Federal Ministry
for Economic Affairs
and Climate Action

中德能源与能效合作
Energiepartnerschaft
DEUTSCHLAND - CHINA

Germany's Regulatory Framework and Instruments for Energy Efficiency in Industry

Sino-German Energy Transition Project

dena
German Energy Agency

giz Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

Imprint

The report “Energy Efficiency Policy in Germany” introduces the importance of energy efficiency in the frame of climate neutrality and the best practice measures and policies for energy efficiency in Germany. The report is published by GIZ in the framework of the Sino-German Energy Transition Project. The project supports the exchange between Chinese government think tanks and German research institutions to strengthen the Sino-German scientific exchange on the energy transition and share German energy transition experiences with a Chinese audience. The project aims to promote a low-carbon-oriented energy policy and help to build a more effective, low-carbon energy system in China through international cooperation, policy research and modelling for mutual benefit. The project is supported by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) in the framework of the Sino-German Energy Partnership, the central platform for energy policy dialogue between Germany and China on a national level. From the Chinese side, the National Energy Administration (NEA) supports the overall steering. The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH leads the project implementation in cooperation with the German Energy Agency (dena) and Agora Energiewende.

Published by

Sino-German Energy Partnership
commissioned by the German Federal Ministry for Economic Affairs and Climate Action (BMWK)
Tayuan Diplomatic Office Building 1-15, 14 Liangmahe South Street, Chaoyang District
100600 Beijing, P. R. China

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Contents

1 Executive Summary

1. Energy efficiency is included in the German and European legal framework as an important measure to secure the energy supply and economic competitiveness. In addition, the legal framework defines energy efficiency as an important part of achieving climate protection targets by reducing absolute energy consumption.

2. National and European laws link energy efficiency targets to primary and final energy consumption to guarantee an absolute reduction in consumption.

In Germany, the primary energy demand must be reduced by 40% by 2030 and 50% by 2050 compared to 1990. The EU's current efficiency targets envision a reduction of 13% compared to 2020, which corresponds to a reduction in primary energy consumption of just over 40% compared to 2007.

3. So far, laws regarding energy efficiency are limited mostly to buildings. An energy efficiency law is currently in the legislative process.

Energy efficiency in Germany is mainly regulated by law through the specification of reduction targets for primary energy consumption in buildings. The reduction targets only apply to new buildings and have led to a considerable reduction in the heat demand for new buildings (1970: > 200 kWh/m²a; 2016: 40 kWh/m²a). Furthermore, a law obliges large companies to carry out energy audits. In addition, companies are subsidised through the free distribution of certificates in the emission trading system if their plants are among the best 10% in Europe regarding energy efficiency. An Energy Efficiency Law is planned for Germany to combine and further expand the legal regulation of energy efficiency. This law will combine some of the measures mentioned above, formulating more ambitious targets for primary and final energy consumption and including new aspects such as the promotion of waste heat.

4. The existing measures mainly focus on identifying efficiency potentials and exploiting them in combination with promoting the continual improvement of the energy efficiency of products and plants via the push and pull principle.

In the EU, energy efficiency is steadily promoted by banning particularly inefficient products and labelling particularly efficient products. As a result, companies have access to increasingly efficient products. In order to exploit these new efficiency potentials as well as to provide information on previously unused potentials, large companies must perform energy audits. During energy audits, potential energy-saving measures are identified with the help of an expert and are then developed, taking costs into account. Companies can also use energy management systems to integrate the identification of potential, the development of strategies and the implementation of measures in their company. This process is standardised in ISO 50001. In addition to measures limited to one company, energy efficiency networks are promoted in Germany. In these networks, a group of companies exchange ideas, experiences and efficiency measures to achieve a specific reduction target together.

5. The use of waste heat offers great potential for energy efficiency but has yet to be fully exploited for various reasons. A legal framework for targeted promotion is not in place in Germany.

From analyses, it is known that there is a waste heat potential in Germany for the temperature range above 140°C, corresponding to 12% of industrial demand. For this reason, there is great interest in promoting the use of waste heat, which poses a challenge: waste heat is often synonymous with energy loss that can be reduced by efficiency measures. In addition, information on waste heat potential in Germany is not sufficient. For this reason, waste heat atlases identifying waste heat sources in an industrial complex, region or country have been compiled for several years. Nevertheless, there is an additional hurdle: a detailed estimation is only possible through an insight analysis of a company. Especially in China, there is potential to integrate waste heat into the district heating network.

2 Introduction

Energy efficiency is an important part of achieving climate protection targets in Germany. As energy efficiency is part of a set of measures, this chapter defines and classifies energy efficiency.

2.1 Definition of energy efficiency

Definition of energy efficiency

"Energy efficiency generally describes the ratio of a certain benefit – for example, the provision of light or heat – to its energy input. The less energy that has to be used, the more energy-efficient a product or service is" (Umweltbundesamt, 2013).

Example: A LED replaces a conventional light bulb; both produce light, but the LED consumes considerably less electricity. The difference in electricity consumption is called the savings potential.

In the context of climate protection and an energy transition that focuses on reducing energy demand, the focus cannot remain on energy efficiency alone. Instead, it must be on reducing the absolute energy demand. For this reason, efficiency targets are often linked to primary and secondary energy consumption. Furthermore, material efficiency should be considered in the context of climate protection. In line with the definition above, material loss is related to material input. A higher material efficiency leads not only to energy savings (depending on the product) but also to a reduction of negative environmental impacts (pollutants, etc.).

Energy efficiency plays an important role in industry as many cross-sectoral technologies such as pumps, motors and others have the potential to decrease final energy consumption [1] by being more efficient. New technologies (e.g. high temperature heat pumps) and the use of waste heat can lead to increased efficiency regarding primary energy consumption [2] (Umweltbundesamt, 2021).

The aim of energy efficiency is to reduce energy consumption, both primary and final, reduce costs, increase the competitiveness of companies and strengthen innovation. Furthermore, energy efficiency should help to achieve the goal of greenhouse gas neutrality by reducing energy demand.

Energy efficiency can be increased by optimising operations, replacing components, introducing new processes or avoiding and using waste heat.

Waste heat usage

Most thermal processes in industry generate some level of waste heat. Where this waste heat cannot be avoided, e.g. through better insulation, it can be re-used within the same plant, used externally (e.g. in other plants for lower temperature processes or in district heating networks) or in some cases converted to electricity. The benefits of using waste heat are reduced energy demand and costs, reduced environmental impact, reduced dependence on external supply, as well as lower expenses for heating and re-cooling. Potential drawbacks include additional expenses and complexity for procurement, maintenance and operation, including possible legal requirements such as approvals and verifications. Furthermore, the use of waste heat might also require reserve infrastructure in case of waste heat network part failure or divergent usage times.

Other hurdles, such as long payback periods or a lack of prioritisation, slow down the implementation of energy efficiency.

Efficiency gains lead to energy savings and often to emission savings and are often economically beneficial. At the same time, the implementation of most energy

[1] Definition of final energy consumption: Final energy refers to forms of energy that have already been converted from primary energy sources into other forms of energy through conversion steps. The end consumer does not yet use the energy. This includes, for example, electricity, district heating or petrochemicals.

[2] Definition of primary energy consumption: Primary energy is a form of energy that occurs in nature and has not already been converted into another form of energy. Primary energy carriers are crude oil, natural gas, coal, wind and solar energy.

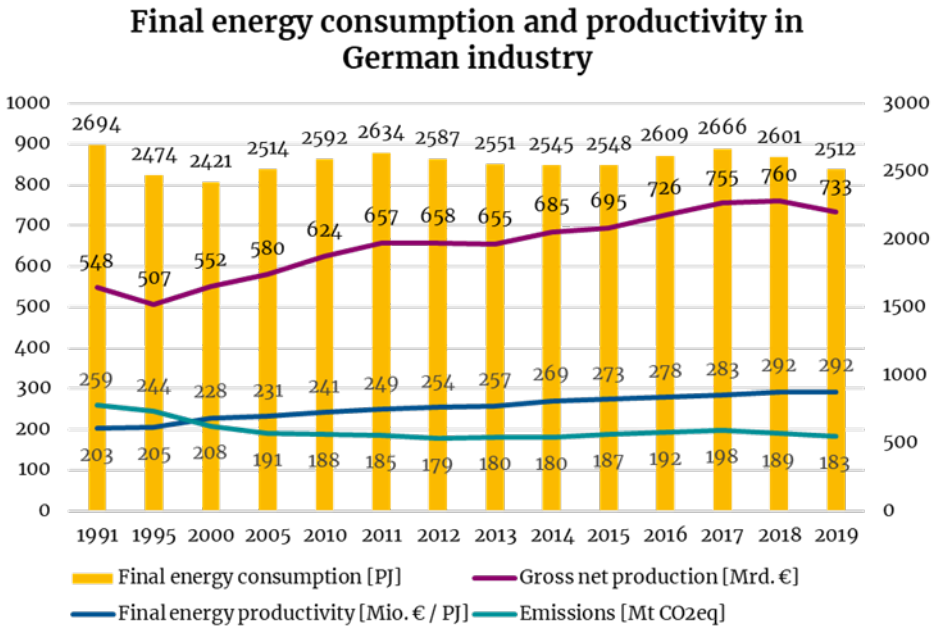

Figure 1: Final energy consumption and productivity in German industry (Umweltbundesamt, 2022a; BMWK, 2021)

efficiency measures requires no fundamental changes to existing processes.

2.2 Difference between efficiency, sufficiency and consistency

The consideration of efficiency requires classification in the context of efficiency, sufficiency and consistency in order to be able to classify the energy efficiency potential. Therefore, sufficiency and consistency are defined below:

- **Sufficiency**: Behaviour changes can lead to energy savings and reduced greenhouse gas emissions. This is often achieved by reducing material consumption. This reduction does not necessarily lead to other activities that offset the savings ("rebound effects").
- **Consistency**: Replacing existing processes with other technologies that continue to deliver the same product (e.g. replacing power generated from fossil fuels with electricity produced by renewable energy sources). These changes are often accompanied by efficiency gains.

2.3 Energy efficiency and rebound effects

Efficiency is particularly important as it is the "easiest" to implement compared to the other two options. There is a risk that efficiency gains lead to economic profits, which, when reinvested, can negate the energy savings (**rebound effect**). Possible rebound effects are presented below:

Direct rebound effect

An increase in efficiency leads to increased demand for the more efficient product or service.

Indirect rebound effect

Energy consumption increases because the more efficient product provides more financial capital, which leads to additional investments.

Macroeconomic rebound effect

Technological efficiency improvements lead to changes in demand, production and distribution patterns that can result in increased total demand (BMWK, 2021).

Rebound effects are one possible reason for the **stagnation of emission reductions** in German industry for the **past 20 years**.

2.4 Potential of energy efficiency to reduce emissions

In the EIA's 2018 report, the authors estimate that product improvements and energy labels between 1990 and 2020 have led to savings of:

- 1,745 TWh of energy
- 3,559 TWh of greenhouse gas emissions

plus extra revenue

- Of €66 billion for industry, sellers and installers

Until 2030, the authors estimate an increase for these values of around 60% (EIA, 2020).

Energy efficiency is a necessary part of limiting global warming to 1.5°C and well below 2°C in accordance with the Paris agreement. However, energy efficiency alone is not enough to achieve this (see Figure 1). Therefore sufficiency and consistency measures are also necessary.

Role of energy efficiency in China

Without the energy efficiency measures implemented since 2010, China's energy consumption would have been 25% higher in 2018. Between 2014 and 2018, the energy savings were 3,056 TWh (IEA, 2021). Furthermore, the World Bank notes that between 1980 and 2010, the GDP of China increased by a factor of 18, whereas energy consumption increased by only a factor of 5. Despite these positive developments, China's energy demand per unit of GDP is still 82% higher than in Germany and 15% higher than in the United States (Columbia University, 2022).

Comparison of energy consumption in Germany and China

In China, the industrial sector has a share of 66% of total primary energy consumption (Germany: 30%). The building sector has a share of 28% as opposed to 40% in Germany. Because of the high share of the industrial sector, Chinese energy efficiency policies focus on energy-intensive sectors such as steel, cement and aluminium.

3 Regulatory Framework (EU and Germany)

There is a need for different policies and measures to address the various barriers surrounding the implementation of energy efficiency measures. Therefore, the set of measures is based on four pillars: regulatory instruments (command- and control-type regulations, works with order and/or bans (quota obligations, etc.)); economic instruments (grants and preferential loans, tax incentives, non-fiscal instruments with market elements); information, motivation, advice; qualification and quality assurance. This chapter highlights the regulatory framework. Chapter 4 presents the other necessary measures.

3.1 European regulatory framework

European Energy Efficiency Directive

> **Definition of the Energy Efficiency Directive**[1]
>
> The aim of this directive is to establish a framework of measures to promote energy efficiency within the EU in order to achieve specific targets.

As part of the first **EU Energy Efficiency Directive** from 2012, the following measures were specified:

- Setting of national energy efficiency targets for 2020
- 3% annual renovation rate for central government buildings
- Obligatory energy savings by the Member States from 2014 to 2020 of 1.5% per year on average
- Combined heat and power (CHP): mandatory cost-benefit analysis for the new construction or modernisation of power plants and industrial installations
- Long-term strategy for the renovation of the national building stock
- Mandatory energy audits for large companies (see chapter 4.4)
- Smart metering/detailed billing

In 2018, the **Energy Efficiency Directive**[3] **(27/2012/EU)** was updated with the aim of achieving energy efficiency gains of 32.5% by 2030 compared to 2007, resulting in 11,118 TWh of final energy consumption and 14,805 TWh of primary energy consumption in 2030.

These targets increased further as part of the 2021 European Green Deal, which set an additional 9% reduction of energy consumption by 2030 compared to the 2020 reference scenario projections. This 9% target is measured against updated baseline projections made in 2020 and corresponds to energy efficiency targets of 39% (11,897 TWh) for primary energy consumption and 36% (9,153 TWh) for final energy consumption compared to 2007 (European Commission, 2022a).

As part of the 2022 REPowerEU Plan[4], the European Commission proposed to raise the target to 13% compared to the 2020 reference scenario, which would result in 8,723 TWh of final energy consumption and 11,397 TWh of primary energy consumption in 2030.

As part of the updated energy efficiency directive in 2018, every EU country needs to establish a 10-year integrated national energy and climate plan (NECP) for 2021–2030 (under Regulation 2018/1999 on the Governance of the Energy Union and Climate Action), highlighting how the targets for energy efficiency are intended to be reached (European Commission, 2022a).

[3] Directive: Directives must be converted into the national regulatory framework by EU member states in a specific amount of time.

[4] REPowerEU: The EU proposed a plan to react to the global energy market disruption by saving energy, producing clean energy, and diversifying energy supplies (European Commission, 2022b).

EU Ecodesign Directive 2009/125/EC

Definition of the EU Ecodesign Directive

The EU Ecodesign Directive from 2009 defines minimum energy efficiency standards for energy-related products (with substantial market volume). The aim of the EU Ecodesign Directive is to achieve a sustainable reduction in energy consumption as well as a basis for implementing measures or regulations for individual product groups. The current directive includes only energy-consuming products.

This directive targets the facilitation of the market penetration of energy-efficient products[5], e.g. through the European Union energy label. The continuous increase in energy efficiency is achieved through regular reviews as well as the possible requirement of verification of the achievement and objectives through market supervision.

This directive is based mainly on the "push and pull" principle, as energy-related products must fulfil specific measures to be placed on the market (push). The use of energy labels promotes the use of particularly efficient products (pull).

In future, the **Sustainable Products Initiative** should broaden the scope to all kinds of products, including textiles, furniture, steel, cement and chemicals. It should also address the presence of harmful chemicals in products such as electronics & ICT equipment, textiles, furniture, steel, cement & chemicals (European Economic and Social Committee, 2022).

At the beginning of 2022, a **new Ecodesign Directive** for regulating sustainable products was proposed. The proposal for the new framework allows setting performance and information requirements for almost all categories of physical goods (exceptions include food and feed). The possible requirements range from product durability and reusability to the presence of substances that inhibit circularity, energy and resource efficiency, as well as carbon environmental footprints and information requirements (European Commission, 2022c).

It is advisable to set requirements in such a way that the functioning of the products is not impaired, safety and health are not endangered, negative environmental impacts are avoided, the cost of the product does not increase inappropriately (life cycle costs), and competition is not impaired.

Energy efficiency policy in China

In comparison to most other countries, China has relatively progressive and far-reaching energy efficiency policies. Energy efficiency is one of the priorities for China's carbon neutrality strategy. China aims to largely improve the energy efficiency rate of energy-intensive industry by 2025 (The State Council, 2022). According to the 14th Five-Year Plan, China aims to reduce energy intensity by 13.5% by 2025 compared to 2020 and CO_2 intensity by 18%. China has been setting province-specific targets for energy intensity and total energy consumption with its "Dual Control Policy" since the 13th Five-Year Plan period. This ensures that national requirements are directly reflected at the local level and in the most energy-intensive companies.

The policy goals formulated in the five-year plan can be divided into the following four categories:

1. Annual targets

2. Provincial targets

3. Government spending

4. Regulations and standards

Building standards

The Ministry of Housing and Urban-Rural Development (MOHURD) established energy-saving green standards for all new urban residential and public buildings (Columbia University, 2022).

Energy Conservation Law

The legal basis for energy efficiency in China is the Energy Conservation Law. In order to achieve the energy conservation targets, financial incentives are provided to firms (The State Council, 2022).

EU ETS Directive

The current price of CO_2 in the EU Emission Trading System (ETS) is around €70/t of CO_2 but has long been around €10/t of CO_2 (2005–2018). As part of the EU ETS system, the allocation of free allowances is based on efficiency benchmarks and the risk of carbon leakage. The benchmarks are based on the average greenhouse gas emissions of the top 10% best performing installations in

[5] Product groups in current EU Commission work programmes: lighting, household electronics, white goods (freezer, dishwasher), motors and motor-driven devices, ventilating and air-conditioning systems, heat generation, and others (transformers, windows, etc.)

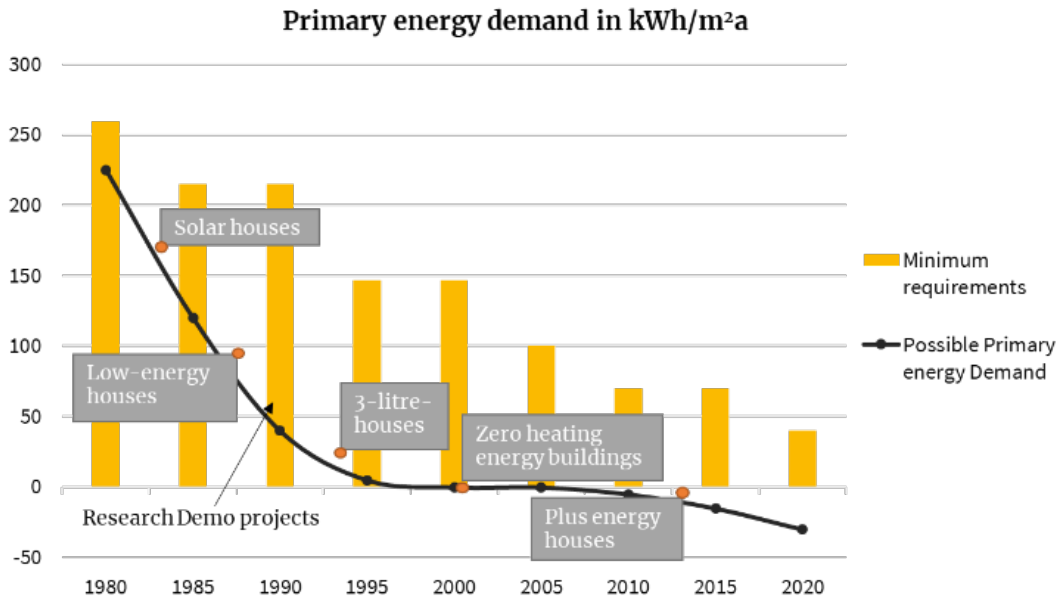

Figure 2: Development of primary energy demand (kWh/m²a) for a new semi-detached building (minimum requirements) and the possible reduction according to demonstration projects, Source: Fraunhofer IBP

the participating states. If installations do not meet the benchmarks, they receive fewer allowances. Therefore, they have an additional incentive to reduce their emissions, lest they have to buy additional allowances to cover their emissions (European Commission, 2022d).

European Industrial Emissions Directive

This directive is the EU's main instrument for regulating emissions in industry. It makes recommendations for the best available techniques for energy efficiency by providing guidance on how to deal with energy efficiency in industrial installations (European Commission, 2022e; European Commission, 2022f).

3.2 Regulatory framework in Germany

Germany has no specific energy efficiency law, as most regulations are part of the regulatory framework for the building sector or other laws. A specific law addressing energy efficiency (with an available design) is currently in the legislative process. This law will contain specific targets for primary and final energy consumption in accordance with the Climate Protection Act. In addition, existing regulations will be consolidated. The use of waste heat will also be included, with a focus on data centres.

National Action Plan for Energy Efficiency (NAPE)

The German government formulated an action plan for energy efficiency called NAPE. The current (2019) NAPE 2.0 sets targets for reducing primary energy consumption by 40% by 2030 and 50% by 2045 compared to 1990. The revision of NAPE (NAPE 3.0) in 2022 will put more emphasis on the circular economy and climate neutrality.

The current NAPE contains measures that link energy efficiency and climate protection law, such as the CO_2 price[6] for heating buildings, tax incentives for the energy-efficient renovation of buildings and further development of existing incentives and regulations.

Measures for the building sector:

- Tax incentives for energy-efficient renovation
- Federal subsidies for energy-efficient buildings
- Promotion of serial renovation
- Further development in areas such as energy consulting

[6] CO_2 prices in Germany: In addition to the EU ETS system (European certificate trading system for emissions in the energy sector and parts of industry), a CO_2 price applies to the transport and heating sectors in Germany (BEHG).

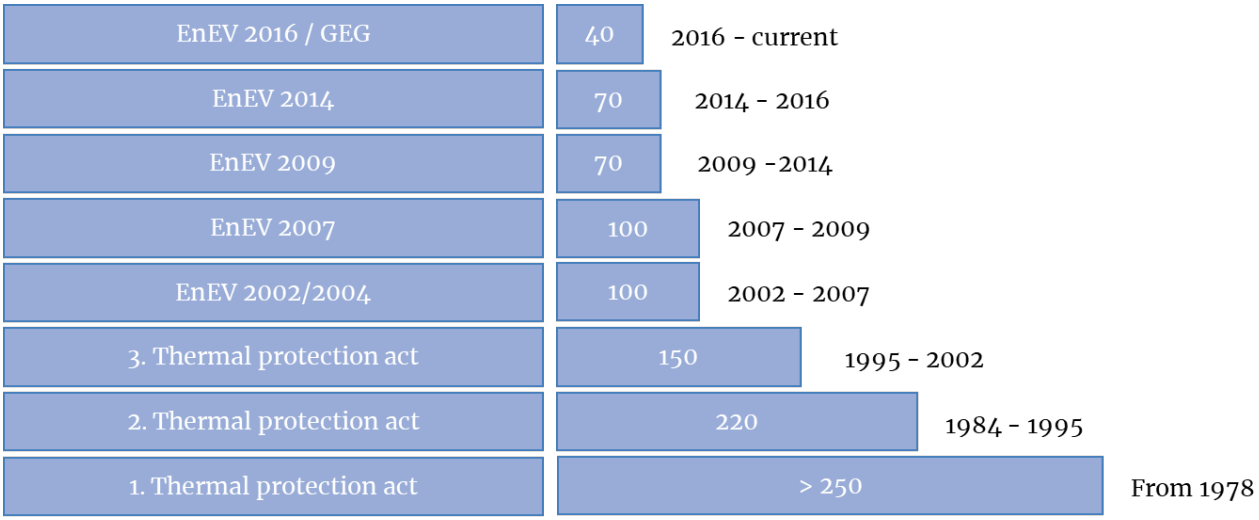

Figure 3: Legal requirements for primary energy demand in new buildings (kWh/m²)

- Further development of the innovation programme
- Conversion and expansion of heating systems and the development of new energy-saving technologies

Industrial sector:

- "Efficiency first" as the lead principle
- Use of waste heat
- Efficient use of renewable energy for the production of process heat (BMWi, 2019)

Building Energy Act (*Gebäudeenergiegesetz – GEG*)

The Building Energy Act is a recent German law (late 2020) that combines a law on energy conservation (Energy Saving Directive – *Energieeinsparverordnung (EnEV)*) with a law on the provision of renewable heating in buildings (Renewable Energies Heating Act – *Erneuerbare Energien Wärmegesetz (EEWärmeG)*). Accordingly, the requirements in the law regarding energy savings are presented first, followed by the requirements for the share of renewable energies in the final heating and cooling energy demand in buildings.

In the GEG, energy savings are linked to two values: primary energy consumption and transmission losses. A reference building[7] is defined in the law to enable and quantify energy efficiency gains in buildings. Based on this reference building, requirements for residential and non-residential buildings are formulated. A new building must meet these reduction targets.

Reducing the primary energy consumption of new buildings was already the main instrument to increase energy efficiency in the previous energy-saving regulations. The evolution is shown in Figure 2 and Figure 3.

The law currently stipulates that non-residential buildings must be built in such a way that the annual primary energy demand for heating, hot water, ventilation, cooling and built-in lighting does not exceed 0.75 times the value of the annual primary energy demand of the reference building based on net floor area (§ 18 Section 1). A similar rule applies to residential buildings.

Various exceptions can be obtained through a higher proportion of renewable energy in the building or mechanical ventilation systems.

The GEG sets requirements for a minimum share of renewable energy in the final energy demand for heating and cooling:

- Solar thermal energy and electricity from renewable energy sources: at least 15% of the final energy demand for heating and cooling (§ 35, 36 GEG)
- Geothermal or environmental heat, solid and liquid biomass, gaseous biomass boiler, waste heat, CHP and district heat (source waste or CHP):

[7] Reference building: The reference building is identical to the building under evaluation in terms of size, area and shape, but all parts of the building and equipment for which it is intended are replaced with reference technology representing the state of the art (Verlag Dashöfer, 2022).

at least 50% of the final energy demand for heating and cooling (§ 37, 38, 39, 40, 42 GEG)
- Other: at least 40% when using fuel cell heating (§ 43 GEG)

The updated version of the GEG, which will come into effect in 2023, further strengthens the requirements: the permissible annual primary energy requirement is reduced from 75% to 55% compared to the reference building. This requirement applies to both residential and non-residential buildings.

Starting in 2024, all new heating systems (even in existing buildings) must operate with at least 65% renewable energy, which means that most newly installed heating systems will be heat pumps (GEG-info, 2022; TGA Fachplaner, 2022).

Energy Services Act (*Energiedienstleistungsgesetz (EDL-G)*)

The aim of the Energy Services Act is to increase energy efficiency through energy services. The main instrument of this law is that large companies must carry out an energy audit every 4 years (see chapter 4.4). Small and medium-sized companies are not obliged to do so, nor are large companies that have implemented an energy management system in accordance with DIN EN ISO 50001 or an environmental management system in accordance with Regulation (EC) 1221/2009 (see chapter 4.5) (dena, 2022).

4 Best Practices in Germany

Germany has implemented various measures to promote energy efficiency. This chapter explains these measures by presenting the funding and information schemes and highlighting examples of best practices in Germany.

4.1 Energy efficiency incentives and regulations

German energy efficiency policy tries to design energy efficiency instruments as market-oriented as possible. Therefore, the strategy is to avoid micromanaging technologies and give stakeholders as much decision-making freedom as possible regarding the implementation of measures.

Market orientation can be achieved by creating business cases for the implementation of efficiency technologies, for example, through carbon pricing plus financial support and special funding instruments such as contracting, bonds and the like. To speed up the process, possible barriers should be overcome by legal requirements.

Funding from BAFA

Funding from BAFA is available for energy consulting, the development of energy-efficient construction and renovation concepts, energy audits and contracting consulting for non-residential buildings for municipalities, commercial enterprises, freelancers, and non-profit organisations (BAFA, 2022). Funding is also available for investments in renewable heating systems such as biomass, heat pumps or solar thermal energy (Unser Haus, 2022).

Funding from KfW

KfW has established a national funding landscape for reducing costs. Furthermore, the KfW also sets various standards. The KfW funding scheme includes numerous renovated buildings in Germany as well as new buildings.

4.2 Financial subsidies

There are two main subsidy programs for energy efficiency in Germany, funded by KfW (Credit Institute for Reconstruction) and BAFA (Federal Office of Economics and Export Control).

Module	Name	Examples	Subsidy*	Maximum amount	Comment
1	**Efficient cross sectional technologies**	Heat recovery Electric engines & devices	30-40 %	200 T. €	Single measures; simplified application; technology-specific (whitelist)
2	**Renewable Process Heat**	Solar heat, biomass, heat pumps	45-55 %	15 M. €	
3	**Digital technology & energy management systems**	Sensors, control systems, software..	30-40 %	15 M. €	
4	**Systemic energetic & resource optimisation**	Combination of any of the above	30-40 %	15 M. €	Technology-neutral; focus on combined measures
5	**Transformation concepts**	CO_2 audit; consulting projects	50-60 %	80 T. €	Strategies & plans to achieve emission reduction targets

Figure 4: Subsidy scheme for the federal funding programme for energy and resource efficiency in industry (BAFA, 2022)

Federal Funding Programme for Energy and Resource Efficiency in Industry (*Bundesförderung für Energie- und Ressourceneffizienz in der Wirtschaft*)

The aim of this programme is to accelerate investments in the modernisation of plants and processes as well as the market penetration of state-of-the-art technologies with the aim of saving 14 TWh and 3.5 Mt of CO_2 per year. The funding volume is €500 million per year. The subsidy is structured in five modules presented in Figure 4 (BAFA, 2022).

Federal Funding for Efficient Buildings (*Bundesförderung effiziente Gebäude*)

BAFA and KfW implement the support programme. The funding covers the entire building sector. KfW is responsible for financing technical building measures and BAFA for heating technologies.

The funding is divided into three areas: residential buildings, non-residential buildings and individual measures (heat pumps, etc.). The subsidy is based on the principle that the higher the efficiency, the higher the subsidy.

Funding for residential buildings takes the form of low-interest loans and/or subsidies. The subsidy is linked to minimum technical requirements, some of which are derived from the Building Energy Act. Subsidies are only granted if the efficiency is higher than that required by regulatory law.

Funding for individual measures is provided in the form of grants, which vary according to the higher efficiency gains and the technologies involved.

The subsidy has different targets, such as the removal of information barriers by involving experts, secure funding through long-term promotional loans, tiered incentives (the intensity of the subsidy increases with energy efficiency) and quality assurance through the mandatory involvement of qualified experts for energy planning and construction supervision services (KfW, 2022).

4.3 Energy efficiency networks

The aim of the energy efficiency networks, established in 2014, is to enable the voluntary targeted and non-bureaucratic exchange of experiences and ideas between participants. In this process, participants define an energy-saving target based on each firm's energy audits. Operators, moderators and energy consultants monitor the process and the activities of the network (Effizienznetzwerke, 2022).

At the end of 2020, the Energy Efficiency and Climate Networks Initiative was launched in Germany with the aim of initiating 300–350 new networks (currently active: about 50 networks).

There are four different types of energy networks:

1. Regional networks: companies geographically close to each other
2. Intrasector networks: companies in the same economic/industrial sector
3. Intracompany networks: various sites of a single company
4. Small company networks: companies with energy costs ≤ €80,000 per year

To identify the effects of energy efficiency networks, two examples of best practices are presented in the following. The description highlights the function of the networks, the participants, the measures and the achieved impact (dena, 2020).

IVH Energy Efficiency Network

The IVH Energy Efficiency Network is a network of industrial companies in Hamburg. The network's actions involve the exchange of ideas as an important element for impulses as well as new investments. The companies involved highlight that comparing is an option for the self-assessment of their company in competition with other companies.

One participant sees this as a potentially stronger sign, as it could signal to the public that industry is doing everything it can to advance climate protection.

The network members meet twice a year and present their energy efficiency measures to each other. The participants emphasise that showing each other measures leads to new ideas for their own companies. They consider this to be the most important benefit. Over the first three years, savings of 105,000 t of CO_2 and 280,000 MWh of energy were achieved (dena, 2020).

Frankfurt am Main Business Energy Efficiency Network

The participants in the Frankfurt am Main Business Energy Efficiency Network range from Commerzbank to Lufthansa, under the leadership of the regional energy supplier Mainova (provision of expertise). Compared to the

first energy efficiency network presented, this network is characterised by its heterogeneity.

The network's approach was to meet four times a year with a "behind-the-scenes" inspection of the measures. The main measures were as follows:

- Switching to LEDs by consensus
- Developing e-mobility
- Converting ventilation system / fans
- Adapting systems to consumers via control technology

The target of 17,500 MWh of energy savings was exceeded by 70% in the first phase.

The participants emphasise that the implementation of the most cost-effective measures came first, such as switching to LEDs, eliminating leaks, improving insulation and recovering waste heat. However, in addition to these technical measures, information on the regulatory framework or potential savings due to changes in behaviour was also communicated.

According to dena (2020), the key measure areas for the various companies are lighting (29%), process technology (13%), heating and hot water (8%) and compressed air (7%), followed by motors and drives, process heat and ventilation / air conditioning / refrigeration at 5–6% each.

4.4 Energy audits

Energy audit

An external or internal expert (auditor) examines the company's energy consumption and costs, identifies potential savings and develops measures for their implementation (dena, 2022; Dekra, 2022).

As described above, the German legal framework requires large companies to perform an energy audit every four years (Energy Services Act). Small and medium-sized companies[8] are not required to do so but may carry out energy audits on a voluntary basis. As part of the measures taken in response to the 2022 energy and gas crisis, every company must perform an energy audit (see chapter 4.8).

China

Tax incentives

Are provided to:

- Environmental protection, energy and water conservation projects
- Companies purchasing environmentally friendly, energy- and water-saving machines
- Comprehensive utilisation of resources
- Energy-saving service companies that implement energy performance contracting

Top 100, 1,000, 10,000 companies program

One of the most important measures of the 13th Five-Year Plan period is the Top 100, 1,000, 10,000 companies program. This programme covers construction, industry, transportation, business and public institutions. The companies included are the 100 companies with an energy consumption of more than 24.2 TWh, the 1,000 companies with an energy consumption of more than 4.07 TWh and other energy-intensive companies. The programme includes more than 16,000 companies, which together account for 60% of industrial primary energy consumption (NDRC, 2022).

Key elements of the program:

- Conducting energy audits and developing energy conservation plans based on the General Technical Principle of Energy Audits in Enterprises
- Establishing energy management systems in accordance with China's energy management standard
- Developing pilot training for energy managers, implementing an energy use reporting system and further phasing out backward technologies, among others (Energy Smart Communities Initiative, 2016)

Leading pilot projects

The project aims to improve energy-saving technologies and establish an energy conservation system by setting energy efficiency benchmarks and improving energy efficiency standards. The target groups are energy-using products, energy-intensive industries and public buildings. The leading project will receive financial incentives for the selected products, firms or buildings (The State Council, 2022).

[8] The definition of small and medium-sized enterprises is based on the recommendation of the European Commission (2003/361/EG).

An energy audit generally follows the following procedure:

1. Kick-off meeting
2. Data collection
3. Field visit (site visit, etc.)
4. Analysis
5. Report & presentation

4.5 Energy management systems

The implementation of an energy management system requires an analysis of the company's energy flows and technologies used. Based on this analysis, proposals for improvement are developed, their cost-effectiveness is assessed, and they are implemented accordingly. In contrast to energy audits, the measures are integrated into the company's strategy through an organisational policy that sets energy targets and action plans and measures the achievement of these targets with the help of key performance indicators. Furthermore, the implementation influences organisational and regulatory processes by regulating responsibilities for energy-related and other processes.

There are international standards for energy management systems. ISO 50001 is a recognised and comprehensive set of standards that has been used in a wide range of companies and industries since 2011 (Umweltbundesamt, 2022b).

4.6 Information campaigns

In addition to the measures already presented, various information campaigns in Germany promote energy efficiency. In the context of the current energy crisis in Europe and Germany, a broader efficiency campaign is currently underway to reduce electricity and gas consumption. The information provided also includes advice on behavioural change and targets measures that can be implemented quickly, such as replacing incandescent light bulbs with LEDs or installing more efficient ventilation systems.

On the one hand, information is provided at the federal level in combination with dena. On the other hand, the state energy agencies also provide information. The beneficiaries are both private individuals and companies (BMWK, 2022; Landesenergieagentur Hessen, 2022).

4.7 Waste heat use / atlas

Waste heat is a by-product of many industrial processes. The use of waste heat has a huge potential for energy savings and energy efficiency.

Waste heat plays a special role in energy efficiency, as the potential of waste heat depends on the following parameters. It is advisable to check these parameters beforehand.

First of all, the size/dimension of the process influences the potential. Possible overcapacities can lead to an increase in waste heat production. In addition, the control of an installation has an impact because inefficient operating points lead to increased waste heat production. One such point is the temperature level, which can be lowered depending on the process. This is directly related to the insulation. Finally, alternatives to operate the same process in a more energy-efficient way should be investigated.

Currently, there are only assumptions about the technical and economic potential of using waste heat in Germany. Pehnt et al. (2010) assume that there is a waste heat use potential for temperatures above 140°C of around 88 TWh (about 12% of the industrial energy input) and for temperatures between 60–140°C of around 44 TWh (about 6% of the industrial energy input) (Pehnt, Arens, Jochem, & Idrissova, 2010).

In order to get a more accurate overview of the waste heat potential in Germany, several regions, cities and states have started to compile waste heat atlases. These provide an overview of heat sources and sinks (Fraunhofer IPM, 2015; Energie-Atlas Bayern, 2022). They can be used as a first step towards identifying waste heat recovery potential. In accordance with the above points, an individual assessment is then necessary to evaluate a possible use at the respective location.

4.8 Short-term "emergency" measures

In response to the 2022 energy and gas crisis in Europe and Germany, various short-term measures have been adopted to reduce energy and especially gas consumption, including ones that aim to improve energy efficiency to cash in on short-term savings potential. They are briefly described and classified in the following.

As part of these measures implemented, an Energy Saving Act was enacted, which has been in force since 1 September.

- Parts of non-residential buildings, such as common areas that are not occupied, shall not be heated. Exceptions apply to sensitive facilities (e.g. schools, medical or care facilities) and for technical reasons.
- The air temperature in workrooms must not exceed 12–19°C, depending on the type and severity of the work.
- Decentralised drinking water heating systems may not be operated if they are intended primarily for hand washing.
- The heating of private swimming pools is prohibited.
- Gas and heat suppliers must inform their customers of the energy consumption and energy costs for previous and future billing periods, as well as the calculated savings potential for the building if the temperature is lowered by 1°C.
- Retail stores must keep their doors and entrance systems closed when operating air conditioning or heating systems.
- Advertising displays must turn off their illumination systems between 10pm and 4pm, with exceptions, including for road safety.
- The illumination of monuments and buildings from the outside is prohibited. (Wirtschaftsmagazin, 2022)

Impact of the measures

It is currently difficult to assess the extent to which the introduced measures lead to gas savings. Multiple factors influence gas demand, such as weather conditions (temperature), electricity demand, the development of electricity generation in other EU countries and the potential for fuel switching. Due to these factors, any savings are not necessarily linked to the savings measures.

The greatest short-term potential identified by Luderer et al. (2022) is not due to energy efficiency measures but fuel switching and reactivating coal and oil-fired power plants. In the medium term, on the other hand, savings potentials due to increased energy efficiency are highlighted (use of waste heat, heat pumps, etc.) (Luderer & et al., 2022).

5 Conclusion

So far, the report has mainly focused on energy efficiency in Germany, which is why the measures presented are finally compared to China's energy efficiency policy.

As mentioned in the introduction, China has one of the world's most progressive energy efficiency policies. Therefore, many of the presented measures of the EU and Germany already exist in one form or another in China. These include building and product standards, energy intensity and energy efficiency targets, as well as energy efficiency taxes and subsidies. Thus, the further development of existing measures is of interest when comparing the situation in China with German and European laws and measures.

When considering the legal situation, it is recommended that China's energy efficiency policy should link annual energy efficiency targets to primary and final energy demand in order to achieve an absolute reduction in energy demand. This can prevent the phenomenon of rebound effects and possibly prevent the stagnation of CO_2 emissions, as was the case in German industry between 2000 and 2020.

Extending the laws on product standards to encompass additional lifecycle aspects, as has been undertaken in the EU, may also be of interest to China. This can improve material efficiency as well as address other environmental protection aspects.

In the case of legislation on building standards, the mistakes made in German legislation could be avoided by requiring the conversion to a sufficiently high share of renewable energy in primary energy consumption to prohibit the installation of new oil-fired boilers and heating systems. The installation of fossil fuel heating systems can lead to path dependencies that result in additional costs when converting to a climate-neutral energy system, which can be avoided by early conversion.

In terms of concrete measures, mandatory energy audits for all companies could also be an option in China. It should be noted that this was introduced in Germany in the context of the current energy crisis.

The use of waste heat is a measure with great potential in Germany, the EU and China. In Germany, the forthcoming Energy Efficiency Act will, for the first time, specifically address waste heat at a legal level.

Due to the many challenges surrounding the use of waste heat, it still needs to be promoted in Germany. It should be noted that the integration of waste heat in new constructions can already be specifically targeted in the planning stage (connection to district heating networks, use in industrial networks, etc.). In Germany, this is of lesser importance as a large part of the facilities already exists. In China, however, the combined consideration of energy efficiency and waste heat may offer more potential due to the higher dynamics in the construction of new industrial plants (sites).

Despite the mentioned possible extension of China's energy efficiency policy, there are potentials in China that have already been exploited in Germany. These include the partial conversion of coal-fired CHP power plants to gas (which should, in future, be combined with flexible Power-to-Heat schemes used during hours of high renewable electricity availability) and the use of highly efficient cross-sectoral technologies. To achieve net zero, it is advisable to avoid lock-in effects from fossil fuel bridge technologies and recommended to switch directly to climate-neutral alternatives, especially renewable energy.

Overall, Germany's experience with energy efficiency shows that an early commitment to measures (long payback periods), as well as the inclusion of conditions in emissions trading schemes or tax systems combined with benefits, are important to promote energy efficiency measures in industry.

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