course of the trilogue negotiations, contrary to the recommendations of the Platform on Sustainable Finance (2022), a decision was made in favour of taxonomy-alignment and natural gas-based electricity and heating technologies were included in the extension of the EU Commission's delegated act (European Commission, 2022b).

We recommend the reversal of this decision and the removal of technical screening criterion 1b (thresholds incompatible with the EU's climate targets) in accordance with the recommendations of the Platform on Sustainable Finance. This would also strengthen the consistency of the EU taxonomy with other sustainability standards and its applicability to financial companies.

Improve the calculation of the GAR and extend the scope of application of the CSRD

The calculation of the Green Asset Ratio (GAR) in accordance with the EU taxonomy, which records the proportion of green assets in the bank portfolio, currently only includes companies that fall within the scope of the CSRD. However, it is desirable for the GAR to encompass a broader range of activities. This is to prevent financial institutions that specialise mainly in loans for SMEs and smaller projects from being disadvantaged. In particular, investments and loans to companies that fall outside the scope of the CSRD but are clearly in line with the objectives of the EU taxonomy – such as green, non-capital market-orientated SMEs – should be allowed to be included in the GAR calculation. This would create a positive incentive for voluntary reporting if, for example, companies improve their credit rating and at the same time improve data quality for banks.

In the medium term we recommend expanding the scope of the CSRD to include non-capital market-orientated SMEs. As a prerequisite, simplified reporting standards for SMEs should be created as part of the implementation of sectoral transition plans and the harmonisation of pending legal regulations to ensure practicability. Furthermore, in future revisions of the CSRD, environmental target-related criteria such as the CO_2-emissions of businesses should be used as a criterion defining the scope of the CSRD instead of company size and turnover. This will ensure the consistency with political targets, particularly for CO_2-intensive businesses, and at the same time reduce the corresponding risks in the portfolios of financial actors.

9. Targeted public funding

Public funding enables stakeholders to act, even if investments are not profitable in the short to medium term but are necessary in the long term (such as infrastructure investments in heating networks), risk profiles prevent access to capital (vulnerable homeowners), wage incentives are too low or retraining costs are too high (skilled labour in the craft sector) or short-term cost disadvantages arise that are only offset in the long term with high CO_2 prices (Industry transition accelerator platform investment funding).

In Chapter 7 we have estimated some of the additional funding requirements, which in total amount to at least three billion euros per year (up to 2030) (max. 4.5 billion euros).[2]

→ **Heating networks:** The gap is particularly high for heating networks, which require long-term planning security due to the high investment volumes involved. As part of the enabling package for municipal heating networks (see Chapter 8.2), we propose increasing the federal subsidy for heating networks. At least twelve billion euros (maximum 13 billion) in additional funding will be required up to and including 2030 to finance the unprofitable costs of converting heating networks to renewable heat generation and expanding them. This corresponds to 1.5–1.6 billion euros per year.

→ **Industry:** In industry, the electrification of process heat requires a minimum of three to a maximum of seven billion euros in additional funding. We assume that half of this will be incurred by 2030, which corresponds to 0.4–1 billion euros per year. Investment subsidies are already possible as part of existing subsidy programmes. However, the volumes are not sufficient to cover all investments. New subsidies could also be processed via accelerated depreciation (see Chapter 8.7 Industry transition accelerator platform).

→ **Skilled labour:** Further costs are incurred for the skilled labour offensive to enable retraining from industries that are not future-proof and the construction industry. We have estimated this at 600 million euros (see Chapter 8.6), which corresponds to 85 million euros per year.

→ **Heating-for-all:** In addition, costs are incurred from the Heating-for-all programme for vulnerable homeowners (see Chapter 8.5). Under the extreme assumption that 75 % of the 1.5 million homeowners take out a loan to finance the remaining 30 % after the BEG subsidy of 10,000 euros in 2024 and half of them default by 2030, this would result in a minimum of 5.6 billion euros in additional funding; in the event of a complete default, the costs would amount to a maximum of 11.3 billion euros (0.8–1.6 billion euros annually).

→ **Scaling bonus.** We have proposed the scaling bonus (see Chapter 8.3) in order to expand the range of energy services on offer and, in particular, to promote institutional providers who bundle the sale of heat pumps. We have estimated the maximum annual costs at 0.2 billion euros (until 2030: 1.2 billion euros).

As can be seen from Figure 8.5, there are numerous options for meeting this small additional funding requirement.

In the following we present options for action[3] that can close the funding gap.

Scope for investment through reform of the debt brake

The debt brake is enshrined in Article 109 of the German Basic Law and aims to ensure that public budgets can manage without structural new borrowing in the long term. It limits net borrowing to 0.35 % of gross domestic product (GDP) per year.

→ **Increasing the upper limit for new loans set out in the Basic Law** will allow more room to manoeuvre for borrowing in the event of sustained economic growth. Raising the debt ceiling to 1.5 % of GDP would provide an additional 47 billion euros in the budget (Beznoska et al., 2023). However, this requires an amendment to the Basic Law.

→ **Reintroduction of the 'golden rule'** by reorganising the debt brake so that new loans can be earmarked for investments instead of being used indefinitely for various expenses. The financing volume can be based on the additional public investment requirement, which in 2019 amounted to at least 457 billion euros for the decade 2020–2030, i. e., 45.7 billion euros per year (Bardt et al., 2019). Adjusted for inflation, this corresponds to around 54 billion euros per year from 2024 to 2030. The golden rule represents a long-term solution that would allow greater flexibility for investment projects. On the other hand this requires a clear distinction between investment and consumption expenditure as well as a two-thirds majority in the Bundestag.

2 The funding gap for energy-efficient insulation renovation and the replacement of heat generation is not included, as no substantial funding gap is expected here until 2030.

3 For a more comprehensive overview, see: Energy Independence Council (2023).

→ **Changing the economic component** by revising the method of estimating potential output (Bundesbank, 2022; Dezernat Zukunft, n.d.) could provide additional leeway of up to 28 billion euros in 2024, depending on the calculation method (Krebs, 2023). The modernisation of the calculation does not require an amendment to the Basic Law.

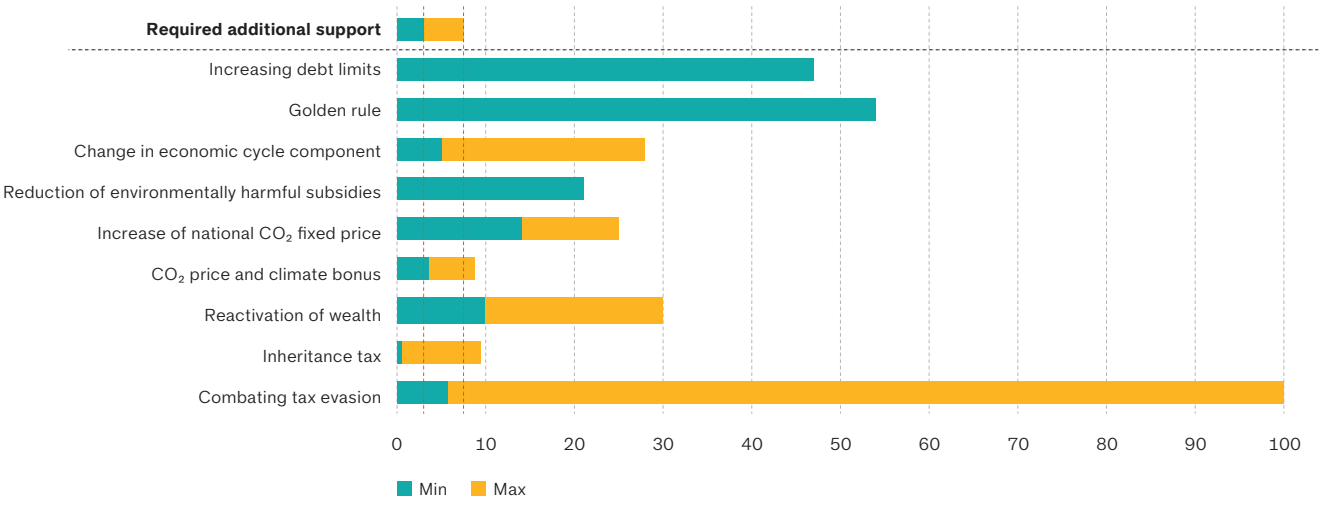


Figure 8.5: Necessary additional funding for natural gas independence and estimated additional fiscal leeway of the options for action in billion euros per year. Own calculations based on the sources below.

Optimisation of the expenditure side

→ The abolition of the privilege for company cars, the exemption from paraffin tax and the tax concessions for diesel fuel not only create fiscal leeway, but also implement the German government's plan **to reduce 'superfluous, ineffective and environmentally and climate-damaging' subsidies**, as set out in the coalition agreement (Meemken et al., 2023). In addition to greenhouse gas reductions, this will result in additional revenue totalling almost 21 billion euros. In 2021 the costs for the diesel privilege amounted to 8.2 billion euros, the company car privilege to 4.4 billion euros and the energy tax exemption for paraffin to 8.3 billion euros (German Environment Agency, 2013; Zerzawy et al., 2021).

New sources of income

1. **The increase in the national fixed CO_2 price** to 60 euros per tonne of CO_2 could generate state income of 14 billion euros. In the medium term, an average price of 150 euros per tonne of CO_2 could generate annual state income of around 35 billion euros (Agora Energiewende & Verkehrswende, 2023). Without accompanying measures, CO_2prices are socially regressive and risk undermining social support for the transformation. Accompanying social equalisation mechanisms are therefore crucial to mitigate the negative effects on low-income households. These have a direct impact on the amount of funding available for the subsidies mentioned here, which is why we discuss them briefly. In the coalition agreement the governing parties decided to introduce the climate allowance, which is a lump-sum payment from the state to consumers to compensate for the increase in carbon pricing. If the CO_2 price is raised to 60 euros or 150 euros per tonne and 75 % is paid out as climate allowance, the potential per capita climate allowance would amount to 127 euros or

316 euros per year (DIW Berlin, 2023a). This would leave the state with around 3.5 billion or 8.75 billion euros per year in additional revenue.

2. A **reactivation of the wealth tax** would amount to one per cent of GDP per percentage point of the tax rate according to estimates (Saez & Zucman, 2022). For Germany, this would be around 38 billion euros per year. Bach and Thiemann (2016) estimate 10–20 billion euros for Germany. Wealth taxes also have a positive effect on the distribution of transition burdens: in 2019 the richest one per cent of the German population produced more than 15 times as much CO_2 as the poorer half of the population (Lorek et al., 2021). However, the valuation of assets such as property, works of art or companies can be complex. The taxation of such non-liquid assets can also trigger liquidity problems in some cases.

3. In the case of **inheritance tax**, the collection and compliance costs are significantly lower than for wealth taxes, as assets do not have to be valued annually, but in the best case only once per generation. In addition, flat-rate allowances and long-term interest-free deferrals can reduce bureaucracy and at the same time protect tied-up assets. Assumptions about the amount vary considerably. Depending on the specific structure and tax rate, additional state income of 0.5–1 billion euros at a tax rate of 10 % or 4–6.5 billion euros at a tax rate of 15 % per year can be realised (Beznoska & Hentze, 2021; Jirmann, 2023). Bach (2022) and Thiemann et al. (2021) assume an additional 9 billion euros if inherited business assets were taxed.

4. The **closure of tax loopholes** brings democratic advantages, such as tax justice or transparency. According to estimates, Germany loses a total of up to 100 billion euros annually through tax evasion and avoidance (Hans Böckler Foundation, 2012). It is difficult to completely avoid tax avoidance and evasion. The exploitation of loopholes in tax law and the use of foreign tax havens make it possible to minimise or avoid taxes, and these are difficult to control. Tax authorities often have limited resources to effectively combat tax evasion.

10. Interest benefits for investments in natural gas independence

We propose that the ECB, in line with its first and second mandate, establish a temporary green Targeted Long Term Refinancing Operations (TLTRO) programme that links interest rate benefits for lending to EU taxonomy-aligned investments.

The interest rate turnaround has worsened the financing conditions for investments. Refinancing costs for renewable energy projects, for example, rose from 16 % to up to 34 % of total costs (Schmidt et al., 2019). This not only inhibits investment in Germany's and Europe's independence from natural gas, but also risks the long-term stability of the financial markets due to risky investments in fossil-fuelled economic activities.

With a temporary green TLTRO, the ECB would help to address market failures in capital markets that are biased in the direction of existing markets and penalise green investments due to different market sizes and historical experience (Klooster & van Tilburg, 2020).[4] Transition risks are currently not adequately recognised by rating agencies.

Objectives

→ **Stimulating the granting of loans:** Encouraging banks to grant more loans for investments in taxonomy-aligned real economic activities, including investments in natural gas independence, by buying up green securities and bonds at favourable interest rates.

→ **Securing long-term price stability:** Green TLTROs complement the ECB's monetary policy and contribute to achieving its inflation targets by lowering energy prices in the long term and reducing transition risks by incentivising early decarbonisation.

Functionality[5]

Temporary green TLTROs are refinancing transactions in which the interest rate that banks pay for refinancing is determined by the volume of taxonomy-aligned loans.

→ The TLTRO programme would differentiate refinancing costs based on the lending profile of the banks and the proportion of green assets in the portfolio.

→ To do this the ECB must assess the extent to which bank lending is green. This can be done on the basis of existing EU environmental criteria for investments, e. g., the EU Taxonomy Regulation. This developed rules for the disclosure of a green asset ratio.

→ The volume of green TLTRO loans is determined by the percentage of new loans for which the bank can prove that they are taxonomy-aligned. Banks receive an ‘interest rate discount‘ for investments in green technologies as part of their refinancing transactions.

→ Like TLTRO-III, a green TLTRO programme would work on an opt-in basis. The programme offers incentives for participation through the price of refinancing.

→ The programme would be **temporarily limited until the market itself is able to remedy the market failure** and rating agencies reflect transition risks in their ratings.

Background

In 2019 the ECB decided to carry out a new series of targeted longer-term refinancing operations (TLTRO-III). TLTRO-III has since been adjusted several times in order to achieve the euro system's price stability targets and support lending. In its TLTRO-III programme the ECB has already defined criteria for the use of interest rate subsidies. At that time banks had to keep their lending constant over a certain period of time in order to benefit from the concessions. Green criteria would be conceivable here. Now that the last programme (TLTRO-III) has been discontinued due to the interest rate turnaround, investments in real economic activities are no longer being explicitly supported. This also affects green investments.

4 The explanations are based on publications on the topic, in particular Klooster & van Tilburg (2020).

5 The design is based on Colesanti Senni et al. (2023).

Compatibility of temporary green TLTROs with the ECB mandate[6]

→ Temporary green TLTROs will contribute to the fulfilment of the ECB's primary mandate by **resolving market failures**that undermine the general economic conditions for monetary stability.

→ Temporary green TLTROs would harmonise **monetary policy with the ECB's secondary mandate**. This results in an obligation to consider climate change as part of the support for general economic policy in the EU. In contrast to other policy objectives, the climate policy objectives are clearly operationalised, which allows the ECB to prioritise them. The second mandate is subordinate to the first mandate. Environmental goals should only be supported if this is possible without jeopardising price stability. This would be the case with a green TLTRO programme. Inflation is also driven by high energy prices (Pallara et al., 2023). It is to be expected that investments in substitution technologies for natural gas and renewable energies will have a price-dampening effect. In addition, green investments can help to mitigate transition risks in the wake of the shortage of emissions trading system (ETS) allowances (Bolton et al., 2020).

→ The narrow interpretation of the ECB's second mandate means that the ECB should avoid going too far and defining climate policy itself, as this does not fall within its mandate and competence. This would be ensured by following the EU taxonomy. The **ECB would not provide its own definition of 'green activities'** .[7]

→ In addition, with a temporary green TLTRO programme, the ECB would promote the financial stability of the euro area and manage the risk of its own balance sheet (Elderson, 2021). It would **minimise climate and transition risks in the real economy**, also because the ECB would thereby promote efforts to improve the disclosure of sustainability data and thus combat market failure.

Temporary green TLTROs would tackle market failures on several levels

→ The current lending behaviour of banks is not based on appropriate risk management practices with regard to climate and environmental risks. Banks lack adequate systems to factor these risks into their lending decisions (ECB, 2022b). In addition, **transition risks are only mapped by rating agencies to a limited extent** (see Chapter 7.3). The ECB would counteract this distortion by incentivising lending to taxonomy-aligned economic activities.

→ The current uneven market development and market size of green and fossil technologies as well as different productivity due to historical learning effects distort the direction of investments (Acemoglu et al., 2012). Such historical path dependencies are another form of market failure that the ECB would address through a green TLTRO programme (see Chapter 6).

→ Differentiated interest rates would not replace the mapping of loan-specific risk profiles. This would continue to be reflected in the banks' mark-ups. Green TLTROs instead follow the logic of increasing capital for green investments overall to compensate for market failures and ensure long-term financial stability.

6 The following explanations are based on Colesanti Senni (2023) and Kooster & van Tilburg (2020).

7 See also Ionannidis et al. (2021).

Appendix

List of stakeholder interviews

In addition to the meetings of the Energy Independence Council, a total of 60 stakeholder discussions were held for the report. The participants took part in the discussions as competent experts and not necessarily as representatives of organisations. The findings of the discussions have been incorporated into this report, although the statements and content of the discussions are not explicitly stated. In order to ensure transparency and to express our thanks for their commitment to the work of the Council, the following list discloses the affiliation of the stakeholders and organisations. A listing does not explicitly imply that this organisation or person agrees with the contents and recommendations of the final report.

Jana Bosse	GasWende
Britta Kleinertz	Forschungsstelle für Energiewirtschaft (FfE)
Andreas Klingemann	Bundesverband der Energie- und Wasserwirtschaft (German Association of Energy and Water Industries, BDEW)
Tim Mennel	German Energy Agency (dena)
Tim Sternkopf	German Energy Agency (dena)
Heribert Jöris	Zentralverband des Deutschen Baugewerbes (ZDB)
Prof Dietmar Walberg	ARGE-SH Arbeitsgemeinschaft für zeitgemäßes Bauen
Lisa Fischer	E3G
Rheanna Johnston	E3G
Aleksandra Waliszewska	E3G
Mareike Herrndorf	Agora Energiewende
Uta Weiß	Agora Energiewende

We were also in contact with other anonymous representatives of the following organisations:

Kreditanstalt für Wiederaufbau (KfW)
German Property Federation (ZIA)
Bundesverband Wärmepumpe (BWP)
Thermondo
Agora Industry
Wuppertal Institute for Climate, Environment and Energy
Georgsmarienhütte
BASF
GasWende
Zentralverband der Deutschen Elektro- und Informationstechnischen Handwerke (ZVEH)
Deutsche Unternehmensinitiative Energieeffizienz (DENEFF)
Hauptverband der Deutschen Bauindustrie (Die BAUINDUSTRIE)
German Association of Towns and Municipalities (DStGB)
German Association of Local Public Utilities (VKU)

Data appendix

The data appendix in the Excel at **fachrat-energieunabhängigkeit.de/bericht** contains the data underlying the graphics.

References

Acemoglu, D., Aghion, P., Bursztyn, L., & Hemous, D. (2012). The Environment and Directed Technical Change. *American Economic Review, 102*(1), 131–166. https://doi.org/10.1257/aer.102.1.131

Acemoglu, D., Akcigit, U., Hanley, D., & Kerr, W. (2016). Transition to Clean Technology. *Journal of Political Economy, 124*(1), 52–104. https://doi.org/10.1086/684511

AGEB. (2023). *Anwendungsbilanzen zur Energiebilanz Deutschland Endenergieverbrauch nach Energieträgern und Anwendungszwecken.* AG Energiebilanzen. https://ag-energiebilanzen.de/wp-content/uploads/2023/01/AGEB_22p2_rev-1.pdf

AGFW. (2020). *Leitfaden zur Erschließung von Abwärmequellen für die Fernwärmeversorgung* (Ein Leitfaden Des AGFW | Der Energieefizienzverband Für Wärme, Kälte Und KWK e. V.). AGFW | Der Energieeffizienzverband für Wärme, Kälte und KWK e. V. https://www.agfw.de/strategien-der-waermewende/perspektive-der-fw-7070-4040

Agora Energiewende. (2020). *Klimaneutrale Industrie: Schlüsseltechnologien und Politikoptionen für Stahl, Chemie und Zement.* https://static.agora-energiewende.de/fileadmin/Projekte/2018/Dekarbonisierung_Industrie/164_A-EW_Klimaneutrale-Industrie_Studie_WEB.pdf

Agora Energiewende. (2023). *Ein neuer Ordnungsrahmen für Erdgasverteilnetze. Analysen und Handlungsoptionen für eine bezahlbare und klimazielkompatible Transformation.* https://static.agora-energiewende.de/fileadmin/Projekte/2022/2022-06_DE_Gasverteilnetze/A-EW_291_Gasverteilnetze_WEB.pdf

Agora Energiewende & Industrie. (2022). *12 Thesen zu Wasserstoff.* https://www.agora-energiewende.de/fileadmin/Projekte/2021/2021_11_H2_Insights/A-EW_258_12_Thesen_zu_Wasserstoff_WEB.pdf

Agora Energiewende & Verkehrswende. (2023). *Der CO_2-Preis für Gebäude und Verkehr. Ein Konzept für den Übergang vom nationalen zum EU-Emissionshandel.* https://www.agora-energiewende.de/fileadmin/Projekte/2023/2023-26_DE_BEH_ETS_II/A-EW_311_BEH_ETS_II_WEB.pdf

Agora Industrie. (2023). *Global Steel Transformation Tracker.* https://www.agora-industry.org/data-tools/global-steel-transformation-tracker

Agora Industry & Wuppertal Institute. (2023). *15 insights on the global steel transformation* (Agora Industry Impulse). https://www.agora-industry.org/fileadmin/Projekte/2021/2021-06_IND_INT_GlobalSteel/A-EW_298_GlobalSteel_Insights_WEB.pdf

Agora Verkehrswende. (2022). *Powering the Automotive Jobs of the Future: How the electrification of transport and other trends will change jobs in the automotive sector up to 2030 – and what this means for policymakers.* https://www.agora-verkehrswende.de/fileadmin/Projekte/2021/BCG-Jobstudie/70_Jobeffekte_EN.pdf

Ahrendts, F., Drechsler, B., Hendricks, J., Küpper, J., Lang, S., Peil, T., Scholz, D., Timofeeva, E., Utri, M., Weidinger, L., Kraus, A., Weiß, U., & Müller, S. (2023). *Roll-out von Großwärmepumpen in Deutschland.* https://doi.org/10.24406/PUBLICA-1440

Albrecht, T., Deffner, J., Dunkelberg, E., Hirschl, B., van der Land, V., Stieß, I., Vogelpohl, T., Weiß, J., & Zundel, S. (2010). *Zum Sanieren motivieren Eigenheimbesitzer zielgerichtet für eine energetische Sanierung gewinnen.* ENEF Haus. https://www.ioew.de/fileadmin/_migrated/tx_ukioewdb/Zum_Sanieren_Motivieren.pdf

Altermatt, P. P., Clausen, J., Brendel, H., Breyer, C., Gerhards, C., Kemfert, C., Weber, U., & Wright, M. (2023). Replacing gas boilers with heat pumps is the fastest way to cut German gas consumption. *Communications Earth & Environment, 4*(1), 56. https://doi.org/10.1038/s43247-023-00715-7

ARGE. (2023). *Status und Prognose: So baut Deutschland – so wohnt Deutschland. Der Chancen-Check für den Wohnungsbau* (Bauforschungsbericht Nr. 86). Arbeitsgemeinschaft für zeitgemäßes Bauen. https://igbau.de/Binaries/Binary18974/WOHNUNGSBAU-STUDIE-So-baut-Deutschland-So-wohnt-Deutschland-ARGE-2023.pdf

Ariadne. (2023, November 21). *Ariadne Transformation Tracker. Ariadne* Transformation Tracker. https://tracker.ariadneprojekt.de/de

Aunedi, M., Olympios, A. V., Pantaleo, A. M., Markides, C. N., & Strbac, G. (2023). System-driven design and integration of low-carbon domestic heating technologies. *Renewable and Sustainable Energy Reviews, 187,* 113695. https://doi.org/10.1016/j.rser.2023.113695

Automobilwoche. (2023, April 14). Deutsche Hersteller verlieren Marktanteile in China. *Automobilwoche.de*. https://www.automobilwoche.de/agenturmeldungen/deutsche-hersteller-verlieren-marktanteile-china

Bach, S. (2022). *Erbschaftsteuer: Privilegien abschaffen.*

BAFA. (n. d.). *Modul 5: Transformationskonzepte. Bundesamt Für Wirtschaft Und Ausfuhrkontrolle.* Retrieved December 4, 2023, from https://www.bafa.de/DE/Energie/Energieeffizienz/Energieeffizienz_und_Prozesswaerme/Modul5_Transformationskonzepte/modul5_transformationskonzepte_node.html

BAFA. (2023). *Aufbauprogramm Wärmepumpe. Bundesamt* Für Wirtschaft Und Ausfuhrkontrolle. https://www.bafa.de/DE/Wirtschaft/Fachkraefte/Aufbauprogramm_Waermepumpe/aufbauprogramm_waermepumpe_node.html

Baker, D., & Whitaker, B. (2023). *The Case for Private Market Investments.* Laird Norton. https://lairdnortonwm.com/wp-content/uploads/Private-Market-Investments-1.pdf

Bantle, C., & Wiersich, J. (2022). *Gasverbrauch: Heizen wir weniger als sonst? Analyse des aktuellen Gasverbrauchs von Haushaltskunden und kleineren bis mittleren Gewerbekunden (SLP-Kunden)* (Diskussionspapier). Bundesverband der Energie- und Wasserwirtschaft. https://www.bdew.de/media/documents/221209_Diskussionspapier_Gaseinsparung_FINAL_mitAP.pdf

Bardt, H., Dullien, S., Hüther, M., & Rietzler, K. (2019). *Für eine solide Finanzpolitik: Investitionen ermöglichen!* (IW-Policy Paper 10/19). Institut der deutschen Wirtschaft Köln. https://www.iwkoeln.de/studien/hubertus-bardt-michael-huether-investitionen-ermoeglichen.html

Barrage, L., & Nordhaus, W. (2023). *Policies, Projections, and the Social Cost of Carbon: Results from the DICE-2023 Model* (w31112; p. w31112). National Bureau of Economic Research. https://doi.org/10.3386/w31112

Baselli, V. (2023, November 24). Europas Gasspeicher sind prall gefüllt. Was sind die Risiken in diesem Winter? *Morningstar DE.* https://www.morningstar.de/de/news/243110/europas-gasspeicher-sind-prall-gef%c3%bcllt-was-sind-die-risiken-in-diesem-winter.aspx

BBSR. (2017). *Börsennotierte Wohnungsunternehmen als neue Akteure auf dem Wohnungsmarkt: Börsengänge und ihre Auswirkungen.* Bundesinstitut für Bau-, Stadt- und Raumforschung. https://www.bbsr.bund.de/BBSR/DE/veroeffentlichungen/bbsr-online/2017/bbsr-online-01-2017-dl.pdf;jsessionid=C2ACAA2D68651D9D19EA47068382F9B1.live21304?__blob=publicationFile&v=1

BBSR. (2021). *Kommunale Wohnungsbestände: Mietengestaltung - Ausweitung - Investition. Ergebnisse der BBSR-Kommunalbefragung 2018.* Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR). https://www.bbsr.bund.de/BBSR/DE/veroeffentlichungen/sonderveroeffentlichungen/2021/kommunale-wohnungsbestaende-dl.pdf?__blob=publicationFile&v=2;

BDEW. (2023a). *Die Energieversorgung 2022. Jahresbericht* (p. 56). https://www.bdew.de/media/documents/Pub_20230601_Jahresbericht-2022-UPDATE-mai-2023.pdf

BDEW. (2023b, June 6). *Entwicklung der Beheizungsstruktur im Neubau – Baufertigstellungen.* https://www.bdew.de/service/daten-und-grafiken/entwicklung-beheizungsstruktur-baufertigstellungen/

BDEW. (2023c, October 10). *Beheizungsstruktur des Wohnungsbestandes in Deutschland.* Bundesverband der Energie- und Wasserwirtschaft. https://www.bdew.de/service/daten-und-grafiken/beheizungsstruktur-wohnungsbestand/

BDEW. (2023d, October 19). *Erdgasabsatz in Deutschland.* Bundesverband der Energie- und Wasserwirtschaft. https://www.bdew.de/service/daten-und-grafiken/erdgasabsatz-nach-kundengruppen/

BDEW & EY. (2022). *Teure neue Energiewelt* (Stadtwerkestudie 2022). https://www.ey.com/de_de/forms/download-forms/2022/05/ey-und-bdew-stadtwerkestudie-2022

BDEW & EY. (2023). *Mit neuen Strategien aus der Krise: Zukunftsinvestitionen in eine nachhaltige Energieversorgung* (Stadtwerkestudie 2023). https://www.bdew.de/media/original_images/2023/06/09/ey_bdew_sws_2023.pdf

BDH. (2023). *Marktentwicklung Wärmemarkt Deutschland 2022.* Bundesverband der deutschen Heizungsindustrie. https://www.bdh-industrie.de/fileadmin/user_upload/Pressemeldungen/Marktentwicklung_Waermemarkt_Deutschland_2022.pdf

BDI. (2023). *Industriebericht: Industrieproduktion und Handel nach Branchen.* Bundesverband der Deutschen Industrie. https://issuu.com/bdi-berlin/docs/20230417_research_bdi_industriebericht_april_2023

Becker Büttner Held. (2023). *Regulatorische Anpassungsbedarfe zur Transformation der Gasversorgung im Kontext der Wärmewende.* https://www.vku.de/fileadmin/user_upload/Verbandsseite/Presse/Pressemitteilungen/2023/Regulatorische_Anpassungsbedarfe_zur_Transformation_der_Gasversorgung_im_Kontext_der_Waermewende__.pdf

Beer, M., Schirrmacher, J., Bichler, M., Hohmeyer, O., Hörter, A., Sommer, B., & Utz, J. (2017). *Schlüsselakteure bewegen kommunalen Klimaschutz. AP 2: Grundlagenpapier zum theoretischen Hintergrund*. Europa-Universität Flensburg und Zentrum für Nachhaltige Energiesysteme. http://schluesselakteure.de/wp-content/uploads/2017/10/20170927_Grundlagenpapier_final.pdf

Behr, S. M., Küçük, M., & Neuhoff, K. (2023). *Energetische Modernisierung von Gebäuden sollte durch Mindeststandards und verbindliche Sanierungsziele beschleunigt werden* (DIW Aktuell Nr. 87). Deutsches Institut für Wirtschaftsforschung. https://www.diw.de/documents/publikationen/73/diw_01.c.868217.de/diw_aktuell_87.pdf

Beier, C., Grunwald, L., Hagemeier, A., Hunstock, B., Krassowski, J., Witkowski, S., Buß, K., Hasselmann, M., Höffner, D., Maitanova, N., Rogotzki, R., & Schill, C. (2020). *Abschlussbericht des Forschungsvorhabens TrafoSW – Transformation von Stadtwerken als wichtige Säule der Energiewende.* Fraunhofer UMSICHT. https://www.umsicht.fraunhofer.de/content/dam/umsicht/de/dokumente/referenzen/trafosw/TrafoSW_03ET1518A_Abschlussbericht_UMSICHT.pdf

Beznoska, M., & Hentze, T. (2021). *Eine Abschätzung des Potential der Erbschaftssteuer zur Entlastung des Faktors Arbeit* (IW-Policy Paper 18/21). Institut der deutschen Wirtschaft Köln. https://www.iwkoeln.de/fileadmin/user_upload/Studien/policy_papers/PDF/2021/IW-Policy_Paper_2021_Potentiale-Erbschaftssteuer.pdf

Beznoska, M., Hentze, T., Rietzler, K., & Werding, M. (2023). *Herausforderungen für nachhaltige Staatsfinanzen* (IW-Trends 3/2023). Institut der deutschen Wirtschaft Köln. https://www.iwkoeln.de/studien/martin-beznoska-tobias-hentze-herausforderungen-fuer-nachhaltige-staatsfinanzen.html

BfEE. (2023). *Contracting.* Bundesstelle Für Energieeffizienz. https://www.bfee-online.de/BfEE/DE/Energiedienstleistungen/Contracting/contracting_node.html

Biesl, A., Burkhardt, M., & Wendel, F. (2023). *Analyse: Transformation und Rolle der Wärmenetze.* Ariadne. https://ariadneprojekt.de/publikation/analyse-transformation-und-rolle-der-waermenetze/

Birk, K. (2022). Klimaschutz und Wohnungsbau misslingen ohne Handwerker. *Deutsche Handwerks Zeitung (DHZ).* https://www.deutsche-handwerks-zeitung.de/klimaschutz-und-wohnungsbau-misslingen-ohne-handwerker-227166/

BLE. (2021). *Merkblatt Technologiereifegrade. Bundesanstalt für Landwirtschaft und Ernährung.* https://www.ble.de/SharedDocs/Downloads/DE/Projektfoerderung/Innovationen/DIP/Merkblatt-Technologiereifegrade.pdf?__blob=publicationFile&v=2

BMF. (2022). *BMF-Monatsbericht November 2022: Bundespolitik und Kommunalfinanzen in Krisenzeiten.* Bundesministerium der Finanzen. https://www.bundesfinanzministerium.de/Monatsberichte/2022/11/Inhalte/Kapitel-3-Analysen/3-1-bundespolitik-und-kommunalfinanzen-in-krisenzeiten.html

BMWK. (2017). *Initiative Energieeffizienz- und Klimaschutz-Netzwerke.* Bundesministerium für Wirtschaft und Klimaschutz. https://www.dena.de/fileadmin/dena/Dokumente/Themen_und_Projekte/Strom/Initiative_EnergieEffizienz_-_Unternehmen_und_Institutionen/Vereinbarung-Effizienznetzwerke_8_8_2017.pdf

BMWK. (2022a). *Bundesministerium für Wirtschaft und Klimaschutz ruft Frühwarnstufe des Notfallplans Gas aus – Versorgungssicherheit weiterhin gewährleistet* [Pressemitteilung]. https://www.bmwk.de/Redaktion/DE/Pressemitteilungen/2022/03/20220330-bmwk-ruft-fruehwarnstufe-des-notfallplan-gas-versorgungssicherheit-gewaehrleistet.html

BMWK. (2022b). *Transformation zu einer klimaneutralen Industrie: Grüne Leitmärkte und Klimaschutzverträge.* Bundesministerium für Wirtschaft und Klimaschutz. https://www.bmwk.de/Redaktion/DE/Publikationen/Ministerium/Veroeffentlichung-Wissenschaftlicher-Beirat/transformation-zu-einer-klimaneutralen-industrie.pdf?__blob=publicationFile&v=8

BMWK. (2023a). *Begleitung von BMWK-Maßnahmen zur Umsetzung einer Wärmepumpen-Offensive* (RV 115/21). Bundesministerium für Wirtschaft und Klimaschutz. https://www.bmwk.de/Redaktion/DE/Publikationen/Energie/ergebnisbericht-warmepumpen-offensive-bf.pdf?__blob=publicationFile&v=1

BMWK. (2023b). *BKR-Bundesregelung Transformationstechnologien* [BAnz AT 04.08.2023 B1]. Bundesanzeiger. https://www.bundesanzeiger.de/pub/publication/z1UOYpff38bpp09Pk9N/content/z1UOYpff38bpp09Pk9N/BAnz%20AT%2004.08.2023%20B1.pdf?inline

BMWK. (2023c). *BMWK baut mit neuem Praxis-Check-Verfahren konkret unnötige Bürokratie ab. Überblickspapier zum neuen Instrument des Praxischecks.* Bundesministerium für Wirtschaft und Klimaschutz. https://www.bmwk.de/Redaktion/DE/Downloads/Gesetz/20230816-uberblickspapier-instrument-praxischeck.pdf?__blob=publicationFile&v=6

BMWK. (2023d). *Dritter Wärmepumpengipfel: Breites Akteursbündnis bekräftigt Zusammenarbeit beim Wärmepumpenhochlauf* [Pressemitteilung]. https://www.bmwk.de/Redaktion/DE/Pressemitteilungen/2023/09/20230919-dritter-waermepumpengipfel-breites-akteursbuendnis-bekraeftigt-zusammenarbeit-beim-waermepumpenhochlauf.html

BMWK. (2023e). *Eckpunktepapier zur Diskussion der Beschleunigung des Wärmepumpenhochlaufs – Vorhaben und Maßnahmen zum 2. Wärmepumpen-Gipfel.* Bundesministerium für Wirtschaft und Klimaschutz. https://www.bmwk.de/Redaktion/DE/Downloads/Energie/2-waermepumpen-gipfel-eckpunktepapier.pdf?__blob=publicationFile&v=6

BMWK. (2023f). *Förderung für den Heizungstausch auf einen Blick (BEG).* Bundesministerium für Wirtschaft und Klimaschutz. https://www.energiewechsel.de/KAENEF/Redaktion/DE/Downloads/230905-foerderung-heizungstausch-beg.pdf?__blob=publicationFile&v=5

BMWK. (2023g). *Fortschreibung der Nationalen Wasserstoffstrategie.* Bundesministerium für Wirtschaft und Klimaschutz. https://www.bmwk.de/Redaktion/DE/Publikationen/Energie/fortschreibung-nationale-wasserstoffstrategie.html

BMWK. (2023h). *Maschinen- und Anlagenbau.* https://www.bmwk.de/Redaktion/DE/Artikel/Branchenfokus/Industrie/branchenfokus-maschinen-und-anlagenbau.html

BMWK. (2023i). *Richtlinie zur Förderung von klimaneutralen Produktionsverfahren in der Industrie durch Klimaschutzverträge.* https://www.bmwk.de/Redaktion/DE/Downloads/F/klimaschutzvertraege-foerderrichtlinie.pdf?__blob=publicationFile&v=2

BMWK. (2023j). *Zwischenbericht der Systementwicklungsstrategie* [Zwischenbericht]. Bundesministerium für Wirtschaft und Klimaschutz (BMWK). https://www.bmwk.de/Redaktion/DE/Publikationen/Energie/20231122-zwischenbericht-der-systementwicklungsstrategie.pdf?__blob=publicationFile&v=11

BMWK. (2023k). *Bundesförderung Aufbauprogramm Wärmepumpe.* Förderdatenbank.de. https://www.foerderdatenbank.de/FDB/Content/DE/Foerderprogramm/Bund/BMWi/aufbauprogramm-waermepumpe.html

BMWK. (2023l). *Erdgasversorgung in Deutschland. Bundesministerium für Wirtschaft und Klimaschutz.* https://www.bmwk.de/Redaktion/DE/Artikel/Energie/gas-erdgasversorgung-in-deutschland.html

BMWK. (2023m, June 13). Fernwärme soll klimaneutrale Wärmeversorgung sichern. *Newsletter „Energiewende Direkt."* https://www.bmwk-energiewende.de/EWD/Redaktion/Newsletter/2023/06/Meldung/News1.html

BMWK. (2023n, July 10). *Reallabore – Testräume für Innovation und Regulierung.* Bundesministerium für Wirtschaft und Klimaschutz. https://www.bmwk.de/Redaktion/DE/Dossier/reallabore-testraeume-fuer-innovation-und-regulierung.html

BMWK. (2023o, October 17). Wärmepumpen: Im Europavergleich muss Deutschland aufholen. *Newsletter „Energiewende Direkt."* https://www.bmwk-energiewende.de/EWD/Redaktion/Newsletter/2023/09/Meldung/direkt-erfasst.html

BMWSB. (2022). *Faktenblätter zum deutschen Wohnungsmarkt 2022.* Bundesministerium für Wohnen, Stadtentwicklung und Bauwesen. https://www.bmwsb.bund.de/SharedDocs/downloads/Webs/BMWSB/DE/veroeffentlichungen/wohnen/faktenblaetter-zum-deutschen-wohnungsmarkt-2022.pdf?__blob=publicationFile&v=2

BMWSB. (2023). *Entwurf eines Gesetzes für die Wärmeplanung und zur Dekarbonisierung der Wärmenetze. Bundesministerium für Wohnen, Stadtentwicklung und Bauwesen.* https://www.bmwsb.bund.de/SharedDocs/gesetzgebungsverfahren/Webs/BMWSB/DE/Downloads/kabinettsfassung/kommunale-waermeplanung.pdf;jsessionid=79B08C8A16F7114D297DFA237D2FB436.2_cid504?__blob=publicationFile&v=1

Bolton, P., Despres, M., Pereira da Silva, L. A., Samama, F., & Svartzman, R. (2020). *The green swan—Central banking and financial stability in the age of climate change.* Bank for International Settlements. https://www.bis.org/publ/othp31.pdf

Bosch. (2023). *Bosch investiert weiter in den Ausbau seiner europäischen Wärmepumpen-Standorte* [Pressemitteilung]. https://www.bosch-homecomfortgroup.com/de/news-und-stories/news/bosch-investiert-weiter-in-den-ausbau-seiner-europaeischen-waermepumpen-standorte/

Brand, S., & Salzgeber, J. (2023). Kommunalfinanzen in Zeiten steigender Zinsen. *Wirtschaftsdienst,* 103(1), 55–61.

Braungart, S., & Bürger, V. (2023). *Abschätzung der Minderungswirkung der 65%- Anforderung im GEG-Entwurf.* Öko-Institut. https://www.oeko.de/publikation/abschaetzung-der-minderungswirkung-der-65-anforderung-im-geg-entwurf/

BSW-Solar. (2023). *Statistische Zahlen der deutschen Solarstrombranche (Photovoltaik).* Bundesverband Solarwirtschaft. https://www.solarwirtschaft.de/datawall/uploads/2022/02/bsw_faktenblatt_photovoltaik.pdf

Buchenau, M.-W. (2023, April 19). *Aufholjagd bei Wärmepumpen: Bosch baut neues Werk in Polen.* https://www.handelsblatt.com/unternehmen/industrie/heizungen-aufholjagd-bei-waermepumpen-bosch-baut-neues-werk-in-polen/29103468.html

Bundesbank. (2021). *Finanzstabilitätsbericht 2021.* https://www.bundesbank.de/resource/blob/879732/ce21f3162cbac988167d9364dbd37f7d/mL/2021-finanzstabilitaetsbericht-data.pdf

Bundesbank. (2022). Die Schuldenbremse des Bundes: Möglichkeiten einer stabilitätsorientierten Weiterentwicklung. *Monatsbericht April 2022,* 53–70.

Bundesnetzagentur. (2023a). *Gas-Winterszenarien 2023/2024.* https://www.bundesnetzagentur.de/DE/Gasversorgung/Krisenvorbereitung/Download/231102_gas_szenarien.pdf?__blob=publicationFile&v=1

Bundesnetzagentur. (2022). *Rückblick: Gasversorgung im Jahr 2022.* https://www.bundesnetzagentur.de/DE/Gasversorgung/aktuelle_gasversorgung/Rueckblick/start.html

Bundesnetzagentur. (2023b). *Aktuelle Lage Gasversorgung—Gasimporte in GWh/Tag.* https://www.bundesnetzagentur.de/DE/Gasversorgung/aktuelle_gasversorgung/_svg/Gasimporte/Gasimporte.html?nn=652300

Bundesnetzagentur. (2023c). *Aktuelle Lage Gasversorgung—Gasverbrauch in Deutschland, monatlicher Mittelwert.* https://www.bundesnetzagentur.de/DE/Gasversorgung/aktuelle_gasversorgung/_svg/Gasverbrauch_Gesamt_monatlich/Gasverbrauch_Gesamt_2023.html?nn=652300

Bundesregierung. (2023a). *Entwurf eines Gesetzes über die Feststellung des Bundeshaushaltsplans für das Haushaltsjahr 2024 – Drucksache 20/7800.*

Bundesregierung. (2023b). *Strompreispaket für produzierende Unternehmen – Bundesregierung entlastet stromintensive Unternehmen* [Pressemitteilung]. https://www.bundesregierung.de/breg-de/aktuelles/strompreispaket-fuer-produzierende-unternehmen-bundesregierung-entlastet-stromintensive-unternehmen-2235602

Bundesregierung. (2022, November 7). *Klimaschutzgesetz: Generationenvertrag für das Klima.* https://www.bundesregierung.de/breg-de/schwerpunkte/klimaschutz/klimaschutzgesetz-2021-1913672

Bundesregierung. (2023c, August 16). Kabinett beschließt Solarpaket. Mehr Solarstrom, weniger Bürokratie. https://www.bundesregierung.de/breg-de/aktuelles/solarpaket-2213726

Bundesregierung. (2023d, September 8). *Gesetz für Erneuerbares Heizen: Für mehr klimafreundliche Heizungen.* https://www.bundesregierung.de/breg-de/schwerpunkte/klimaschutz/neues-gebaeudeenergiegesetz-2184942

Bundestag. (2023). *Finanzplan des Bundes 2023 bis 2027 (Drucksache 20/7801).* https://dserver.bundestag.de/btd/20/078/2007801.pdf

Bürger, V. (2022). *Fernwärme – bedeutender Baustein für die Wärmewende.* Transforming Economies. https://transforming-economies.de/fernwaerme-bedeutender-baustein-fuer-die-waermewende/

Bürger, V., Braungardt, S., & Miara, M. (2022). *Durchbruch für die Wärmepumpe. Praxisoptionen für eine effiziente Wärmewende im Gebäudebestand. Studie im Auftrag von Agora Energiewende.* Agora Energiewende. https://www.agora-energiewende.de/publikationen/durchbruch-fuer-die-waermepumpe

Burret, H., Kirchner, A., Kreidelmeyer, S., Ambros, J., Limbers, J., Brutsche, A., Granzow, M., & Häßler, R. D. (2021). *Beitrag von Green Finance zum Erreichen von Klimaneutralität in Deutschland* [Prognos im Auftrag der KfW]. https://www.kfw.de/PDF/Download-Center/Konzernthemen/Research/PDF-Dokumente-Studien-und-Materialien/Green-Finance-und-Klimaneutralitaet.pdf

BWP. (2023a). *Wärmepumpenabsatz 2022: Wachstum von 53 Prozent gegenüber dem Vorjahr* [Pressemitteilung]. Bundesverband Wärmepumpe. https://www.waermepumpe.de/presse/news/details/waermepumpenabsatz-2022-wachstum-von-53-prozent-gegenueber-dem-vorjahr/

BWP. (2014, June 16). *Wie hoch ist die Lebensdauer einer Wärmepumpe? Wie kann ich diese erhöhen?* Bundesverband Wärmepumpe. https://www.waermepumpe.de/waermepumpe/darum-waermepumpe/experten/wie-hoch-ist-die-lebensdauer-einer-waermepumpe-wie-kann-ich-diese-erhoehen/

BWP. (2023b, November 13). *Zusammensetzung des Strom-, Gas- und Ölpreises im Jahr 2022.* Bundesverband Wärmepumpe. https://www.waermepumpe.de/politik/energiepreise/

Cebon, D. (2020). *Hydrogen for Heating?* Centre for Sustainable Road Freight. https://www.csrf.ac.uk/blog/hydrogen-for-heating/

Ciummo, S., Walch, F., & Breitenstein, M. (2022). Disclosure of Climate Change Risk in Credit Ratings. *SSRN Electronic Journal.* https://doi.org/10.2139/ssrn.4218357

Climate Action Tracker. (2023). *Targets for Germany.* https://climateactiontracker.org/countries/germany/targets/

Coalition for Urban Transitions. (2019). *Climate Emergency, Urban Opportunity. Climate-Emergency-Urban-Opportunity-report.pdf.* World Resources Institute (WRI) Ross Center for Sustainable Cities and C40 Cities Climate Leadership Group. https://urbantransitions.global/wp-content/uploads/2019/09/Climate-Emergency-Urban-Opportunity-report.pdf

Colesanti Senni, C., Pagliari, M. S., & Klooster, J. (2023). *The CO_2 Content of the TLTRO III Scheme and its Greening* (Working Paper No. 792). De Nederlandsche Bank. https://doi.org/10.2139/ssrn.4613820

CRIF. (2022). *10 Prozent der Unternehmen in Deutschland sind insolvenzgefährdet – Anstieg der Firmeninsolvenzen in 2022 und 2023 prognostiziert* [Pressemitteilung]. https://crif.de/pr-events/pressemitteilungen/2022/november/15/10-prozent-der-unternehmen-in-deutschland-sind-insolvenzgefaehrdet-anstieg-der-firmeninsolvenzen-in-2022-und-2023-prognostiziert/

Daikin. (2021). *Investitionen in Höhe von 840 Millionen Euro und Schaffung von 4.000 Arbeitsplätzen—Daikin Europe N.V. stellt 5-Jahres-Plan vor* [Pressemitteilung]. https://www.daikin.de/de_de/pressemeldungen/investitionen_in_hoehe_von_840_millionen.html

Daikin. (2022). *Daikin Europe investiert 300 Mio. Euro in neues Werk für Wärmepumpen in Polen* [Pressemitteilung]. https://www.daikin.at/de_at/pressemeldungen/daikin-europe-invests-300-million-in-new-polish-heat-pump-heatin.html

Danish Energy Agency. (2015). *Regulation and planning of district heating in Denmark.* https://ens.dk/sites/ens.dk/files/contents/material/file/regulation_and_planning_of_district_heating_in_denmark.pdf

Daube, C. H., & Krivenkov, V. (2023). *Aktuelle Bewertung von Bonitätsrisiken bei deutschen Immobilien-Unternehmen* (IUCF Working Paper No. 2/2023 2/2023). ZBW – Leibniz Information Centre for Economics. https://www.econstor.eu/handle/10419/267845

DEHSt. (2023). *Nationalen Emissionshandel verstehen.* Deutsche Emissionshandelsstelle. https://www.dehst.de/DE/Nationaler-Emissionshandel/nEHS-verstehen/nehs-verstehen_node.html

dena. (2023). *Wärmepumpen im Gebäudesektor: Eine Technologie für eine fossilfreie Wärmeversorgung.* Deutsche Energie-Agentur. https://www.dena.de/newsroom/publikationsdetailansicht/pub/analyse-waermepumpen-im-gebaeudesektor/

DENEFF. (2023). *Finanzinnovationen für die Wärmewende.* Deutsche Unternehmensinitiative Energieeffizienz. https://deneff.org/wp-content/uploads/2023/09/20230922_DENEFF_Finanzinnovationen-Waermewende.pdf

Der Neue Kämmerer. (2017). *Stadtwerke—Fit für die Zukunft?* https://www.parlament-berlin.de/ados/18/WiEnBe/vorgang/web18-0007-DNK-Stadtwerke-Studie.pdf

Der Neue Kämmerer. (2019). *Stadtwerke – fit für die Zukunft? 2019.* https://www.derneuekaemmerer.de/research/studien/stadtwerke-fit-fuer-die-zukunft-2019/

Destatis. (2023a). *Energieverbrauch der Industrie 2022 um 9,1 % gegenüber dem Vorjahr gesunken* [Pressemitteilung]. Statistisches Bundesamt. https://www.destatis.de/DE/Presse/Pressemitteilungen/2023/11/PD23_432_435.html

Destatis. (2023b). *Inflationsrate im Jahr 2022 bei +7,9 %* [Pressemitteilung]. Statistisches Bundesamt. https://www.destatis.de/DE/Presse/Pressemitteilungen/2023/01/PD23_022_611.html

Destatis. (2023c). *Produktion von Wärmepumpen in den ersten drei Quartalen 2022 um 49 % gegenüber Vorjahreszeitraum gestiegen* [Pressemitteilung]. Statistisches Bundesamt. https://www.destatis.de/DE/Presse/Pressemitteilungen/2023/03/PD23_N014_42_51.html

Destatis. (2023d). *Kleine und mittlere Unternehmen (KMU).* Statistisches Bundesamt. https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Unternehmen/Kleine-Unternehmen-Mittlere-Unternehmen/Glossar/kmu.html

Destatis. (2023e, December 13). *Beschäftigte und Umsatz der Betriebe im Verarbeitenden Gewerbe: Deutschland, Jahre, Beschäftigtengrößenklassen, Wirtschaftszweige.* GENESIS-Online. https://www-genesis.destatis.de/genesis/online?operation=table&code=42271-0006&bypass=true&levelindex=1&levelid=1700400543155#abreadcrumb

Dezernat Zukunft. (n. d.). *Die deutsche Schuldenbremse.* schuldenbremse.info. Retrieved December 18, 2023, from https://schuldenbremse.info/

Dezernat Zukunft & Agora Energiewende. (2023). *LNG, Energiesicherheit und Klimaschutz: Wege aus dem Spannung ….* https://www.dezernatzukunft.org/wp-content/uploads/2023/06/Heilmann-et-al.-2023-LNG-Energiesicherheit-und-Klimaschutz-Wege-aus-dem-Spannungsfeld.pdf

DIW Berlin. (2023a). *CO_2-Bepreisung: Klimageld würde insbesondere einkommensschwachen Haushalten helfen* [Pressemitteilung]. Deutsches Institut für Wirtschaftsforschung. https://www.diw.de/de/diw_01.c.874267.de/co2-bepreisung__klimageld_wuerde_insbesondere_einkommensschwachen_haushalten_helfen.html

DIW Berlin. (2023b, July 4). Die Bundesregierung überschätzt den Bedarf an Flüssiggas-Infrastruktur. *Deutsche Institut für Wirtschaftsforschung.* https://www.diw.de/de/diw_01.c.876568.de/nachrichten/die_bundesregierung_ueberschaetzt_den_bedarf_an_fluessiggas-infrastruktur.html

Dixit, R. K., & Pindyck, R. S. (1994). *Investment under Uncertainty.* Princeton University Press. https://doi.org/10.1515/9781400830176

DStGB. (2022a). *Bilanz 2022 + Ausblick 2023 der deutschen Städte und Gemeinden: Mit starken Kommunen sicher durch unsichere Zeiten.* Deutscher Städte- und Gemeindebund. https://www.dstgb.de/publikationen/dokumentationen/bilanz-2022-ausblick-2023/bilanz-22-23-final-web.pdf?cid=tzv

DStGB. (2022b). *Düstere Aussichten für die Kommunalfinanzen—Schutzschirm für Stadtwerke notwendig* [Pressemitteilung]. https://www.dstgb.de/publikationen/pressemitteilungen/duestere-aussichten-fuer-die-kommunalfinanzen/

DStGB. (2023). *Kommunen fordern Wärmewende mit Plan und Augenmaß* [Pressemitteilung]. Deutscher Städte- und Gemeindebund. https://www.dstgb.de/publikationen/pressemitteilungen/kommunen-fordern-waermewende-mit-plan-und-augenmass/

Durth, R. (2017). *Sanieren oder nicht sanieren – Welche Gründe entscheiden über die energetische Sanierung von Wohngebäuden?* (194; KfW Research). Kreditanstalt für Wiederaufbau. https://www.kfw.de/PDF/Download-Center/Konzernthemen/Research/PDF-Dokumente-Fokus-Volkswirtschaft/Fokus-2017/Fokus-Nr.-194-Dezember-2017-Sanierungshemmnisse.pdf

DZ Bank Group. (2022). *2022 Sustainability Report.* https://www.dzbank.com/content/dam/dzbank/dokumente/en/dz-bank/investor-relations/reports/archive/2022/DZB_NHB_2022_EN.pdf

ECB. (2022a). *2022 climate risk stress test.* ECB Banking Supervision. https://www.bankingsupervision.europa.eu/ecb/pub/pdf/ssm.climate_stress_test_report.20220708~2e3cc0999f.en.pdf

ECB. (2022b). *Supervisory assessment of institutions' climate-related and environmental risks disclosures.* ECB Banking Supervision. https://www.bankingsupervision.europa.eu/ecb/pub/pdf/ssm.ECB_Report_on_climate_and_environmental_disclosures_202203~4ae33f2a70.en.pdf

ECB. (2023a). *Economic Bulletin Issue 4, 2023.* European Central Bank. https://www.ecb.europa.eu/pub/economic-bulletin/html/eb202304.en.html

ECB. (2023b, July 25). *Stress tests.* https://www.bankingsupervision.europa.eu/banking/tasks/stresstests/html/index.en.html

Effenberger, A., Enkelmann, S., Menzel, C., Neumann, D., & Stolle, J. (2020). *Marktkonzentration, Produktivität und Preisaufschläge: Deskriptive Evidenz auf Basis amtlicher Daten für Deutschland* (Diskussionspapier Nr. 9). Bundesministerium für Wirtschaft und Klimaschutz. https://www.bmwk.de/Redaktion/DE/Downloads/Diskussionspapiere/20200716-diskussionspapier-marktkonzentration-produktivitaet-und-preisaufschlaege.pdf?__blob=publicationFile

EFRAG. (2022). *Draft European Sustainability Reporting Standards.* https://www.efrag.org/lab6

EHI. (2021). *Heating Market Report 2021.* European Heating Industry. https://ehi.eu/heating-market-report/heating-market-report-2021/

EHPA. (2023). *PORT PC: 2022 was the Year of Heat Pumps in Poland.* European Heat Pump Association. https://www.ehpa.org/news-and-resources/news/port-pc-2022-was-the-year-of-heat-pumps-in-poland/

Eicke, A., Hirth, L., Mühlenpfordt, J., & Schlecht, I. (2023). *Industriestrompreis: Ausgestaltungsoptionen für eine befristete Produktionssubvention für die stromkostenintensive Industrie im internationalen Wettbewerb.* Neon Neue Energieökonomik. https://neon.energy/Neon-Industriestrompreis.pdf

Elderson, F. (2021, February 13). Greening monetary policy. *ECB Blog.* https://www.ecb.europa.eu/press/blog/date/2021/html/ecb.blog210213~7e26af8606.en.html

Ember. (2023). *Carbon Price Tracker.* Ember. https://ember-climate.org/data/data-tools/carbon-price-viewer/

Endres, L. (2023). *Verteilungswirkung der CO_2-Bepreisung in den Sektoren Verkehr und Wärme mit Pro-Kopf Klimageld* (IMK Policy Brief). Institut für Makroökonomie und Konjunkturforschung. https://www.imk-boeckler.de/de/faust-detail.htm?sync_id=HBS-008757

Energiekrise solidarisch bewältigen, neue Realität gestalten (Jahresgutachten 22/23). (2022). *Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung.* https://www.sachverstaendigenrat-wirtschaft.de/fileadmin/dateiablage/gutachten/jg202223/JG202223_Gesamtausgabe.pdf

Engelmann, P., Köhler, B., Meyer, R., Dengler, J., Herkel, S., Kießling, L., Quast, A., Berneiser, J., Bär, C., Sterchele, P., Heilig, J., Bürger, V., Braungardt, S., Hesse, T., Sandrock, M., Maaß, C., & Strodel, N. (2021). *Systemische Herausforderung der Wärmewende* (Climate Change 18/2021). Umweltbundesamt. https://www.umweltbundesamt.de/sites/default/files/medien/5750/publikationen/2021-04-26_cc_18-2021_waermewende.pdf

EUPD Research. (2023, April 12). *Wärmewende – Wärmepumpenboom mit großem Potential für Energieversorger.* https://www.eupd-research.com/waermewende-waermepumpenboom-mit-grossem-potential-fuer-energieversorger/

Europäische Kommission. (n. d.). *Approved Important Projects of Common European Interest (IPCEI).* Retrieved November 24, 2023, from https://competition-policy.ec.europa.eu/state-aid/legislation/modernisation/ipcei/approved-ipceis_en

Europäische Kommission. (2021a). *Delegierte Verordnung (EU) 2021/2139 der Kommission vom 4. Juni 2021* (L 442/1). https://eur-lex.europa.eu/legal-content/DE/TXT/?uri=CELEX:32021R2139

Europäische Kommission. (2021b). *Factsheet: How does the eu taxonomy fit within the sustainable finance framework?* https://finance.ec.europa.eu/system/files/2021-04/sustainable-finance-taxonomy-factsheet_en.pdf

Europäische Kommission. (2022a). *Commission invests €3 billion in innovative clean tech projects to deliver on REPowerEU and accelerate Europe's energy independence from Russian fossil fuels* [Press release]. https://ec.europa.eu/commission/presscorner/detail/en/ip_22_6489

Europäische Kommission. (2022b). *Delegierte Verordnung (EU) 2022/1214 der Kommission vom 9. März 2022* (L 188/1). https://eur-lex.europa.eu/legal-content/DE/TXT/?uri=CELEX:32022R1214

Europäische Kommission. (2022c). *Kommission genehmigt deutsche Beihilfe für energieintensive Unternehmen in Höhe von 27,5 Milliarden Euro* [Pressemitteilung]. Vertretung der Europäischen Kommission in Deutschland. https://germany.representation.ec.europa.eu/news/kommission-genehmigt-deutsche-beihilfe-fur-energieintensive-unternehmen-hohe-von-275-milliarden-euro-2022-08-19_de

Europäische Kommission. (2023a). *Arbeitsprogramm der Kommission 2024* (COM(2023) 638 final). https://eur-lex.europa.eu/legal-content/DE/TXT/HTML/?uri=CELEX:52023DC0638

Europäische Kommission. (2023b). Net-Zero Industry Act: Making the EU the home of clean technologies manufacturing and green jobs [Press release]. https://ec.europa.eu/commission/presscorner/detail/en/IP_23_1665

Europäische Kommission. (2023c). *Staatliche Beihilfen: Kommission genehmigt 6,5 Milliarden Euro für deutsche energieintensive Unternehmen* [Pressemitteilung]. Vertretung der Europäischen Kommission in Deutschland. https://germany.representation.ec.europa.eu/news/staatliche-beihilfen-kommission-genehmigt-65-milliarden-euro-fur-deutsche-energieintensive-2023-08-10_de

Europäische Kommission. (2023d). *Temporary Crisis and Transition Framework for State Aid measures to support the economy following the aggression against Ukraine by Russia* (C 101/3). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.C_.2023.101.01.0003.01.ENG&toc=OJ%3AC%3A2023%3A101%3ATOC

Europäische Kommission. (2023e). *Effort sharing 2021-2030: Targets and flexibilities.* https://climate.ec.europa.eu/eu-action/effort-sharing-member-states-emission-targets/effort-sharing-2021-2030-targets-and-flexibilities_en

Europäische Union. (2021). *Consolidated text: Directive 2011/61/EU of the European Parliament and of the Council of 8 June 2011 on Alternative Investment Fund Managers and amending Directives 2003/41/EC and 2009/65/EC and Regulations (EC) No 1060/2009 and (EU) No 1095/2010.* https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02011L0061-20210802&qid=1702832246789

Europäische Union. (2023a). *Consolidated text: Directive 2009/65/EC of the European Parliament and of the Council of 13 July 2009 on the coordination of laws, regulations and administrative provisions relating to undertakings for collective investment in transferable securities (UCITS) (recast).* https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02009L0065-20230101

Europäische Union. (2023b). *The update of the nationally determined contribution of the European Union and its Member States.* United Nations Framework Convention on Climate Change (UNFCCC). https://unfccc.int/sites/default/files/NDC/2023-10/ES-2023-10-17%20EU%20submission%20NDC%20update.pdf

Europäischer Rat. (2023, May 15). *„Fit für 55“: Reform des EU-Emissionshandelssystems.* https://www.consilium.europa.eu/de/infographics/fit-for-55-eu-emissions-trading-system/

Europäisches Parlament und der Rat. (2020). *Verordnung (EU) 2020/852 des Europäischen Parlaments und des Rates vom 18. Juni 2020 über die Einrichtung eines Rahmens zur Erleichterung nachhaltiger Investitionen und zur Änderung der Verordnung (EU) 2019/2088* (L 198/13). https://eur-lex.europa.eu/legal-content/DE/TXT/?uri=CELEX:32020R0852

Europäisches Parlament und der Rat. (2021). *Verordnung des europäischen Parlaments und des Rates zur Schaffung des Rahmens für die Verwirklichung der Klimaneutralität und zur Änderung der Verordnungen (EG) Nr. 401/2009 und (EU) 2018/1999 („Europäisches Klimagesetz“)* (PE-CONS 27/21). https://data.consilium.europa.eu/doc/document/PE-27-2021-INIT/de/pdf

Europäisches Parlament und der Rat. (2023). *Richtlinie (EU) 2023/1791 des Europäischen Parlaments und des Rates zur Energieeffizienz und zur Änderung der Verordnung (EU) 2023/955.* https://eur-lex.europa.eu/legal-content/DE/TXT/HTML/?uri=CELEX:32023L1791

European Commission. (2017). *Energy service companies in the EU: Status review and recommendations for further market development with a focus on energy performance contracting.* Publications Office. https://data.europa.eu/doi/10.2760/12258

European Commission. (2021, July 6). *Annexes to the COMMISSION DELEGATED REGULATION supplementing Regulation (EU) 2020/852 of the European Parliament and of the Council by specifying the content and presentation of information to be disclosed by undertakings subject to Articles 19a or 29 of Directive 2013/34/EU concerning environmentally sustainable economic activities, and specifying the methodology to comply with that disclosure obligation.* https://ec.europa.eu/finance/docs/level-2-measures/taxonomy-regulation-delegated-act-2021-4987-annex-1-5_en.pdf

Eurostat. (2008). *NACE Rev. 2: Statistical classification of economic activities in the European Community.* Eurostat Methodologies and Working Papers. https://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF

Eurostat. (2023a). *Euro area annual inflation down to 2.4%.* https://ec.europa.eu/eurostat/documents/2995521/18005473/2-30112023-AP-EN.pdf/a5c354ab-dd3d-1e1b-72dc-fae2c31244d6

Eurostat. (2023b, December 5). *Financial balance sheets—Annual data.* https://ec.europa.eu/eurostat/databrowser/view/nasa_10_f_bs__custom_8452439/default/table?lang=en

EWI. (2023). *Ausblick auf die Gasversorgung in der EU im kommenden Gaswirtschaftsjahr 2023/2024. Energiewirtschaftliche Institut an der Universität zu Köln.* https://www.ewi.uni-koeln.de/de/publikationen/ausblick-auf-die-gasversorgung-in-der-eu-im-kommenden-gaswirtschaftsjahr-2023-2024/

Fachrat Energieunabhängigkeit. (2023). *Fachkräftelücke im Gebäudesektor – Engpass für die Wärmewende.* https://fachrat-energieunabhängigkeit.de/wp-content/uploads/2023/07/Factsheet-Fachkraeftemangel-fuer-die-Waermewende-Fachrat-Energieunabhaengigkeit.pdf

Fernwärmegipfel. (2023). *Mehr Tempo bei der Transformation der Wärmeversorgung: Wärmenetze klimaneutral um- und ausbauen.* https://www.bmwk.de/Redaktion/DE/Downloads/Energie/0612-erklaerung-fernwaeme-gipfel.pdf?__blob=publicationFile&v=10

Fink, A. (2020, April 29). *Venture Capital in Germany: Nothing ventured, nothing gained.* IREF Europe. https://en.irefeurope.org/publications/online-articles/article/venture-capital-in-germany-nothing-ventured-nothing-gained/

Fitch Ratings. (2023, September 12). Australian LNG Strikes to Temporarily Affect European Gas Prices. *Fitch Wire.* https://www.fitchratings.com/research/corporate-finance/australian-lng-strikes-to-temporarily-affect-european-gas-prices-12-09-2023

Fleiter, T., Rehfeldt, M., Hirzel, S., Neusel, L., Aydemir, A., Schwotzer, C., Kaiser, F., Gondorf, C., Hauch, J., Hof, J., Sankowski, L., & Langhorst, M. (2023). *CO_2-neutrale Prozesswärmeerzeugung. Umbau des industriellen Anlagenparks im Rahmen der Energiewende: Ermittlung des aktuellen SdT und des weiteren Handlungsbedarfs zum Einsatz strombasierter Prozesswärmeanlagen.* Umweltbundesamt. https://www.umweltbundesamt.de/sites/default/files/medien/11850/publikationen/161_2023_texte_prozesswaermepumpen_0.pdf

Fleten, S.-E., Linnerud, K., Molnár, P., & Tandberg Nygaard, M. (2016). Green electricity investment timing in practice: Real options or net present value? *Energy, 116,* 498–506. https://doi.org/10.1016/j.energy.2016.09.114

Fraunhofer ISI. (2022). *Erstellung von Anwendungsbilanzen für die Jahre 2021 bis 2023 für die Sektoren Industrie und GHD.* Arbeitsgesmeinschaft Energiebilanzen e. V. https://ag-energiebilanzen.de/wp-content/uploads/2021/02/Anwendungsbilanz_Industrie_2021_final_20221222.pdf

Fraunhofer ISI, consentec, ifeu, & TU Berlin. (2022). *Langfristszenarien 3: Wissenschaftliche Analysen zur Dekarbonisierung Deutschlands.* Langfristszenarien. https://langfristszenarien.de/enertile-explorer-de/

GDW. (2013). *Nachhaltigkeitsberichterstattung in der Wohnungswirtschaft: Berichterstattung über wirtschaftliches, ökologisches und soziales Engagement von Wohnungsunternehmen* (GdW Arbeitshilfe 73). Bundesverband deutscher Wohnungs- und Immobilienunternehmen. https://www.gdw.de/uploads/pdf/publikationen/GdW_AH_73_voll.pdf

GDW. (2019). *Alternative Finanzierungsinstrumente in der Wohnungswirtschaft* (GdW Information 158). Bundesverband deutscher Wohnungs- und Immobilienunternehmen. https://www.gdw.de/downloads/publikationen/gdw-information-158-alternative-finanzierungsinstrumente-in-der-wohnungswirtschaft/

GDW. (2023). *Daten und Trends der Wohnungs- und Immobilienwirtschaft 2022/2023.* https://www.gdw.de/media/2023/07/praesentation_gdw-jahrespressekonferenz-2023.pdf

Gerhardt, N., Bard, J., Schmitz, R., Beil, M., Pfennig, M., & Kneiske, D. T. (2020). *Hydrogen in the energy system of the future: Focus on heat in buildings.* Fraunhofer IEE. https://www.iee.fraunhofer.de/content/dam/iee/energiesystemtechnik/en/documents/Studies-Reports/FraunhoferIEE_Study_H2_Heat_in_Buildings_final_EN_20200619.pdf

Gerrard, J., Zöllner, U., & Peters, M. (2023). *Rendite mit der Miete – Wie die Finanzmärkte die Wohnungskrise in Deutschland befeuern.* Finanzwende Recherche. https://www.finanzwende-recherche.de/wp-content/uploads/Immobilien_Report_20231107-1.pdf

Gibb, D., Rosenow, J., Lowes, R., & Hewitt, N. J. (2023). Coming in from the cold: Heat pump efficiency at low temperatures. *Joule, 7*(9), 1939–1942. https://doi.org/10.1016/j.joule.2023.08.005

Gigli, M. (2008). *Nachhaltiger Energiekonsum als Beitrag zum Klimaschutz: Erfolgsfaktoren und Barrieren der Realisierung von energetischen Sanierungen durch Eigenheimbesitzer* [Diplomarbeit, Universität Trier]. https://www.psycharchives.org/en/item/6faa12fe-817c-487d-865d-326e18ed4964

Giovannetti, F., Kastner, O., Lampe, C., Reinecke-Koch, R., Park, S., & Steinweg, J. (2018). *Technologiebericht 1.4 Solare Wärme und Kälte innerhalb des Forschungsprojekts TF_Energiewende.* Institut für Solarenergieforschung Hameln. https://epub.wupperinst.org/frontdoor/deliver/index/docId/7044/file/7044_Solare_Waerme_Kaelte.pdf

Graebner, C., & Hafele, J. (2020). *The emergence of core-periphery structures in the European Union: A complexity perspective* (ICAE Working Paper 113). Institute for Comprehensive Analysis of the Economy. https://econpapers.repec.org/paper/icowpaper/113.htm

Grashof, K. (2023). *Erneuerbare Energien und energetische Sanierung in Eigenheimen in Deutschland. Repräsentative Umfrage zum derzeitigen Status sowie zu Planungen, Motiven und Hemmnissen.* Zenodo. https://doi.org/10.5281/zenodo.8325018

Hamacher, K. (2023, January 13). *Wärmepumpe mieten statt kaufen: Für wen lohnt sich das?* Wohnglück.de. https://wohnglueck.de/artikel/waermepumpe-mieten

Hans Böckler Stiftung. (2012). Steuerhinterziehung kostet 100 Milliarden. *Magazin Mitbestimmung, 2012*(10). https://www.boeckler.de/de/magazin-mitbestimmung-2744-steuerhinterziehung-kostet-100-milliarden-5391.htm

Hauser, P. D., Münnich, P. J., Burmeister, H., Kohn, A., & Görlach, B. (2022). *Klimaschutzverträge für die Industrietransformation.* https://static.agora-energiewende.de/fileadmin/Projekte/2021/2021_10_DE_KIT/A-EW_249_Klimaschutzvertraege-Industrietransformation-Studie_WEB.pdf

Heidelberg Materials. (2023). *Climate Transition Plan.* https://www.heidelbergmaterials.com/sites/default/files/2023-07/07-2023_Heidelberg_Materials_Climate_Transition_Plan.pdf

Heidorn, H., & Weche, J. P. (2021). Business Concentration Data for Germany. *Jahrbücher Für Nationalökonomie Und Statistik, 241*(5–6), 801–811. https://doi.org/10.1515/jbnst-2020-0010

Henger, R., Braungardt, S., Karras, J., Köhler, B., & Reeh, G. (2023). *Schweden als Vorbild zur Überwindung des Vermieter-Mieter-Dilemmas – (Teil-)warmmieten oder Reform der Modernisierungsumlage?* (p. 75 pages, 1.3 MB). Potsdam Institute for Climate Impact Research. https://doi.org/10.48485/PIK.2023.027

Henger, R., Braungardt, S., Köhler, B., & Meyer, R. (2021). *Wer zahlt für den Klimaschutz im Gebäudesektor? Reformoptionen der Modernisierungsumlage.* Ariadne. https://ariadneprojekt.de/media/2021/07/Ariadne-Analyse_Modernisierungsumlage_August2021.pdf

Hoffmeister, T. (2022, July 15). Viessmann baut für 200 Millionen Euro Wärmepumpen-Standort in Polen. *HNA.* https://www.hna.de/lokales/frankenberg/allendorf-eder-ort317395/viessmann-baut-fuer-200-millionen-euro-waermepumpen-standort-in-polen-91667742.html

Hüncke, A., Plessing, J., & Ratzmann, N. (2022). *Kollaborative Klima-Governance in Marburg. Chancen und Hemmnisse auf dem Weg zur Klimaneutralität.* Institute for Advanced Sustainability Studies. https://publications.iass-potsdam.de/rest/items/item_6001520_2/component/file_6001521/content

Hüther, M., Bialek, S., Schaffranka, C., Schnitzer, M., Müller, S., Heymann, E., Maier, T., Falck, O., Flach, L., Pfaffl, C., & Schneider, C. (2023). Deindustrialisierung: Schreckgespenst oder notwendiger Schritt im Strukturwandel der deutschen Wirtschaft? *ifo Schnelldienst, 76*(3), 1–30.

IEA. (2022). *The Future of Heat Pumps.* International Energy Agency. https://doi.org/10.1787/2bd71107-en

IEA. (2023a). *The State of Clean Technology Manufacturing: An Energy Technology Perspectives Special Briefing.* International Energy Agency. https://iea.blob.core.windows.net/assets/32e7d448-4f0b-4ae8-85c4-d72924bf8a4f/TheStateofCleanTechnologyManufacturing.pdf

IEA. (2023b). *World Energy Outlook 2023.* International Energy Agency. https://www.iea.org/news/the-energy-world-is-set-to-change-significantly-by-2030-based-on-today-s-policy-settings-alone

IEA. (2023c). *Global EV Data Explorer.* International Energy Agency. https://www.iea.org/data-and-statistics/data-tools/global-ev-data-explorer

IEA PVPS. (2023). *Trends in photovoltaic applications 2023.* IEA Photovoltaic Power Systems Technology Collaboration Programme. https://iea-pvps.org/wp-content/uploads/2023/10/PVPS_Trends_Report_2023_WEB.pdf

IEEKN. (n. d.). *Die Netzwerkinitiative in Zahlen. Initiative Energieeffizienz- und Klimaschutz-Netzwerke.* Retrieved December 4, 2023, from https://www.effizienznetzwerke.org/

IFRS. (2023). *IFRS S1 General Requirements for Disclosure of Sustainability-related Financial Information.* https://www.ifrs.org/issued-standards/ifrs-sustainability-standards-navigator/ifrs-s1-general-requirements/#about

IMD. (2023). *IMD World Competitiveness Booklet 2023*. International Institute for Management Development. https://www.imd.org/wp-content/uploads/2023/06/WCY_Booklet_2023-FINAL.pdf

IN4climate.NRW. (2021). *Industriewärme klimaneutral: Strategien und Voraussetzungen für die Transformation (Diskussionspapier der Arbeitsgruppe Wärme).* https://www.energy4climate.nrw/fileadmin/Service/Publikationen/Ergebnisse_IN4climate.NRW/2021/diskussionspapier-klimaneutrale-waerme-industrie-cr-in4climatenrw.pdf

Ioannidis, M., Hlásková, S. J., & Zilioli, C. (2021). *The Mandate of the ECB: Legal Considerations in the Ecb's Monetary Policy Strategy Review* (Occasional Paper No. 2021276). European Central Bank. https://doi.org/10.2139/ssrn.3928298

IW Köln. (2017). *Perspektiven für private Kleinvermieter. Institut der deutschen Wirtschaft Köln.* https://www.iwkoeln.de/fileadmin/publikationen/2017/361123/Gutachten_Perspektiven_fuer_private_Kleinvermieter.pdf

Jenny, A., Mages, P., Bösch, L., & Artho, J. (2012). *Themenbereich Haushalte Praxisbeitrag Forschungsprojekt FP-1.3 Zusammmenfassung* (Forschungsprojekt FP-1.3 Zusammenfassung Bericht Nr. 03; p. 24). Energieforschung Stadt Zürich. https://energieforschung-zuerich.ch/media/topics/report/Zusammenfassung_Praxisbeitrag_FP-1.3.pdf

Jirmann, J. (2023). *Eckpunkte einer Reform der Erbschafts- und Schenkungsteuer.* Netzwerk Steuergerechtigkeit. https://www.netzwerk-steuergerechtigkeit.de/wp-content/uploads/2023/10/EUS_Reformvorschlag_Erbschaftsteuer.pdf

KAGB. (2023, December 11). *Kapitalanlagegesetzbuch vom 4. Juli 2013 (BGBl. I S. 1981), das zuletzt durch Artikel 29 des Gesetzes vom 11. Dezember 2023 (BGBl. 2023 I Nr. 354) geändert worden ist.* https://www.gesetze-im-internet.de/kagb/BJNR198110013.html

Kalkuhl, M., Amberg, M., Bergmann, T., Knopf, B., & Edenhofer, O. (2022). Gaspreisdeckel, Mehrwertsteuersenkung, Energiepauschale – Wie kann die Bevölkerung zielgenau und schnell entlastet werden? *Mercator Research Institute on Global Commons and Climate Change (MCC).*

Karnitschnig, M. (2021, July 26). Why Merkel chose Russia over US on Nord Stream 2. *POLITICO.* https://www.politico.eu/article/vladimir-putin-german-chancellors-nord-stream-russia-energy-angela-merkel/

KEI. (n.d.). *Über das KEI.* Kompetenzzentrum Klimaschutz in energieintensiven Industrien. Retrieved December 4, 2023, from https://www.klimaschutz-industrie.de/ueber-uns/ueber-das-kei/

KfW. (2023a). *KfW Research: Deutscher Mittelstand hat Energiepreisschwankungen bisher gut verkraftet | KfW* [Pressemitteilung]. Kreditanstalt für Wiederaufbau. https://www.kfw.de/Über-die-KfW/Newsroom/Aktuelles/Pressemitteilungen-Details_781184.html

KfW. (2023b). *KfW-Mittelstandspanel 2023. Belastungsfähigkeit des Mittel- stands wird auf die Probe gestellt: Bislang nur leichte Blessuren, aber erhöhte Anspannung ist spürbar.* Kreditanstalt für Wiederaufbau. https://www.kfw.de/PDF/Download-Center/Konzernthemen/Research/PDF-Dokumente-KfW-Mittelstandspanel/KfW-Mittelstandspanel-2023.pdf

KfW. (2023c). *Der individuelle Sanierungsfahrplan (iSFP) | KfW.* Kreditanstalt für Wiederaufbau. https://www.kfw.de/inlandsfoerderung/Privatpersonen/Bestehende-Immobilie/Energieeffizient-sanieren/Individueller-Sanierungsfahrplan/

KfW. (2023d). *KfW-Kommunalpanel 2023 | KfW.* https://www.kfw.de/Über-die-KfW/Newsroom/Aktuelles/News-Details_762624.html

KfW. (2023e, October 18). *Mittelstand ist der Motor der deutschen Wirtschaft* [KfW Research Dossier]. Kreditanstalt für Wiederaufbau. https://www.kfw.de/Über-die-KfW/KfW-Research/Mittelstand.html

Kilian, L. (2008). The Economic Effects of Energy Price Shocks. *Journal of Economic Literature, 46*(4), 871–909. https://doi.org/10.1257/jel.46.4.871

Klooster, J. van't, & van Tilburg, R. (2020). *Targeting a sustainable recovery with Green TLTROs* [Preprint]. Positive Money Europe & Sustainable Finance Lab. https://doi.org/10.31235/osf.io/2bx8h

KOFA. (2023, April 24). *Quereinsteiger zu Wärmepumpen-Spezialisten qualifizieren.* Kompetenzzentrum Fachkräftesicherung. https://www.kofa.de/mitarbeiter-finden/zielgruppen/praxisbeispiele-und-interviews/quereinstieg-zum-waermepumpen-spezialist/

Köhler, B., Bürger, V., & Bieser, J. (2023). *Preise und Preistransparenz als Akzeptanzfaktor in der Fernwärme.* Umweltbundesamt. https://www.umweltbundesamt.de/sites/default/files/medien/11850/publikationen/factsheet_kurzanalyse_fw_preistransparenz_10_2023.pdf

Krebs, T. (2023a). Modern climate policy: Moving beyond the market-liberal paradigm. *Forum New Economy Working Papers, 1.* https://newforum.org/wp-content/uploads/2023/01/FNE-WP01-2023.pdf

Krebs, T. (2023b). *Zeitenwende: Wie wir unsere Wirtschaft und das Klima retten* [FES Diskurs]. Friedrich Ebert Stiftung. https://library.fes.de/pdf-files/a-p-b/20716.pdf

Krusell, P., & Smith, A. (2022). *Climate Change Around the World* (w30338; p. w30338). National Bureau of Economic Research. https://doi.org/10.3386/w30338

KWW. (2023). *Kompetenzzentrum Kommunale Wärmewende.* KWW. https://www.kww-halle.de

Löffler, K. U., Petreski, A., & Stephan, A. (2021). Drivers of green bond issuance and new evidence on the „greenium." *Eurasian Economic Review, 11(*1), 1–24. https://doi.org/10.1007/s40822-020-00165-y

Lohse, M. (2006). *Die wirtschaftliche Situation deutscher Wohnungsunternehmen – eine empirische Untersuchung* (Arbeitspapiere zur immobilienwirtschaftlichen Forschung und Praxis, No. 7). TU Darmstadt, Forschungscenter Betriebliche Immobilienwirtschaft. https://www.econstor.eu/bitstream/10419/85310/1/arbeitspapier_7.pdf

Lorek, S., Gran, C., Barth, J., Lavorel, C., Tomany, S., & Oswald, Y. (2021). *Equitable 1.5-Degree Lifestyles – How socially fair policies can support the implementation of the European Green Deal* (Policy Brief #1). ZOE-Institute for future-fit economies. https://zoe-institut.de/wp-content/uploads/2023/09/ZOE_1-5-Degree_Policy_Equitable_Lifestyles_WEB_211221_2.pdf

Luderer, G., Bartels, F., Blesl, M., Burkhardt, A., Edenhofer, O., Fahl, U., Gillich, A., Herbst, A., Hufendiek, K., Kaiser, M., Kittel, L., Koller, F., Kost, C., Pietzcker, R., Rehfeldt, M., Schreyer, F., Seibert, D., & Sievers, L. (2022). Deutschland auf dem Weg aus der Gaskrise: Wie sich Klimaschutz und Energiesouveränität vereinen lassen. *Kopernikus-Projekt Ariadne Potsdam-Institut Für Klimafolgenforschung (PIK).*

Luderer, G., Kost, C., & Sörgel, D. (2021). *Deutschland auf dem Weg zur Klimaneutralität 2045—Szenarien und Pfade im Modellvergleich.* Ariadne. https://ariadneprojekt.de/publikation/deutschland-auf-dem-weg-zur-klimaneutralitat-2045-szenarienreport/

Lyons, L., Lecomte, E., Georgakaki, A., Letout, S., & Mountraki, A. (2023). *Clean Energy Technology Observatory: Heat pumps in the European Union - 2023 Status Report on Technology Development, Trends, Value Chains and Markets* (EUR 31699 EN). EU Joint Research Centre. https://doi.org/10.2760/69478

Malin, L., & Köppen, R. (2023). *Fachkräftemangel und Ausbildung im Handwerk* (KOFA Kompakt 5/2023). Institut der deutschen Wirtschaft Köln. https://www.iwkoeln.de/studien/lydia-malin-fachkraeftemangel-und-ausbildung-im-handwerk.html

McCauley, D. (2018). *Energy Justice: Re-Balancing the Trilemma of Security, Poverty and Climate Change.* Springer International Publishing. https://doi.org/10.1007/978-3-319-62494-5

McKinsey. (2008). *The carbon productivity challenge: Curbing climate change and sustaining economic growth.* McKinsey Global Institute. https://www.mckinsey.com/capabilities/sustainability/our-insights/the-carbon-productivity-challenge

Meemken, S., Peiseler, F., Runkel, M., Zerzawy, F., Limbers, J., & auf der Maur, A. (2023). *Reform umweltschädlicher Subventionen: Auswirkungen auf Klima, Gesellschaft und Wirtschaft. Bertelsmann Stiftung.* https://www.bertelsmann-stiftung.de/fileadmin/files/user_upload/W_Reform_umweltschaedlicher_Subventionen.pdf

Merten, F., & Scholz, A. (2023). *Metaanalyse zu Wasserstoffkosten und -bedarfen für die CO_2-neutrale Transformation.* Wuppertal Institut. https://epub.wupperinst.org/frontdoor/deliver/index/docId/8344/file/8344_Wasserstoffkosten.pdf

Mischler, T. (2017). *Die Attraktivität von Ausbildungsberufen im Handwerk. Eine empirische Studie zur beruflichen Orientierung von Jugendlichen.* Bundesinstitut für Berufsbildung. https://www.bibb.de/dienst/publikationen/de/8551

Monopolkommission (Ed.). (2022). Kapitel I: Stand und Entwicklung der Unternehmenskonzentration in Deutschland. *In Hauptgutachten. Wettbewerb 2022* (pp. 5–97). Nomos Verlagsgesellschaft. https://doi.org/10.5771/9783748938330-5

Nordhaus, W. D. (1993). Rolling the 'DICE': An optimal transition path for controlling greenhouse gases. *Resource and Energy Economics, 15*(1), 27–50. https://doi.org/10.1016/0928-7655(93)90017-O

OBR. (2023). *Fiscal risks and sustainability: July 2023* (CP 870). Office for Budget Responsibility. https://obr.uk/docs/dlm_uploads/Fiscal_risks_and_sustainability_report_July_2023.pdf

OEC. (2021). *Country Rankings.* The Observatory of Economic Complexity. https://oec.world/en/rankings/eci/hs6/hs96?tab=ranking

OGJ. (2022, January). *Oil, gas investments to hit $628 billion in 2022 led by upstream gas and LNG.* Oil & Gas Journal. https://www.ogj.com/general-interest/economics-markets/article/14223445/oil-and-gas-investments-to-hit-628-billion-in-2022-led-by-upstream-gas-and-lng

OICA. (2022). *OICA production statistics.* International Organization of Motor Vehicle Manufacturers. https://www.oica.net/production-statistics/

Öko-Institut. (2023). *Abschätzung der Minderungswirkung der 65%-Anforderung im GEG-Entwurf.* https://www.oeko.de/publikation/abschaetzung-der-minderungswirkung-der-65-anforderung-im-geg-entwurf

Öko-Institut, dena, ITG Dresden, Stiftung Umweltenergierecht, & ifeu. (2023). *Heizen mit 65 % erneuerbaren Energien – Begleitende Analysen zur Ausgestaltung der Regelung aus dem Koalitionsvertrag 2021*. https://www.bmwk.de/Redaktion/DE/Downloads/Energie/heizen-mit-65-prozent-erneuerbaren-energien.pdf?__blob=publicationFile&v=8

Ortner, D. S., Pehnt, D. M., Over, M., & Blömer, S. (2023). *Dekarbonisierung der Energieinfrastrukturen—Ein politischer Unterstützungsrahmen für das Beispiel Wärmenetze.* Umweltbundesamt. https://www.umweltbundesamt.de/sites/default/files/medien/479/publikationen/cc_08-2023_dekarbonisierung_von_energieinfrastrukturen.pdf

Ortner, S., & Pehnt, M. (2022). *Drittzugang bei Wärmenetzen* (Climate Change 32/2022). Umweltbundesamt. https://www.umweltbundesamt.de/sites/default/files/medien/479/publikationen/cc_32-2022_drittzugang_bei_waermenetzen_0.pdf

Pahle, M., Günther, C., Osorio, S., & Quemin, S. (2023). *The Emerging Endgame: The EU ETS on the Road Towards Climate Neutrality* (SSRN Scholarly Paper 4373443). https://doi.org/10.2139/ssrn.4373443

Pahle, M., Sitarz, J., Osorio, S., & Görlach, B. (2022). *The EU-ETS price through 2030 and beyond: A closer look at drivers, models and assumptions.* Ariadne. https://ariadneprojekt.de/media/2023/01/Ariadne-Documentation_ETSWorkshopBruessel_December2022.pdf

Pallara, K., Rossi, L., Sfregola, M., & Venditti, F. (2023, August 14). The impact of energy shocks on core inflation in the US and the euro area. *CEPR VoxEU.* https://cepr.org/voxeu/columns/impact-energy-shocks-core-inflation-us-and-euro-area

Pehnt, M., Blömer, S., Nast, M., Paar, Angelika, Klotz, E.-M., Rau, D., Wünsch, M., Kahles, M., Jacobshagen, U., Maiworm, C., Kaspers, J., Miljes, R., Vorhoff, S. V., Beshah, D., Richter, S., Ochse, S., Schmelcher, S., & Müller, M. (2020). *Wissenschaftliche Unterstützungsleistung und Wirkungsabschätzung für ein Basisförderprogramm zur Transformation von Wärmenetzen—Endbericht, Vorfassung.* BMWi. https://www.ifeu.de/fileadmin/uploads/Publikationen/Energie/Wirkungsabsch%C3%A4tzung_W%C3%A4rmenetze_Endbericht_V10.pdf

Pehnt, M., Mellwig, P., Lambrecht, K., Wieniwska, B., Oschatz, B., Mailach, B., Keimeyer, F., Braungardt, S., Köhler, B., & Kahl, H. (2023). *Heizen mit 65 % erneuerbaren Energien – Begleitende Analysen zur Ausgestaltung der Regelung aus dem Koalitionsvertrag 2021* [Teilbericht im Rahmen des Projektes „Gebäudeenergiegesetz und EPBD"]. https://www.bmwk.de/Redaktion/DE/Downloads/Energie/heizen-mit-65-prozent-erneuerbaren-energien.pdf?__blob=publicationFile&v=8

Pietzcker, R., Feuerhahn, J., Haywood, L., Knopf, B., Leukhardt, F., Luderer, G., Osorio, S., Pahle, M., Rodrigues, R., & Edenhofer, O. (2021). *Notwendige CO_2-Preise zum Erreichen des europäischen Klimaziels 2030.* Ariadne. https://doi.org/10.48485/pik.2021.007

Pindyck, R. S., & Rubinfeld, D. L. (2012). *Microeconomics* (8. ed). Pearson.

Platform on Sustainable Finance. (2022, January 24). *Response to the Complementary Delegated Act.* https://www.politico.eu/wp-content/uploads/2022/01/24/Platform-draft-CDA-response_embargoed-until-10am-CET-24th-Jan.pdf

Prognos, FIW München, ITG Dresden, ifeu, Öko-Institut, adelphi, BBH, dena, & EY Law. (2022). *Hintergrundpapier zur Gebäudestrategie Klimaneutralität 2045* (p. 253) [Gutachten im Auftrag des Bundesministeriums für Wirtschaft und Klimaschutz]. https://www.bmwk.de/Redaktion/DE/Publikationen/Klimaschutz/gebaeudestrategie-klimaneutralitaet-2045.pdf?__blob=publicationFile&v=6

PwC. (2023a). *Der Wärmepumpenhochlauf nach der Heizungsdebatte. Aktuelle Herausforderungen für die deutsche Heizungsindustrie im globalen Wettbewerb* (p. 64) [Studie]. Bundesverband Wärmepumpe (BWP). https://www.pwc.de/de/energiewirtschaft/pwc-studie-2023-waermepumpenhochlauf-nach-der-heizungsdebatte.pdf

PwC. (2023b). *EU-Taxonomie 2023: Kennzahlen für das Geschäftsjahr wenig aussagekräftig.* PricewaterhouseCoopers. https://www.pwc.de/de/im-fokus/accounting-reporting/eu-taxonomie.html

Rickels, W., Rischer, C., Schenuit, F., & Peterson, S. (2023). *Potential efficiency gains from the introduction of an emissions trading system for the buildings and road transport sectors in the European Union* (Kiel Working Papers 2249). Kiel Institute for the World Economy. https://www.ifw-kiel.de/fileadmin/Dateiverwaltung/IfW-Publications/fis-import/200f22d3-1461-4366-ab70-c1a83fd7dd7f-KWP_2249.pdf

Römer, Dr. D., & Salzgeber, Dr. J. (2023). *KfW-Energiewendebarometer 2023: Energiewende im Spannungsfeld zwischen Handlungsbedarfen und finanziellen Möglichkeiten* (KfW-Energiewendebarometer) [KfW Research]. Kreditanstalt für Wiederaufbau. https://www.kfw.de/PDF/Download-Center/Konzernthemen/Research/PDF-Dokumente-KfW-Energiewendebarometer/KfW-Energiewendebarometer-2023.pdf

Sachverständigenrat. (2019). *Setting out for a new climate policy.* [Special Report 2019 by the German Council of Economic Experts.]. https://www.sachverstaendigenrat-wirtschaft.de/en/special-report-2019.html

Sachverständigenrat. (2023). *Wachstumsschwäche überwinden – In die Zukunft investieren (Jahresgutachten 23/24).* Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung. https://www.sachverstaendigenrat-wirtschaft.de/fileadmin/dateiablage/gutachten/jg202324/JG202324_Gesamtausgabe.pdf

Saez, E., & Zucman, G. (2022). Wealth Taxation: Lessons from History and Recent Developments. *AEA Papers and Proceedings, 112,* 58–62. https://doi.org/10.1257/pandp.20221055

Samadi, S. (2022). *Quantitativer Vergleich aktueller Klimaschutzszenarien für Deutschland.* SCI4climate.NRW. https://www.energy4climate.nrw/fileadmin/Service/Publikationen/Ergebnisse_SCI4climate.NRW/Szenarien/2022/Samadi-2022-Vergleich_aktueller_Klimaschutzszenari_en_fu__r_Deutschland__final_-_Korrektur_Dez._2022.pdf

SASB. (2023). *Future of the SASB Standards: What you need to know for 2023 disclosure.* SASB Blog. https://sasb.org/blog/future-of-the-sasb-standards-what-you-need-to-know-for-2023-reporting/

Savills. (2019). *Eigentümerstruktur am deutschen Wohnungsmarkt.* https://pdf.euro.savills.co.uk/germany-research/ger-2019/spotlight-eigentumerstruktur-am-wohnungsmarkt.pdf

Schäfers, M. (2023, July 6). *Wegfall des Spitzenausgleichs: Unternehmen drohen hohe Energiekosten. FAZ.NET.* https://www.faz.net/aktuell/wirtschaft/wegfall-des-spitzenausgleichs-unternehmen-drohen-hohe-energiekosten-19015398.html

Schmidt, T. S., Steffen, B., Egli, F., Pahle, M., Tietjen, O., & Edenhofer, O. (2019). Adverse effects of rising interest rates on sustainable energy transitions. *Nature Sustainability, 2*(9), 879–885. https://doi.org/10.1038/s41893-019-0375-2

Schrems, I., & Eulgem, L. (2022). *Die Rolle des Erdgasgeschäfts von Stadtwerken für die kommunale Daseinsvorsoge – Eine Fallstudienanalyse* (Analyse 11/2022). Forum Ökologisch-Soziale Marktwirtschaft. https://foes.de/publikationen/2022/2022-11_FOES_Stadtwerke_Analyse.pdf

Schumacher, K., Nissen, C., & Braungardt, S. (2022). *Energetische Sanierung schützt Verbraucher*innen vor hohen Energiepreisen – Vorschläge für eine soziale Ausrichtung der Förderung.* Öko-Institut. https://www.oeko.de/fileadmin/oekodoc/Kurzstudie-Sanierung-Ein--und-Zweifamilienhaeuser.pdf

Schwartz, D. M., & Leifels, D. A. (2022). ***Geschäftsaufgaben im Mittelstand: Nachfolgermangel, Rentenalter und geringe wirtschaftliche Attraktivität entscheidend*** (KfW Research No. 393). Kreditanstalt für Wiederaufbau. https://www.kfw.de/PDF/Download-Center/Konzernthemen/Research/PDF-Dokumente-Fokus-Volkswirtschaft/Fokus-2022/Fokus-Nr.-393-Juli-2022-Geschaeftsaufgaben.pdf

Seefeldt, F., Stein, K., Sahnoun, M., Thome, S., & Dominkovic, S. (2021). ***Evaluation der Wärmelieferverordnung—Wirksamkeit der im Jahr 2013 eingeführten Regelungen zur Umstellung auf gewerbliche Wärmelieferung für Mietwohnraum.*** KEA-BW & Prognos. https://www.bmj.de/SharedDocs/Downloads/DE/Fachpublikationen/Evaluierung_WaermelieferVO.pdf?__blob=publicationFile&v=4

SMS group. (2021, October 29). ***Midrex Direct reduction plants: Clean and reliable solutions for direct reduced iron.*** https://www.sms-group.com/de-de/plants/midrex-direct-reduction-plants

Sokolowski, A., Boldyreva, T., Jenkins-Long, E., Bamkole, S., & Twigg, S. (2023). ***Are Companies Developing Credible Climate Transition Plans? Disclosure to key climate transition-focused indicators in CDP's 2022 Climate Change Questionnaire.*** Carbon Disclosure Project. https://cdn.cdp.net/cdp-production/cms/reports/documents/000/006/785/original/Climate_transition_plan_report_2022_%2810%29.pdf?1676456406#:~:text=only%2081%20(0.4%25)%20of,a%20credible%20plan%20in%20place

Statista. (2022). ***Erdgas: Durchschnittspreis in Europa bis 2022.*** Statista. https://de.statista.com/statistik/daten/studie/1282641/umfrage/durchschnittlicher-preis-fuer-erdgas-in-europa/

Statista. (2023a). ***Inflation in Deutschland bis November 2023.*** Statista. https://de.statista.com/statistik/daten/studie/1045/umfrage/inflationsrate-in-deutschland-veraenderung-des-verbraucherpreisindexes-zum-vorjahresmonat/

Statista. (2023b). ***Wind energy capacity worldwide 1998-2022.*** Statista. https://www.statista.com/statistics/268385/global-new-installed-wind-power-capacity/

Stiebel Eltron. (2023). ***Neuer Gruppen-Geschäftsführer für Vertrieb und Marketing*** [Pressemitteilung]. https://www.stiebel-eltron.ch/de/home/unternehmen/presse/pressemitteilungen/230817_geschftsfuehrung.html

Stieß, I., van der Land, V., Birzle-Harder, B., & Deffner, J. (2010). ***Handlungsmotive,-hemmnisse und Zielgruppen für eine energetische Gebäudesanierung. Ergebnisse einer standardisierten Befragung von Eigenheimsanierern.*** ENEF Haus. https://www.forum-hausbau.de/data/Energieeffiziente-Sanierung-von-Eigenheimen.pdf

Süddeutsche Zeitung. (2023, January 31). Vonovia stoppt Neubau-Projekte. ***Süddeutsche.de.*** https://www.sueddeutsche.de/wirtschaft/vonovia-neubau-wohnungsmangel-immobilien-1.5742513

Tacke, B., Böhm, U., Dunkelberg, E., Möller, S., Meyer, K., & Knies, J. (2019). ***Bericht zum Erfahrungsaustausch „Energiewende im Kontext der Gesellschaft- Partizipation und Akzeptanz bei innovativen Bauprojekten"*** [Tagungsbericht]. Sustainability Freie Universität Berlin. https://www.lokale-passung.de/wp-content/uploads/2020/01/Tagungsbericht-Partizipation-und-Akzeptanz-bei-innovativen-Bauprojekten.pdf

Tagesschau. (2023, July 16). Weniger Förderung für Wärmepumpen in diesem Jahr beantragt. ***tagesschau.de.*** https://www.tagesschau.de/wirtschaft/waermepumpen-foerderung-100.html

TGM Research. (2023). ***Globale Tracker-Abfrage zu Einstellungen zu Klima und Energie mit national repräsentativen Stichproben (n=1000) (in Veröffentlichung)*** [Umfrage]. Global Strategic Communications Council.

Theurl, T. (2023). Wohnungsgenossenschaften in herausfordernden Zeiten. ***Wirtschaftsdienst, 103***(1), 12–15.

Thiemann, A., Ognyanova, D., Narazani, E., Palvolgyi, B., Kalyva, A., & Leodolter, A. (2021). ***Shifting the Tax Burden away from Labour towards Inheritances and Gifts – Simulation results for Germany.*** https://joint-research-centre.ec.europa.eu/system/files/2022-01/jrc127424.pdf

Thöne, M., Gierkink, M., Pickert, L., Kreuter, H., & Decker, H. (2019). ***CO_2-Bepreisung im Gebäudesektor und notwendige Zusatzinstrumente*** [Im Auftrag des Zentralen Immobilien Ausschusses (ZIA)]. Energiewirtschaftliches Institut an der Universität zu Köln (EWI) & Finanzwissenschaftliches Forschungsinstitut an der Universität zu Köln (FiFo Köln). https://www.ewi.uni-koeln.de/cms/wp-content/uploads/2019/09/EWI_FiFo_Studie_CO2-Bepreisung-im-Geb%C3%A4udesektor_190918.pdf

thyssenkrupp. (2023). ***thyssenkrupp Steel vergibt Milliardenauftrag für Direktreduktionsanlage an SMS group: Start eines der weltweit größten industriellen Dekarbonisierungsprojekte.*** https://www.thyssenkrupp.com/de/newsroom/pressemeldungen/pressedetailseite/thyssenkrupp-steel-vergibt-milliardenauftrag-fur-direktreduktionsanlage-an-sms-group--start-eines-der-weltweit-grossten-industriellen-dekarbonisierungsprojekte-163183

Toleikyte, A., Roca, R. J. C., Volt, J., Carlsson, J., Lyons, L., Gasparella, A., Koolen, D., De, F. M., Tarvydas, D., Czako, V., Koukoufikis, G., Kuokkanen, A., & Letout, S. (2023). ***The Heat Pump Wave: Opportunities and Challenges.*** EU Joint Research Centre. https://doi.org/10.2760/27877

UCLA IoES. (2020). ***Impacts of Oil and Gas Drilling on Indigenous Communities in New Mexico's Greater Chaco Landscape.*** UCLA Institute of the Environment and Sustainability. https://www.ioes.ucla.edu/wp-content/uploads/2020/09/ucla-ioes-practicum-impacts-of-oil-and-gas-on-indigenous-communities-in-new-mexico-final-report-9-2020.pdf

Uhlenbroich, B. (2023, November 11). Bauunternehmer sprechen Krisen-Klartext: 300 000 Jobs sind in 2 Jahren weg! ***BILD.De.*** https://www.bild.de/politik/inland/politik-inland/bauunternehmer-sprechen-krisen-klartext-300-000-jobs-sind-in-2-jahren-weg-86054954.bild.html?t_ref=https%3A%2F%2Fstatics.teams.cdn.office.net%2F

Umweltbundesamt. (2023). ***Projektionsbericht 2023 für Deutschland.*** https://www.umweltbundesamt.de/publikationen/projektionsbericht-2023-fuer-deutschland

Umweltbundesamt. (2013, September 9). ***Umweltschädliche Subventionen in Deutschland*** [Text]. Umweltbundesamt. https://www.umweltbundesamt.de/daten/umwelt-wirtschaft/umweltschaedliche-subventionen-in-deutschland

UNEP. (2008). ***Public finance mechanisms to mobilise investment in climate change mitigation.*** United Nations Environment Programme. https://wedocs.unep.org/handle/20.500.11822/7973

Vaillant Group. (2023). ***Vaillant Group investiert bis zu 2 Milliarden Euro in den Ausbau des Wärmepumpengeschäfts*** [Pressemitteilung]. https://www.vaillant-group.com/news-storys/vaillant-group-investiert-bis-zu-2-milliarden-euro-in-den-ausbau-des-waermepumpengeschaefts.html

vbw. (2023). ***Monitoring der deutschen Gasbilanz. Vereinigung der Bayerischen Wirtschaft.*** https://www.vbw-bayern.de/Redaktion/Frei-zugaengliche-Medien/Abteilungen-GS/Wirtschaftspolitik/2023/Downloads/vbw_Studie-Monitoring-der-deutschen-Gasbilanz_Mai-2023.pdf

VCI. (2023). ***Energiestatistik 2023.*** Verband der chemischen Industrie. https://www.vci.de/ergaenzende-downloads/energiestatistik-2023-16.pdf

Verbraucherzentrale. (2022, June 22). ***Energie-Contracting: Was Sie beim Vertragsabschluss beachten sollten.*** Verbraucherzentrale.de. https://www.verbraucherzentrale.de/wissen/energie/energetische-sanierung/energiecontracting-was-sie-beim-vertragsabschluss-beachten-sollten-10911

Verbraucherzentrale. (2023). *Ihre Energieberatung der Verbraucherzentrale.* Energieberatung der Verbraucherzentrale. https://verbraucherzentrale-energieberatung.de/

Viessmann. (2022). *Viessmann Group plant 1 Milliarde Euro in Wärmepumpen und grüne Klimalösungen zu investieren* [Pressemitteilung]. https://www.viessmann.family/de/newsroom/unternehmen/viessmann-group-plant-1-milliarde-euro-in-waermepumpen-und-gruene-klimaloesungen-zu-investieren.html

VKU. (2023). *Stellungnahme zum Regierungsentwurf zur Änderung des Gebäudeenergiegesetzes und zur Änderung der Heizkostenverordnung sowie zur Änderung der Kehr- und Überprüfungsordnung vom 19. April 2023: VKU.* Verband kommunaler Unternehmen. https://www.vku.de/vku-positionen/kommunale-energieversorgung/stellungnahme-zum-regierungsentwurf-zur-aenderung-des-gebaeudeenergiegesetzes-und-zur-aenderung-der-heizkostenverordnung-sowie-zur-aenderung-der-kehr-und-ueberpruefungsordnung-vom-19-april-2023/

Whitehouse, S., Lacy, P., Veillard, X., Keeble, J., & Richardson, S. (2020). *Carbon Capital: Financing the low carbon economy.* Barclays Group. https://www.compromisorse.com/upload/estudios/000/108/CarbonCapital.pdf

Wietschel, M., Eckstein, J., Riemer, M., Zheng, L., Lux, B., Neuner, F., Breitschopf, B., Fragoso, J., Kleinschmitt, C., Pieton, N., Nolden, C., Pfluger, B., Thiel, Z., & Löschel, A. (2021). *Import von Wasserstoff und Wasserstoffderivaten: Von Kosten zu Preisen* (HYPAT Working Paper 01/2021). Fraunhofer ISI. https://publica-rest.fraunhofer.de/server/api/core/bitstreams/7d880f55-93b4-461b-9088-99b7f228b69b/content

WPKS. (2023). *LNG-Bedarf für die deutsche Energieversorgung im Prozess des Übergangs zur Klimaneutralität.* Wissenschaftsplattform Klimaschutz. https://www.wissenschaftsplattform-klimaschutz.de/files/WPKS-Studie-LNG-Bedarfe.pdf

ZDH. (2023a). *Die Wärmewende braucht ein starkes Handwerk* [Pressemitteilung]. Zentralverband des Deutschen Handwerks. https://www.zdh.de/presse/veroeffentlichungen/interviews-und-statements/die-waermewende-braucht-ein-starkes-handwerk/

ZDH. (2023b). *Klimahandwerk – Klimaschutz als Beruf.* Zentralverband des Deutschen Handwerks. https://www.zdh.de/themen-und-positionen/klimahandwerk/

Zerzawy, F., Beermann, A.-C., Fiedler, S., & Runkel, M. (2021). *Umweltschädliche Subventionen in Deutschland: Fokus Biodiversität.* Forum Ökologisch-Soziale Marktwirtschaft & Deutscher Naturschutzring. https://www.dnr.de/sites/default/files/Publikationen/2021-05-11_FOES-Subventionen_Biodiversitaet.pdf

Zukunft Gas. (2022a). *Erdgas in Deutschland: Zahlen und Fakten für das Jahr 2021.* https://gas.info/fileadmin/Public/PDF-Download/Faktenblatt-Erdgas.pdf

Zukunft Gas. (2022b). *Dekarbonisierungspartner der Industrie.* https://gas.info/gas-im-energiemix/industrie

ZVEH. (2022). *Erfolgreiche Klimawende braucht leistungsfähiges Handwerk* [Pressemitteilung]. Zentralverband der Deutschen Elektro- und Informationstechnischen Handwerke. https://www.zveh.de/news/detailansicht/erfolgreiche-klimawende-braucht-leistungsfaehiges-handwerk.html

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