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Energy end-use efficiency potentials and policies and the development of energy service markets

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The Institute of Applied Energy

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Germany and Japan

Final Report

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Country Report Germany
Country Report Japan
Mutual Review and recommendations

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Executive Summary

Germany

This report presents the analysis of energy efficiency potentials, barriers and policies in Germany. It takes a detailed look at the sectors buildings, appliances, industry and transport. Additionally, the role of information and communication technologies, demand response, smart cities, behavioural aspects and the energy service market are analysed.

Energy efficiency policies in Germany date back several decades with the first laws on efficiency in buildings being passed in 1976 in response to the first oil price crisis. Today, energy efficiency policies are embedded in the so-called **energy transition (*Energiewende*)** which was initiated in Germany in 2010. The concept of the energy transition implies a comprehensive transformation of energy supply and use. The German energy transition comes with ambitious climate and energy goals for 2050 that are laid out in the **Energy Concept**. By 2050 Germany strives to cut CO_2 emissions by 80 to 95%, boost renewables to a share of 80% in electricity generation, and reduce primary energy consumption by 50% until 2050 (compared to 2008) (cf. BMWi/BMU 2010). Strategies and measures to achieve the German energy efficiency targets for 2020 are laid out in the **National Action Plan on Energy Efficiency** (NAPE) adopted in 2014. In November 2016, the **Climate Action Plan 2050** was adopted. It is the first official document that describes the path to a nearly greenhouse gas neutral Germany in 2050. While Germany has made considerable efforts in improving its energy efficiency and reducing the primary energy consumption, by reducing the primary energy demand of buildings by 15.9% (compared to 2008) for example, significant work remains in order to reach the set targets. This is the case in the transport sector for example, where final energy consumption has increased by 16% since 1990, as absolute traffic volume continues to rise and offset efficiency gains via technical improvements (BMWi 2017a).

In 2015, **final energy consumption** totalled 8,877 PJ (BMWi 2017a). The transport sector consumed 29.5% (2,616 PJ) of final energy, the industrial sector used 29% (2,576 PJ), and households used 25.8%, (2,289 PJ) while the service sector consumed 15.7% (1,393 PJ).

The total additional **savings potential** that can be achieved through strong policies for all sectors until 2030, relative to the reference scenario, which already includes the current policies, is estimated at 1,158 PJ of final energy (Fraunhofer ISI, TU Vienna, PwC 2014b, p. 25). The largest savings potential lies in the buildings sector with 417 PJ, corresponding to about 36% of total savings potential. On one hand, even these strong policies are not assumed to achieve to total technical potential, which is estimated to allow reducing the absolute energy consumption by more than 50% within 20 years (Fraunhofer ISI 2012a, p. 182). On the other hand, when reaping these potentials, the **rebound effect** needs to be considered.

The **buildings sector** must be virtually climate neutral by 2050. In order to reach this target, renovation rates, which are currently about 1%, need to double. The efforts of the German government to improve energy efficiency in buildings were, until recently, mainly focused on residential buildings as data on non-residential buildings is still weaker. Yet in the last years, various programmes and research projects were implemented to overcome this gap. The German building stock is quite old, which contributes to the fact that out of the 19 million residential buildings with ca. 40 million apartments, 50% must be renovated in the next 20 years (BMWi 2017b). In the buildings sector, financial and informational barriers present a large obstacle for realizing energy efficiency. For years, the government has followed the three-pronged policy approach of 'Inform, Support, Regulate' and will continue this approach in the future. Best practices are the continuously tightened building codes under the Energy Saving Ordinance (EnEV) which led to steep learning curves in the buildings sector (best practice example 1, Figure 10). Additionally, the KfW Programmes (best practice example 2, Figure 12) which link the amount of funding available for energy efficiency refurbishments or new built houses to the Minimum Energy Performance Standard also serve as an example of best practice in Germany.

Looking at **residential and tertiary appliances**, the total savings potential for 2030 is estimated to be 244 PJ, where slightly more savings can be realised in the tertiary sector (Fraunhofer ISI, TU Vienna, PwC 2014b, p.25). Appliances are regulated EU-wide by the Ecodesign and Energy Labelling Directives (best practice example 3). The Ecodesign Directive involves a large number of stakeholders in the regulatory process, which makes it very transparent; however, this also means that tightening product standards often takes a long time (cf. Energy Efficiency Watch 3). Also for some appliances, e.g. in ICT, technological developments are moving very fast, making it difficult to keep up with adequate standard setting. While financial incentives for product replacements for poor households are in place, further push and pull strategies are absent to a large extent. Additionally, while benchmarks are available for absolute consumption levels, benchmarks for the operation of appliances are often absent in the tertiary sector.

The **industrial sector** does not have an implicit energy efficiency target, yet under Germany's long-term climate action plan, it needs to reduce its CO_2 emissions by 51-49% (compared to 1990) until 2030, which is equivalent to 140-143 $MtCO_{2eq}$. The final energy consumption in the industry sector varies enormously for the different branches. The most energy-intensive branches in Germany are iron and steel, chemical and mineral industry as well as paper and pulp industry. For 2030, the total savings potentials in the industrial sector are estimated to be 222 PJ (Fraunhofer ISI, TU Vienna, PwC 2014b, p. 25). Cross-cutting electric measures (77 PJ) and cross-cutting thermal measures (73 PJ) have the largest saving potential. The German energy intensive industry, which has the highest energy savings potentials in this sector, is covered by the EU ETS; however, the small and medium sized companies (SMEs) are also an important part of the industry sector in Germany, representing 99.95% of all companies and employing 68% of the work force (KfW 2015d). In these smaller enterprises, information deficits play a major role in the financing of energy efficiency investments, whereas in larger enterprises, organisational aspects, such as the distribution of responsibilities for energy efficiency or the in-house flow of information, are inhibitive. Germany has implemented a variety of financial instruments aiming to reduce financial barriers. However, currently there is still a reduced willingness of companies to implement energy saving measures with pay-back times of more than three years. Energy efficiency networks (best practice example 4, Figure 17) allow for a goal-oriented, non-bureaucratic exchange between companies.

The **transport sector** has to reduce final energy consumption by 10% until 2020 and by ca. 40% until 2050 (compared to 2005). Since 1990, final energy consumption has increased by 16%. 90% of fuels used are fossil fuels, meaning that biofuels and electricity only play a minor role. The largest share in the transport sector is road traffic. The high investment costs for the expansion of the transport infrastructure and a lack of technical innovations for vehicle efficiency constitute a major obstacle to energy efficiency in the transport sector. Various tax-related instruments have been implemented in the transport sector. However, tax rates have not been progressively adjusted and remain too low to increase energy efficiency.

The digitalisation of the energy system is expected to yield energy efficiency potentials through the analysis of increasing volumes of data on energy flows. The Digital Agenda 2014-2017 sets out the guiding principles of the digitalisation and in June 2016, the law on the digitalisation of the energy transition was passed. Under the premise of data security and protection, modern technologies such as smart grids and smart metering shall positively impact energy efficiency. **Information and communication technologies (ICT)** can manage considerable amounts of data needed to allow for flexible distribution of energy supply and demand. Real-time information and communication about energy supply, grid load and storage capacity opens opportunities for the optimal and efficient use of energy. Smart metres in industries and private households are envisioned to provide detailed information about energy consumption patterns and are therefore a key technology for new **demand response** applications. According to estimates, the introduction of smart meters coupled with monitoring tools can account for electricity savings of 3-5%. For heating, energy savings are expected to be slightly higher (up to 6,5%) (Hoffmann et al. 2012). In particular, the visualisation of energy use has been found to be crucial as it enables the consumer to use energy more consciously. Automated energy management systems in buildings can make up for 10-20% of energy savings. Another key technology is the internet of things. The internet of things (IoT) refers to things and communication networks, whose primary function is not directly related to information and communication technology, e.g. a washing machine. Despite the considerable potential, mass-market applications of IoT are not yet economically feasible. In particular, German SMEs are hesitant to become part of “industry 4.0” as the advantages are often unclear (Deloitte 2016).

ICT, big data and the internet of things are also key for the future of **smart cities and urban planning**. Smart cities may increase energy efficiency through smart street lights, smart grids and intelligent building systems. German cities currently face a huge challenge to adapt to technology developments and implement fundamental changes in urban infrastructure (e.g. for e-mobility). Many cities are suffering from investment lags in conventional urban infrastructure. Due to a shift from an industrial economy to a service economy and the related demographical changes, some cities are growing rapidly while others are shrinking along with the local economy.

Compared to other European countries, the German **energy service market** is particularly well developed on the supply side, which is characterised by a high level of competition. The market comprises the product groups of information, consulting, energy management and energy (performance) contracting (best practice example 5, Figure 23). Despite different market situations for the different products, around 77% and more of energy service providers see growth potential or strong growth potential for the market for energy services. Yet, various barriers slow the development of the energy service markets in Germany. Among them are an uncertainty of investments, capital shortages, investor-user dilemma, as well as information and motivation deficiencies of the final customer (cf. BAFA 2013). Important policies have been the promotion of energy consultations for residential buildings (renters and owners) as well as for SMEs and industry (buildings and processes). Additionally, the availability of tax relief for companies that have implemented an energy management system has led to a great push in demand since 2011. Nevertheless, a gap between existing policies, energy efficiency targets and potentials remains, hence further energy efficiency policies are necessary.

Japan

Motivations of energy efficiency improvement in Japan

Two oil shocks in the 1970s were the initial milestones that influenced energy efficiency improvement in Japan. After the shocks, various energy saving technologies have been widely disseminated through energy efficiency improvement in production processes and end-use energy equipment developments by businesses and institutions for energy management and energy efficiency. From other perspectives, the issues raised after the 1990s, such as the global environmental agenda and the Great East Japan Earthquake, were the influential factors in energy efficiency improvement in Japan.

Policy targets of energy efficiency in Japan

The Paris Agreement of United Nations Framework of Climate Change requested mid-century target for parties. Currently, some Japanese government ministries discuss mid-century low carbon social system but comprehensive energy package plan with policy initiatives has not shown. Therefore, we should limit the policy related discussion up to 2030 in Japan report. Transition of final energy consumption in the Long-term Energy Supply and Demand Outlook is consistent with greenhouse gas emission national target of 2030. Both the reference case and the aggressive conservation case are shown for 2030.

Energy saving potentials

Difference between the reference and aggressive conservation corresponds to the energy saving potential in Japan in 2030. In February 2015, the Energy Conservation Division of Agency of Natural Resource and Energy reported a provisional estimate of energy saving potential. Through the formulation of the long-term energy supply and demand forecast for 2030, the estimate is also the basis of the greenhouse gases reduction target of 2030, which the Japanese government submitted to the UN Framework Climate Change Convention in July 2015 as an Intended Nationally Determined Contributions (INDC) document. Provisional energy saving potential is defined as the differences between reference case and aggressive conservation case. Total potential is 14% of reference energy demand, and 6% for industry, 19% for commercial, 24% for residential and 21% for transportation.

In addition, The Institute of Energy Economics Japan published the IEEJ Outlook 2018 in October 2017. Its assessment time horizon has extended to 2050 and prepares a reference scenario and an advanced technology scenario by global region. Japan is one of the global regions, and the demand difference between reference and advanced technology scenario in 2050 can be regarded as energy saving potential of Japan in 2050. Best practice industrial demand technology, clean energy automobile for transportation as well as home appliances, hot water supply, illumination, thermal insulation of buildings technologies are listed for building energy saving technologies. The estimated potential numbers are smaller than Agency of Natural Resource and Energy assessment targeted in 2030, and further saving opportunities should be elaborated.

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Regulation measures on energy conservation

The Energy Conservation Act is the foundation of Japanese energy efficiency and conservation policy. Building performance is now regulated under the Building Energy Conservation Act, which was established in 2015 and enforced in 2016. Two acts cover industrial, commercial, residential, and transportation, in terms of product performance and business operation.

Supporting measures on energy conservation

Supporting measures are categorized into subsidy, demonstration, energy saving diagnosis, research and development, and tax institution. Subsidies are found in all sectors for energy systems or individual equipment. Demonstration is underway with subsidies in building and transportation. Energy saving diagnosis for small and medium enterprise is also one of the conservation policies. Industrial production process is a strategic area of R&D, while a broad range of energy efficiency R&D has been conducted covering all sectors. Tax is another tool to accelerate energy efficiency in building and transportation.

Market opportunity in energy saving business

Energy saving itself has business opportunity. The energy service company or energy service provider aims at initial conservation related cost recovery by energy saved. It is closely coupled with building energy management system diffusion and it will provide energy saving opportunity especially in commercial sector.

Mutual Review and Recommendations: Germany and Japan

The findings of the German and the Japanese country reports are compared to each other in Part III of the report. This includes a **mutual review** of the two individual country reports with a focus on similarities and differences in potentials as well as the regulatory frameworks. It also aims to explain the historical, political and cultural background of differences where relevant. The second part formulates policy and business **recommendations** for both countries, highlights opportunities for mutual learning, and identifies areas for further research.

Conclusions on the mutual review

The mutual review of the individual country reports has revealed a number of parallel developments as well as clear differences in the regulation of energy efficiency in both countries.

While energy efficiency is regulated by two comprehensive Acts in Japan including the Energy Conservation Act and Buildings Energy Performance Act, the regulatory landscape in Germany has more complexity, also due to the EU which has created an additional governance layer.

In contrast to Germany, which has a comprehensive energy transition strategy in place known under the term “Energiewende”, a similar, but less comprehensive strategy called "Long-term Energy Outlook" exists in Japan. However, while Germany has formulated targets for 2050, there are no such long-term quantitative energy targets in Japan.

Especially for the regulation of buildings and in the industry as well as appliances covering both sectors, mandatory competitive benchmarks play an important role in Japan. This instrument is not commonly used in Germany, where standards for appliances are agreed for each individual appliance at EU level. In Germany, the building envelope performance regulation is advanced. The Japanese regulation however, was rather weak in the past, but the recent establishment of the Building Energy Conservation Act will accelerate energy efficiency especially in large buildings. In contrast to the German energy performance certificate, labelling for new and existing buildings is encouraged, but not mandatory in Japan.

Energy efficiency developments and regulation in the industry are difficult to compare in detail because the production style of each industry differs. However, the monitoring and compliance systems are different. While in Germany, mostly third party audits are contracted for energy consumption reports, Japan requires in-house reporting from each company. In some cases, energy diagnosis for small and medium enterprises are done by third parties as well in Japan.

Efficiency improvement of vehicle and next generation vehicle diffusion are a common agenda for Germany and Japan, as the automobile (i.e. passenger cars, buses, freight trucks) share is dominant in both countries’ transportation energy demand.

With regard to information and communication technologies, demand management and response measures and smart cities and communities, both countries seem to be in a similar position. Research and development is being undertaken and supported by the government. Yet, there are no wide-scale applications employed for improved energy efficiency and the energy savings potential remains largely unclear.

Energy consulting services as well as energy providing services exist in both countries. Yet, the energy efficiency service market seems to be more defined in Germany compared to Japan. One explanation is that most energy services are done by in-house management as energy managers are required by Japanese law. Nevertheless, both countries expect a growth in energy services especially with regard to digitisation.

Summary on the recommendations part

Both countries, Germany and Japan, are already among those with the highest energy productivity in the world. The fact that there have been energy efficiency policies in place in both countries for many years has contributed to this. Still, both countries have ambitious energy efficiency targets for the future and high energy efficiency potentials. Hence, the overarching **policy recommendation** for both countries is to continuously assess, develop, and strengthen the overall and sectoral packages of energy efficiency policies. In general, more balanced and comprehensive policy packages that use regulatory, financial, informational and all other instrument types can be expected to be effective in overcoming the multiple barriers for actors in the value chain of energy efficiency. The report then offers potential improvements to the existing policies, overarching and per sector, for each Germany and Japan.

Energy efficiency policies will be one driver for **business opportunities**. Digitisation can also provide an opportunity for new consulting tools to save energy in equipment by enabling cost-effective consulting services, which at the same time are more responsive to individual, real-world use. This also includes building automation. For the industry sector, business opportunities lie in demand response. Big data and a market for energy savings can bring further business opportunities. An example is autonomous driving, which in the future would combine driving data and traffic data to assure the driving function as a service.

All of these areas also provide manifold opportunities for mutual learning. From the analysis, it appears that Germany could learn for example, from Japan’s experiences with using energy efficiency benchmarks in industry, the Japanese Top-Runner approach, and Japan’s transport system and policies. On the other hand, Japan could learn from Germany about the long-term view on an energy transition, also related to energy efficiency targets and policies, as well as in policies to advance energy efficiency in buildings.

Finally, the report includes **recommendations for further research**.

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The information on energy efficiency potentials varies between Germany and Japan and also within sectors. More detailed studies about energy efficiency potentials in Japan will be beneficial and would allow for a more detailed comparison between the two countries. Additionally, also for Germany energy efficiency potential studies for the timeframe 2050 are needed. This also includes studies analysing the cost-effective saving potentials containing information on economic efficiency (e.g. Net benefit/Cost curves of negawatts). It should be expanded to the multiple impacts of energy efficiency.

Further analysis is also needed to understand the differences in per capita energy consumption in buildings and transport between the two countries. This will allow to learn on the role of energy efficiency and daily routines of use in both countries, and how policy can influence and support these.

For a better understanding of the differences in energy service markets, a dedicated line-up by type of services would provide insights why and in what services the German market has a higher turnover.

Additionally, a more detailed assessment on the impact of existing and potential new or improved energy policies is needed. This includes their impact on energy prices in both countries as well as the role of energy prices as drivers for energy efficiency.

Table of contents

Part I: Country Report Germany

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1 Introduction to this study

The German Japanese Energy Transition Council (GJETC) has been established to exchange knowledge in the field of energy between two high-tech countries. Both countries must overcome great challenges in the coming years and decades to decarbonise their energy systems while at the same time develop smart, reliable and low-risk systems with competitive energy prices. Both countries can learn from each other to better tackle the energy transition.

Ecofys and Japan's Institute of Applied Energy in parallel conducted studies on the energy end-use efficiency potentials, barriers and policies as well as the development of energy service markets in both Germany and Japan. As one of the Council's four study programmes, the aim of this project is to analyse topics of mutual interests to both countries, facilitate research-based exchange between experts, and ultimately craft solutions and policy advice to enable the sustainable energy transition. In this study the energy end-use efficiency potential and the potential for demand response in the buildings, appliances, industry, and transport sectors along with the barriers and policy landscape thereof, were studied by both the German and Japanese teams. In addition, they examined how ICT, the Internet of Things, and Big Data impacts these potentials and promote Smart Cities and Communities. Energy service markets were also examined as well as how the rebound effect and behavioural change impact energy efficiency. By comparing the German and Japanese approaches, we outline similarities and differences, best practices, policy recommendations, and business opportunities.

This part of the report is the result of the analysis of energy efficiency potentials, barriers and policies in Germany. It has been structured to provide a holistic overview of the specific situation of Germany and provides readers who are not familiar with the German context with background information on policy targets, indicators and the structure of the German energy market. It is structured in the following chapters:

- Chapter 2 "Energy efficiency targets, strategies, institutions and potentials in Germany": This chapter sets the context for understanding energy efficiency policies in Germany. It does so by providing an overview of national and sectoral energy efficiency targets and strategies as well as showing energy statistics and historical developments of energy efficiency and quantifying energy efficiency potentials.
- Chapter 3 "Buildings": This chapter discusses energy statistics and developments of the buildings sector, as well as sector-specific potentials, barriers and existing policies. Additionally, best practice examples are highlighted.
- Chapter 4 "Appliances": The "Appliances" chapter discusses energy statistics and developments of the appliance sector, as well as sector-specific potentials, barriers and existing policies. Additionally, best practice examples are highlighted.
- Chapter 5: "Industry" deals with developments, potentials, barriers and policies in the industry sector.

- Chapter 6: "Transport" follows the same structure as outlined for the previous chapters and discusses transport-specific aspects.
- Chapter 7: "Cross-sector": This chapter comprises the potentials, barriers, and policies of information and communication technologies, demand response measures, smart cities, behavioural measures, sufficiency, and the energy service market respectively.
- Chapter 8: "Summary and Outlook" gives a summary of all sectors and provides an outlook on energy efficiency policy developments until 2050.

Chapters 3-7 include information about energy statistics and developments and present the potentials, barriers, and current policies of the respective sector. The existing policies are categorised into different types, including regulatory, financial, informational, and research and development. The individual policies are assessed according to their relevance in the respective sector. The aim is to pinpoint and describe these main policies and instruments that support end-use energy efficiency and demand response, and in doing so, identify sector-specific instruments that make up coherent policy packages. The instruments are outlined in easy-to-read tables, followed by a description of the most important instruments and the impact thereof.

The categorisation of instruments can be understood as follows:

- **Regulatory and planning**: National and EU legal regulations including ordinances, technical standards and mandatory product labelling requirements.
- **Financial**: subsidies and public infrastructure spending, public investments, tax benefits, direct grants, interest-reduced loans in connection with redemption payments, and price controlling instruments like energy taxes and toll models
- **Informational and consulting**: Provision of information by the public authorities and consulting services, such as on-site consultation, energy audits and checks
- **Research & development**: support for energy efficiency research, the development of new technologies, and ways in which such technologies can be brought to the market.

2 Energy efficiency targets, strategies, institutions, and potentials in Germany

2.1 Energy efficiency targets and strategies within the German "Energiewende" and the European Union

Energy efficiency targets and policies in Germany are mainly embedded in the climate and energy framework of the European Union (EU). With the 20-20-20 goals, the EU has set climate protection targets for the reduction of energy consumption and greenhouse gas emissions and the increase of renewable energies. By 2020, greenhouse gas emissions shall be reduced by 20% compared to 1990, the share of renewable energies shall increase to at least 20%, and efficiency improvements shall save at least 20% of the primary and final energy consumption forecasted for 2020. In October 2014, the European Council agreed to increase energy efficiency by at least 27% by 2030 (with a view to increase this target to 30%) under the 2030 Climate and Energy Policy Framework (European Council 2014). In November 2016, the European Commission proposed an amended Energy Efficiency Directive with a binding target of 30% for 2030 in its "Winter Package". Four EU directives describe the main framework of EU energy efficiency policies[1] and significantly influence German policies.

The **Energy Efficiency Directive** (2012/27/EU, EED) aims for a 20% reduction in the EU's primary energy consumption by 2020, relative to the 2007 reference scenario. The directive is a set of measures to target energy efficiency potentials in energy use, energy supply, and horizontally. Article 7 of the EED places an obligation on each Member State to achieve final energy savings of 1.5% annually by using energy efficiency obligation schemes or other targeted policy measures to improve energy efficiency in households, industries and transport sectors. Germany does not have energy efficiency obligations for energy companies but opted for achieving the savings through policy measures. Additionally, large enterprises are obliged to carry out an energy audit at least every four years. The exemplary role of public bodies is also emphasised. Central governments in EU countries must carry out energy efficient renovations annually on at least 3% (by floor area) of the buildings they own and occupy. The public sector is encouraged to purchase energy efficient buildings, products and services.

The **Energy Performance of Buildings Directive** (2010/31/EU, EPBD) regulates energy efficiency in the building sector. In order to increase energy efficiency, Member States must implement minimum energy performance requirements for new buildings and when retrofitting existing buildings. The level of energy performance requirements is decided by each Member State. Additionally, energy performance certificates have to be included in all sales or rental

[1] EU directives need to be transposed into national law and often allow flexibility in the way measures are implemented at national level.

advertisements of buildings. Furthermore, Member States are required to ensure that all new buildings are 'nearly zero-energy'[2] by 2021.

The **Ecodesign Directive** (2009/125/EG, ED) establishes a framework to set mandatory minimum energy efficiency standards for energy-using and energy-related products. More than 40 product groups are covered under this framework. The standards are EU-wide, which means that manufacturers do not have to comply with disparate national legislations. This also strengthens intra-EU trade. Energy efficiency standards are developed through extensive product studies, by examining market data, technological status and recommendations for the European Commission. Stakeholders are actively included in the product studies.

The **Energy Labelling Directive** (2010/30/EU, ELD) introduced a coloured EU Energy Efficiency Label to inform consumers on the energy efficiency of energy-related products. In principle, the directive covers all energy-related products. Such products include home appliances, as well as products for commercial applications and products which themselves do not consume energy, but significantly influence energy consumption (e.g. windows or tyres).

Energy efficiency policies in Germany date back several decades. The first laws on efficiency in buildings were passed in 1976 in response to the first oil price crisis. Today, energy efficiency policies are embedded in the so-called energy transition (*Energiewende*) which was initiated in Germany in 2010. The concept of the energy transition implies a comprehensive transformation of energy supply and use. The initial document was the **Energy Concept 2010,** which formulated guidelines for an environmentally-friendly, reliable, and affordable energy supply and a pathway for a new age of renewable energies. While the Energy Concept formulated a long-term phase-out of non-renewable energies, it also proposed longer lifetimes of nuclear power plants. In the wake of the Fukushima accident, however, the German government changed its position on nuclear power plants and decided to immediately shut down eight nuclear power plants and proceed with the phase out of all nuclear power by 2022. So far, the focus of the energy transition debate has been on the phase out of nuclear power stations, the expansion (and the costs) of renewable energies, the associated requirements for energy infrastructure, and the role of conventional power, especially coal fired power plants, in the energy mix. Besides the generation of renewable energies, energy efficiency is considered the second pillar of the energy transition.

The German energy transition comes with ambitious climate and energy goals until 2050 that are laid out in the Energy Concept. By 2050 Germany wants to cut CO_2 emissions by 80 to 95%, boost renewables to a share of 80% in electricity and reduce primary energy consumption by 50% until 2050 (compared to 2008) (cf. BMWi/BMU 2010). According to the International Energy Agency (IEA), energy efficiency plays a key role in contributing to CO_2 emission reductions, approximately 49%

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[2] 'nearly zero-energy building' (NZEB) are defined by the EPBD as "a building that has a very high energy performance […]. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.

(IEA 2013). The following figure gives an overview of the short, medium, and long-term targets of Germany's climate and energy policy and what has already been achieved.

		Achieved 2015	2020	2030	2040	2050
Climate	% greenhouse gas reduction (vs. 1990)	-27.2 %	-40	-55	-70	-80 to -95
Renewable Energies	% gross electricity consumption	31.6 %	35	40 to 45	55 to 60	80
	% gross final energy consumption	14.9 %	18	30	45	60
Energy Efficiency	% primary energy consumption (vs. 2008)	-7.3 %	-20			-50
	final energy productivity (vs. 2008)	1.3 % p.a.	2.1 % per year (2008-2050)			
	gross electricity consumption (vs. 2008)	-4 %	-10 %			-25 %
	buildings -primary energy demand (vs. 2008)	-15.9 %				-80 %
	building renovation	~1 % p.a.	doubling of renovation rate: 1% → 2% p.a.			
	transport final energy consumption (vs. 2005)	+1.3 %	-10 %			-40 %

Figure 1: 2050 Energiewende targets[3]
(Source: BMWi/BMU 2010, BMWi/BMUB 2014, BMWi 2015a, AGEB 2016, BMWi 2016a)

Energy efficiency is key to the success of the German energy transition. Besides a 20% reduction in primary energy consumption by 2020 and 50% by 2050 (the linear target for 2030 would be 30%), the electricity consumption should be reduced by 10% in 2020 (respectively 25% in 2050) (compared to 2008). Furthermore, the final energy productivity should be increased by 2.1% per year.

Strategies and measures to achieve the German 2020 energy efficiency targets are laid out in the **National Action Plan on Energy Efficiency** (NAPE) adopted in 2014. These comprise measures in the building sector as the building stock should be virtually climate-neutral by 2050. Selected measures include expanding on-site energy consulting and additional funding for improving the CO_2 building modernisation program. Energy efficiency investments allow countless opportunities for companies. Hence, the NAPE tries to incentivise the development of new business models. This includes a tendering scheme for efficiency measures in the electricity sector, promoting energy

[3] The increase in final energy productivity of the buildings sector also includes a reduction of the heating demand by 20% by 2020.

performance contracting with energy saving guarantees and a focus on heat recovery. Furthermore, consumers are empowered to conserve more energy. Measures for this include energy efficiency networks for industry to share best practices, highlighting energy-efficiency products ("National Top Runner Initiative"), and labelling old, inefficient heating systems to promote replacement. The NAPE is part of the **Climate Action Program 2020**, which offers additional policy measures to enhance climate mitigation. To increase participation by responsible stakeholders and civil society, an energy efficiency platform and other stakeholder dialogues were initiated by the government. The central financing instrument of energy efficiency measures is the energy and climate fund, which is fed by public funds and revenues of the EU emission trading system (BMWi 2016b).

Within the EU the "energy efficiency first" principle is a key element of energy policy. In 2016, the German Ministry for Economic Affairs and Energy (BMWi) published the **Green Paper on Energy Efficiency** (*Grünbuch Energieeffizienz*), which initiates public dialogue on additional efficiency measures and thereby prioritises the principle of *energy efficiency first* in Germany. This principle means considering the potential value of investing in energy efficiency in all decisions on energy system development. Where efficiency improvements are shown to be most cost-effective, they should be prioritised over any investment in new power generation, grids or pipelines, or fuel supplies.

In November 2016, the **Climate Action Plan 2050** was adopted. It is the first official document that describes the path to a nearly greenhouse gas neutral Germany in 2050. The plan comprises greenhouse gas reduction targets for the different sectors for the first time and provides guidance for strategic decisions in the coming decade. The following table shows the different greenhouse gas reduction targets of the sectors until 2030.

Area of action	1990 *(in million tonnes of CO_2 equivalent)*	2014 *(in million tonnes of CO_2 equivalent)*	2030 *(in million tonnes of CO_2 equivalent)*	2030 (reduction in % compared to 1990)
Energy sector	466	358	175 – 183	62 – 61 %
Buildings	209	119	70 – 72	67 – 66 %
Transport	163	160	95 – 98	42 – 40 %
Industry	283	181	140 – 143	51 – 49 %
Agriculture	88	72	58 – 61	34 – 31 %
Subtotal	1209	890	538 – 557	56 – 54 %
Other	39	12	5	87%
Total	**1248**	**902**	**543 – 562**	**56 – 55 %**

Figure 2: GHG reduction targets of different sectors until 2030
(Source: BMUB 2016a)

The German energy transition is accompanied by a comprehensive **monitoring process** called the "Energy of the Future"[4]. This monitoring process is accompanied by an annual Climate Protection Report that evaluates the energy and CO_2 savings achieved by each measure.

Two important cross sectoral policy measures are **energy taxation** which applies to all sectors and the **Emissions Trading Scheme** which impacts the industry and transport sectors. Both measures are regulated at EU level by the Energy Taxation Directive (2003/96/EC) and the Emission Trading Directive (2003/87/EC) respectively.

The **energy tax** is a consumption tax on the use of fossil resources and electricity. Different tax rates apply to different energy carriers. Tax rates can be found under §2 of the law (Energiesteuergesetz, EnergieStG). Until 31.12.2018, lower tariffs apply to the use of natural gas. Industrial producers in general pay a reduced tariff. Compared to other European countries, German electricity prices are among the highest (Eurostat 2017). Nevertheless, a number of environmentally harmful subsidies exist. Low electricity prices reduce the incentive to save energy.[5] These include tax breaks for industrial companies and free allocation of CO_2-emission allowances. According to the Electricity Tax Law (Stromsteuergesetz, StromStG) the tax is fully reimbursed for electrolysis, glass, ceramics, cement, lime, metals, fertilisers and chemical reduction methods. The company pays the tax in full and then applies for a complete reimbursement for the electricity used in eligible processes.

Under the **Emissions Trading System (ETS)**, installation operators had to reduce their greenhouse gas emissions by 57 million tonnes annually in the second trading period (2008-2012). Compared to the first trading period (2005-2007), the amount of emission allowances was reduced by more than 7% (BMUB 2016b). The ETS only has a secondary effect on energy efficiency. The increase in the price of CO_2-intensive energy is an incentive to implement greenhouse gas mitigation measures, which can also reduce energy consumption. However, the effect is small due to low certificate prices.

2.2 Energy efficiency governance

To achieve the objectives of the German *Energiewende*, an effective and good governance is an important prerequisite. On the national level, six ministries have relevant jurisdiction concerning the *Energiewende*. The three most important actors are the Federal Ministry of Economic Affairs and Energy (BMWi), the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and the Federal Ministry of Transport and Digital Infrastructure (BMVI).

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[4] Annual reports are published as well as strategic progress reports every three years. The first progress report was published in 2014 (BMWi 2014b).

[5] For a detailed assessment of environmentally harmful subsidies in Germany see: UBA (2014): Fachbroschüre Umweltschädliche Subventionen in Deutschland. Aktualisierte Ausgabe 2014.

As Germany has a federalist system, the sixteen states (*Bundesländer*) additionally operate autonomously on subjects such as state support schemes, land-use planning and permitting procedures.

Besides the national and federal ministries, other governing bodies support the *Energiewende*. For energy efficiency policies, important bodies are the Federal Office of Economics and Export Control (Bafa) and the federal government's KfW investment bank, which are responsible for various support schemes, and the German Energy Agency (dena), which provides expertise and awareness raising to support the implementation of energy efficiency measures. The dena also provides a list of qualified energy consultants and energy efficiency experts for energy efficiency measures in the building and industrial sector. Furthermore, consumer protection agencies provide advice and information on energy efficiency policies and measures.

Additionally, Germany installed the so-called "Energy and Climate Fund". To accelerate the *Energiewende*, the German Government earmarks three billion Euros annually for the fund. With the Energy and Climate Fund various energy efficiency research, building renovation and energy advice programmes are financed (BMWi 2016b).

2.3 Energy statistics and energy efficiency developments

To fully understand the German context surrounding energy efficiency, it is necessary to not only look at the policy landscape, but have an overview of relevant indicators. The following section presents indicators and trends about Germany and of each of the four sectors buildings, appliances, industry, and transport.

Germany has a population of 82 million and is the largest economy in Europe and the fourth largest economy in the world. **Primary energy consumption** in 2016 totalled 13,400 PJ (BMWi 2017a, p.12). Compared to the year 2008, Germany reduced its primary energy consumption by 1,000 PJ, which is larger than Portugal's entire primary energy consumption in 2016. Out of 13,300 PJ in primary energy in 2015, ca. 8,900 PJ (70%) in final energy remained, due to conversion losses during power generation and transmission of ca. 30%.

Primary energy consumption in 2016 was comprised of 34% oil, 22.7% gas, 12.6% renewables, 12.2% black coal, 11.4% lignite and 7.5% nuclear energy. While the percentage of other energy carriers for primary energy consumption decreased from 2014 to 2016, oil, gas, and renewables increased their shares. The following table shows the developments of primary energy consumption from 1990 until 2016 including future milestones in 2020 and 2050.

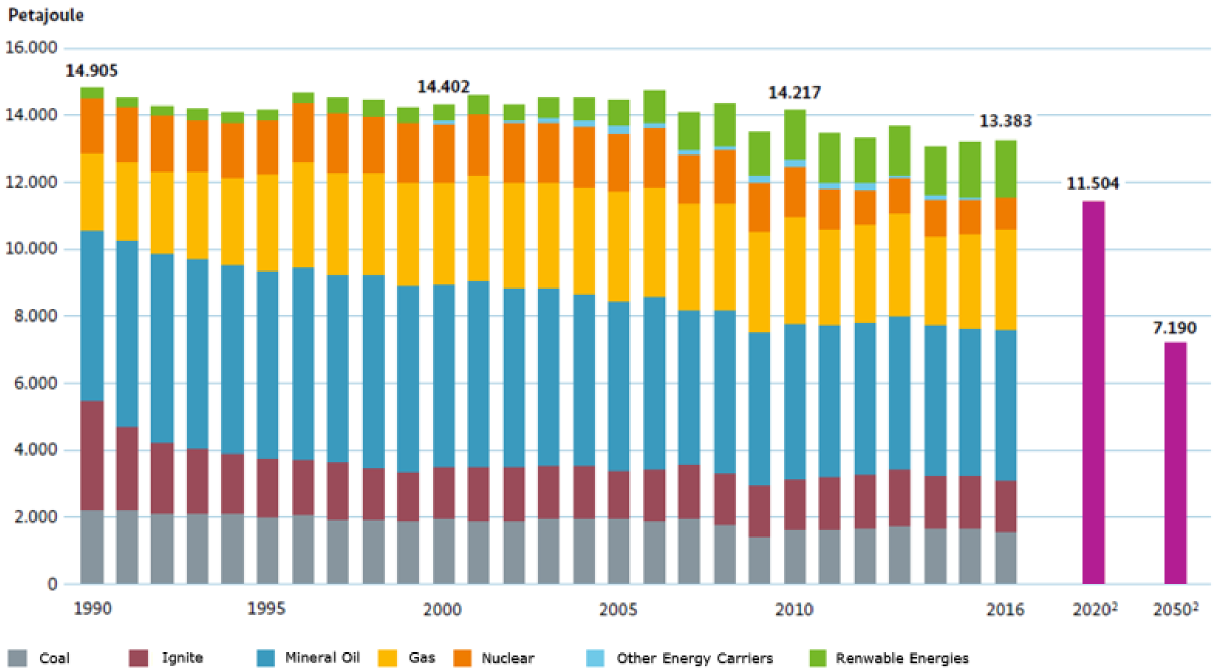

Figure 3: Development of primary energy consumption per energy carrier
(Source: UBA 2017 in BMWi 2017a, p. 13).

The figure below shows the development of final energy consumption per sector. In 2015, the transport sector consumed 29.5% (2,616 PJ) of final energy, the industrial sector used 29% (2,576 PJ), households used 25.8% (2,289 PJ) while the service sector consumed 15.7% (1,393 PJ).

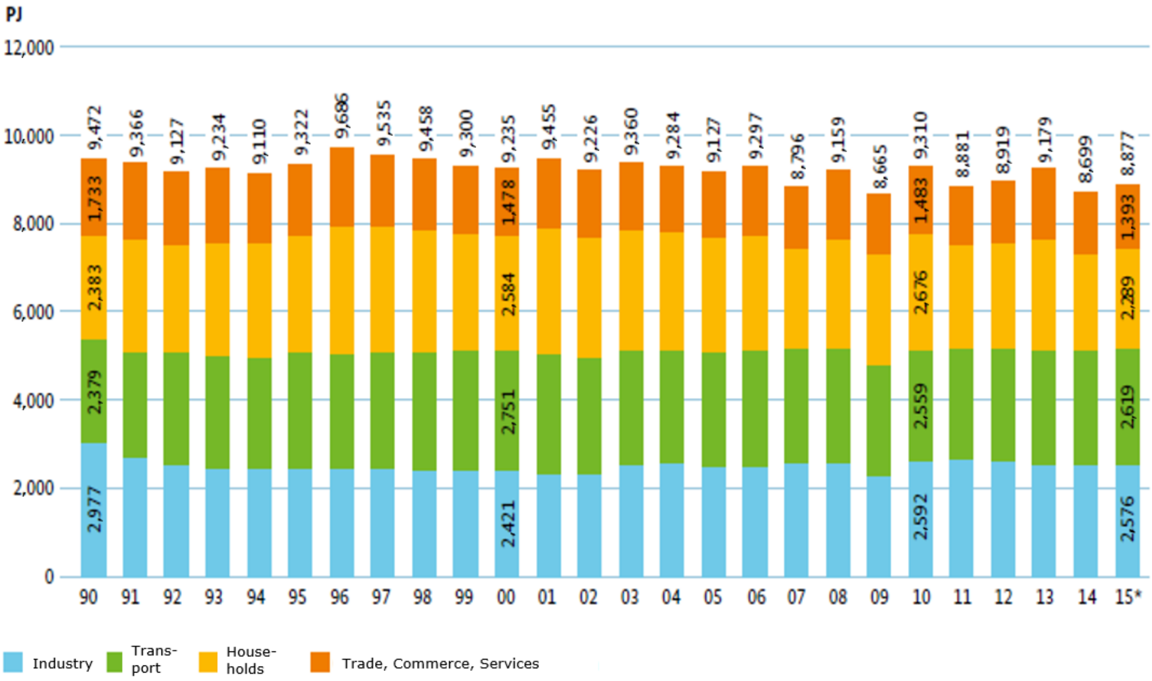

Figure 4: Development of final energy consumption per sector
(Source: UBA 2017 in BMWi 2017a, p. 18)

In 2015, **final energy consumption** totalled 8,877 PJ, the largest portion of which was oil 37%, followed by gas 24%, electricity 21%, renewables 6.9%, black coal 4.2%, and lastly lignite and other sources at less than 1% each. With the exception of transport, the absolute consumption in households, industry, and trade and services has decreased since 1990 (as of 2015).

Gross annual electricity generation now hovers around the levels achieved in the years 2006, 2007, 2008. In 2016, electricity production stemmed from coal (17.2%), lignite (23.1%), oil (0.9%), gas (12.4%), nuclear energy (13%), renewables (29%) and other sources (4.2%).

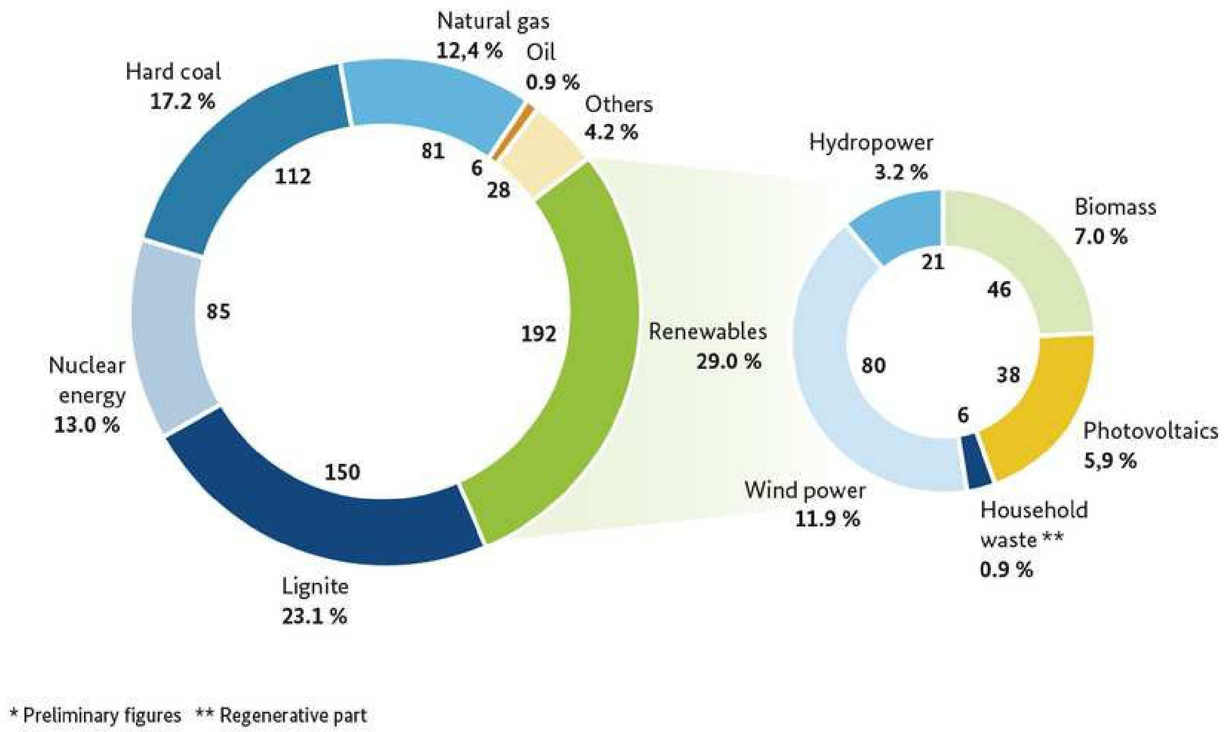

Figure 5: Gross electricity generation in Germany in 2016 in TWh
(Source: BMWI 2017c)

Energy efficiency has also, with a few exceptions, risen since 1990. Primary energy consumption per capita has dropped from 187 GJ/capita in 1990 to 162 in 2015. Energy productivity, the real gross domestic product (GDP) per unit energy consumption, has increased by more than 53.6% since 1990. The average annual increase from 1990 to 2015 was 1.7% per year. While GDP has increased by 43.9% during that time, energy consumption was reduced by 6.3%. The following table shows the development of final energy consumption and energy productivity between 1990 and 2015.

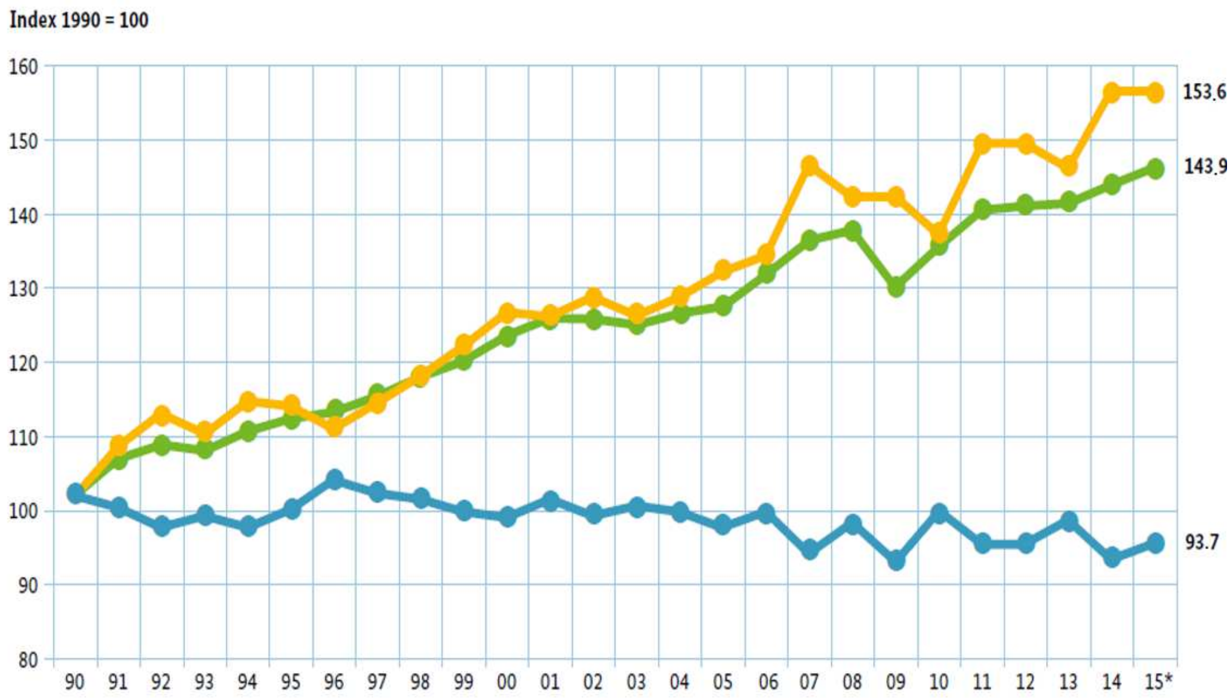

Figure 6: Final energy consumption and energy productivity
(Source: UBA 2017 in BMWi 2017a, p. 17)

The largest share of final energy consumption (3,441 PJ, 38.8%) was used in the production of mechanical energy, followed by space heating (2,408 PJ, 27.1%) and process heat 1,917 PJ (21.6%).

2.4 Energy efficiency potentials in Germany

This chapter gives an overview of the size of the cost-effective, energy end-use efficiency potential across sectors in Germany. More details of the potentials in the respective sectors are shown in the sector specific chapters 3 to 7. The analysis is based on data of saving potentials until 2030 (cf. Fraunhofer ISI, TU Vienna, PwC 2014a). This is one of the most current potential studies available for Germany. Further potential studies are available such as ifeu, Fraunhofer ISI, et al. 2011; Fraunhofer ISI, Ecofys et al. 2012; Fraunhofer ISI, Prognos et al. 2014, however, they are based on different time horizons, assumptions, baselines and other indicators.

The academic literature distinguishes four different types of potentials. These are the physical, technical, economic and achievable potential. The *physical potential* gives an estimate of the theoretically possible savings. The *technical potential* considers the technical engineering limitations. The *economic potential* considers economic restrictions in addition to the technical limitations and makes assumptions about the lifetime of measures and opportunity costs. The *achievable potential* describes the potential that can be realistically achieved by a very aggressive intervention. In addition to economic restrictions achievable potential also considers information deficits, organisational obstacles (user/investor dilemma) and other barriers to implementation that cannot fully be overcome by policies.

The following figure depicts the technical saving potential for Germany by sector (transport, industry, tertiary sector and households), analysed by Fraunhofer ISI. It shows that technically final energy consumption in Germany could be reduced by about half within just 20 years. This is equivalent to an improvement of final energy productivity of around 3.5% per year, in addition to what current trends and policies would achieve. More than three quarters of this potential was also estimated to be cost-effective (achieving net economic benefits over the lifetime of the technologies) by the authors of the study.

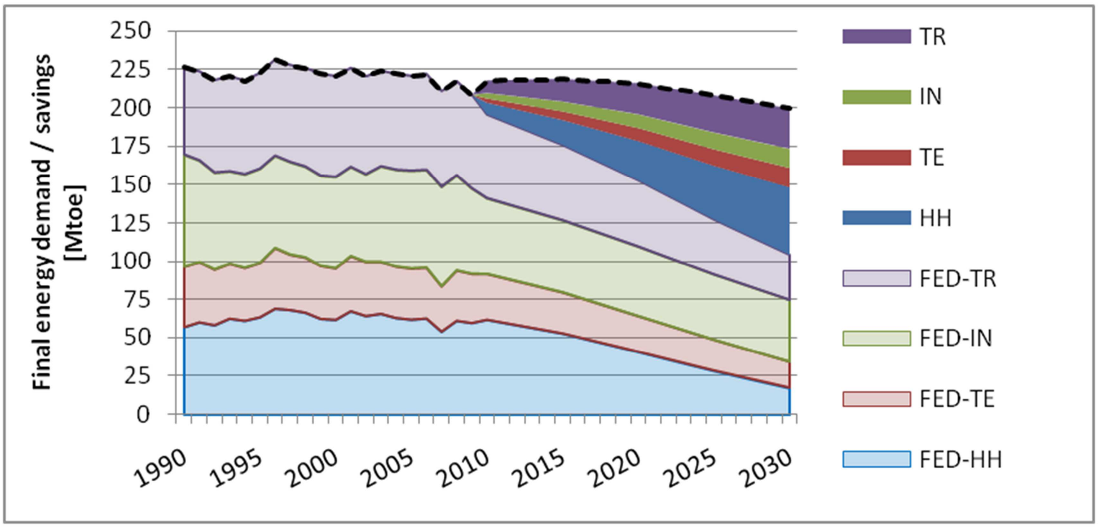

Figure 7: Technical energy saving potentials in Germany, by sector
(Source: Fraunhofer ISI 2012a, p. 182)

As this report focuses on policy measures, it was decided to use a policy-based scenario for the potential analysis which already includes the impacts of existing policy measures and therewith the economic potential and not solely the technical potential. In addition, the policy-based scenario is the most recent analysis available. Therefore, the study by Fraunhofer ISI, TU Vienna, PWC (2014a, b) which evaluates efficiency policies in the EU Member States and provides scenarios on how final energy needs to be developed in different baseline scenarios and in potential scenarios for 2020 and 2030 for each EU Member State is used for the depiction of saving potentials until 2030. Efficiency potentials in a high policy intensity (HPI) scenario are depicted below. The high policy scenario contains low sector-specific discount rates while barriers are partially or completely removed. The following table gives an overview of the discount rates used in both the HPI scenario and the reference scenario (base_WM), which includes the existing policy measures. For space heating and hot water, the discount rates are distinguished between countries and different investor types.

Table 1: Overview of discount rates used

Sector	Scenario	Discount rates
Households – space heating and hot water	HPI, base_WM	3.1% to 3.7%
Tertiary – space heating and hot water	HPI, base_WM	4.7% to 5.4%
Household - appliances	HPI	2% (assuming removal of barriers from 2020)
Tertiary – appliances	base_WM HPI	30% 5%
Industry	HPI	Payback up to 5 years accepted by 60% of companies; heating systems 15%
Transport	N/A	N/A

(Source: Fraunhofer ISI, TU Vienna, PWC 2014a, p. 89)

The high policy intensity scenario shows economic potentials that require ambitious efficiency policies to be realised. It is evaluated against a baseline scenario ("baseline with measures" base_WM), which includes measures that have been implemented in 2014 or were about to be implemented (Fraunhofer ISI, TU Vienna, PWC 2014a, p. 82f.).[6] By calculating the difference between the two scenarios, the efficiency potentials that are deemed achievable through the additional policies assumed for the HPI scenario until 2030 can be estimated.

To ensure comparability with the PRIMES projects, drivers such as the international fuel prices, the energy wholesale prices, the number of dwellings and the carbon prices were adapted from PRIMES 2013 in the scenario. Based on the international fuel prices and country-specific electricity wholesale prices, the end-use energy prices were projected based on historical country- and sector-specific tax rates. The following table gives an overview of international fuel prices.

Table 2: International fuel prices (in €'10 per boe)

Fuel	2010	2015	2020	2025	2030
Oil	60.0	86.0	88.5	89.2	93.1
Gas	37.9	53.8	61.5	58.9	64.5
Coal	16.0	22.0	22.6	23.7	24.0

(Source: PRIMES 2013)

Total savings potential for all sectors, including transport, until 2030 is estimated at 1158 PJ final energy (Fraunhofer ISI, TU Vienna, PwC 2014b, p. 25). The largest savings potential lies in the buildings sector with 417 PJ, corresponding to about 36% of the total savings potential. This is equivalent to 19% of the energy consumption in the baseline scenario. The transport sector has a

[6] The following models were used in the study to estimate savings: INVERT/EE_Lab for buildings, FORECAST for the industrial, residential and service sectors and the ASTRA model for the transport sector.

savings potential of 275 PJ which is equivalent to 14% of the baseline scenario. The appliances and the industry sector have savings potentials of 244 PJ and 222 PJ respectively, which are equivalent to 19% and 10% of energy savings. Figure 8 presents these potentials by sector, while Figure 43 in the comparison part of this study compares the base year consumption, the baseline scenario, and the HPI scenario.

It should be noted that this is only a part of the technical energy efficiency potential that would exist until 2030 (cf. figure 7), and that further energy efficiency potential exists until 2050. Especially in the buildings sector, renovation cycles providing opportunities to achieve energy efficiency potentials are often 30 to 40 years long. The report on GJETC Strategic Topic 1 provides more data on energy efficiency potentials and energy demand modelled in scenarios for 2050.

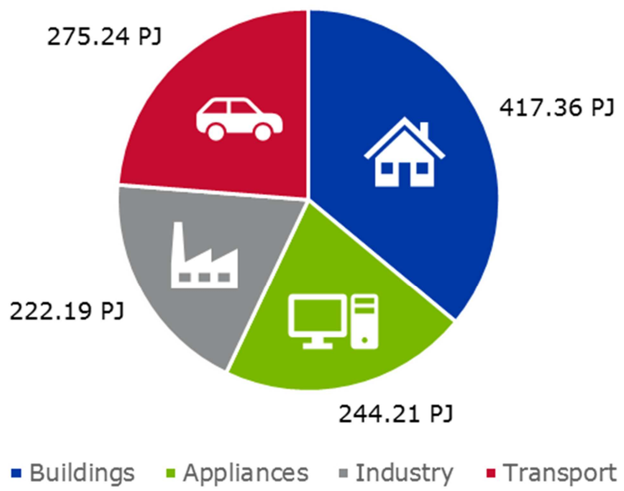

Figure 8: Energy saving potentials in Germany from ambitious new policies vs. existing policies until 2030 (in PJ)
(Source: Fraunhofer ISI, TU Vienna, PwC 2014b)

3 Buildings

- ***The buildings sector must be virtually climate neutral by 2050. To reach this target, renovation rates need to be doubled.***

3.1 Energy statistics and developments

The buildings sector in Germany is responsible for 35% of final energy consumption and one third of greenhouse gas emissions. The final energy consumption of households totalled 2,289 PJ in 2015. The share of renewable energies in the heating sector is about 13.4% (BMWi 2017a). In Germany about 5.5 million apartments are connected to district heating, especially in the larger cities in the north and east of Germany. This corresponds with approximately 13.5% (2015) of heat supply (bdew 2016).

The average household in Germany is composed of 2.01 people and with the exception of 2012, the number of households has risen consistently since 1990, reaching 40.3 million in 2015 (Eurostat 2016). The housing stock and amount of living space has also increased steadily since 1990. The living space per inhabitant increased only between 2000 and 2014 from 39.5 m² to 46.5 m². One reason for this was the increase in one-person households, but also the tendency to remain in larger family homes in old age.

The efforts of the German government to develop energy efficiency policies and measures in buildings used to be predominantly focused on residential buildings as data on non-residential buildings was largely absent (BMWi 2014a). In recent years, however the German Government has made considerable efforts to improve the data on the non-residential building stock and also introduced more policies targeting it, e.g. with financial support for energy advice and energy efficiency investments.

The German building stock is quite old, which leads to the fact that out of the 19 million residential buildings with ca. 40 million apartments, 50% have to be renovated in the next 20 years (BMWi 2017b).

The following figure gives an overview of the distribution of the building stock per age of the building

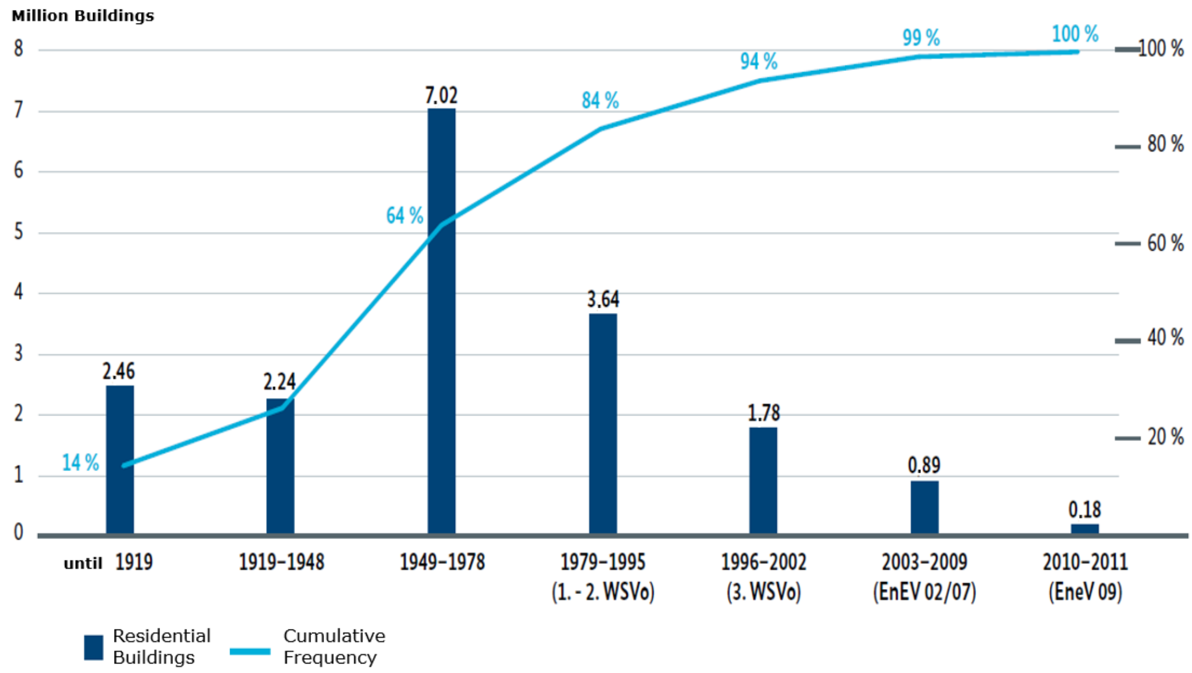

Figure 9: Distribution of the building stock per age of building
(Source: Wohnen und Bauen in Zahlen in BMWi 2014a)

The structure of the buildings sector is very heterogenous, with 83% of the residential building stock being comprised of one-and two-family houses. Multi-family dwellings only make up 3 million of the building stock, yet 53% of all apartments. Additionally, the building market in Germany is dominated by renters, which traditionally make up close to 60% of the population, while 40% own an apartment or a house (Destatista 2013). This is an important factor to consider for energy efficiency improvements in the existing building stock as the split incentive between landlord and tenant has a large effect. This barrier is discussed in section 3.3.

Compared to the residential building stock, estimates on the total number of non-residential buildings vary. Without buildings for the industrial sector, the total number of non-residential buildings is assumed to be 2.7 million (dena 2015). Industrial buildings are estimated to be around 300,000 to 600,000. Additionally, 3.8 million buildings have a mixed usage. A large share of the non-residential building stock is also rather old. It is estimated that 80% of buildings used for commerce are older than 40 years. Due to the economic revival after the reunification of Germany in 1990, more than 38,000 new non-residential buildings were built annually until 2005. After 2005, this rate declined and remains constant at around 27,500 since 2013 (dena 2015). In total, non-residential buildings are responsible for around 37% of the energy demand within the building stock.

3.2 Potentials

As new-build rates are quite low in Germany (between 0.5 and 1% per year relative to the existing stock) and the stock is quite old, most potential rests with renovation of the existing stock. The technical and economic potential is high. In Germany's heating-dominated climate, new very energy-efficient buildings, such as Passive Houses, now need around 90% less heating energy than before 1970 vintages (cf. Figure 10 below which shows 'Research (Model projects)' with building concepts achieving zero or below net heat demand while relying on building-integrated renewable energies to cover the remaining 10% of heat demand). Although this cannot normally be achieved in renovation of existing buildings, there are model projects achieving up to 80 or 90 % savings at least in primary energy for heating and cooling, and more than 50% is easily achieved in most pre-1970 buildings[7].

The energy savings potential that can be achieved with additional policies relative to the baseline in the building sector until 2030 is estimated at 417 PJ. This is split into 332 PJ for residential buildings and 85 PJ for tertiary buildings (Fraunhofer ISI, TU Vienna, PwC 2014b, p. 25), of which 75% can be realised by renovating existing buildings. The HPI scenario assumes renovation rates from 1.4% to 2.5%[8]. The share of renovation depth in total renovation activities is presented in the following table.[9]

Table 3: Share of renovation depth on total renovation activities in 2030

Building	Type	Base_WM	HPI 2030
Residential	Share of standard renovation	65%	25%
	Share of 'deeper' renovation	21%	32%
	Share of ambitious renovation	15%	43%
Tertiary	Share of standard renovation	72%	33%
	Share of 'deeper' renovation	16%	24%
	Share of ambitious renovation	13%	43%

The following table shows the estimated energy consumption in the baseline scenario, the high policy intensity scenario as well as the resulting absolute and relative potentials for energy savings.

[7] Cf, eg, the database of the German energy agency at https://effizienzhaus.zukunft-haus.info/effizienzhaeuser/
[8] All values average from 2008-2030, differing between building categories.
[9] Numbers were rounded. 'Deep' renovation means very energy-efficient renovation.

Table 4: Energy saving potentials in the buildings sector until 2030[10]

Building type	Energy saving measures/technologies	Energy consumption Base_WM in 2030 (in PJ)	Energy consumption HPI in 2030 (in PJ)	Absolute energy savings until 2030 (in PJ)	Relative Energy Savings until 2030
Residential	New buildings	118	93	26	22%
	Existing buildings	1266	990	276	22%
	Hot water	288	250	38	13%
Tertiary	New buildings	38	32	6	15%
	Existing buildings	446	374	72	16%
	Hot water	61	55	6	10%
Total		**2217**	**1794**	**424**	**19%**

3.3 Barriers

In the buildings sector, financial and informational barriers present a large obstacle for realising energy efficiency. For many market players, energy consumption is not yet an important decision criterion, which often leads to sub-optimal actions and therewith lock-in effects. Underlying reasons are a lack of awareness, anticipated inconvenience during the renovation period or lacking visibility of energy efficiency technologies. Property owners often have insufficient knowledge of energy savings potentials and are not certain whether renovation measures will bring the anticipated savings. This is often aggravated by the split incentive between landlord and tenant. Additionally, measures in the building sector are very costly and access to loans is associated with administrative effort. The following table summarises main existing barriers (cf. Fraunhofer ISI, Ecofys, Öko-Institut, IREES 2016):

[10] Saving potentials include heating and hot water, but not lighting and ventilation. Lighting and ventilation are counted towards appliances for residential buildings and in industry for tertiary buildings.

Table 5: Barriers in the building sector

Barrier type	Individual barrier	Relevant	Actors
Informational	Building stock given an incorrect classification (too good)	very high	Private property owner, housing association
	Insufficient knowledge of energy savings potentials	very high	Private property owner, renter
	Difficulty of finding good auditors and builders is overestimated	high	Private property owner, renter
Financial	Insufficient own capital	very high	Private property owner, renter, housing association
	Insufficient access to loans	high	Private property owner, renter, housing association, financial institutions
Behavioural	Landlord-tenant problem	high	Private property owner, renter
	Lacking trust in energy efficiency auditors (lacking qualifications)	high	Private property owner, auditor
Operational	Refurbishment schedule might lead to lock-in effects	medium	Government, Private property owner, renter, housing association
	Relatively old building stock, which requires large number of refurbishments/renovations	medium	Government, Private property owner, renter, housing association

3.4 Policies

In November 2015, the German government adopted the Energy Efficiency Strategy for Buildings (ESG) that shows how both, energy savings and the use of renewable energies can be systematically analysed and incorporated into an integrated approach. It includes the areas of electricity, heating, and efficiency and serves as an overarching strategy for the sector. It also incorporates two scenarios ('Energy Efficiency' and 'Renewable Energy'), which were used to illustrate the goal of having a nearly climate neutral building stock by 2050 and a corridor within which the desired reduction in primary energy consumption can be achieved.

For years, the government has followed the three-pronged approach of 'Inform, Support, Regulate' and will continue this approach in the future. In order to overcome existing barriers, a consistent policy package is necessary. A policy package combines a governance framework including strategies, concepts, institutions and all types of policies (regulatory, financial, information, capacity building, research and development).[11]

By combining both energy savings and the use of renewable energies, Germany aims to achieve an 80% reduction in primary energy consumption of buildings by 2050. The instruments currently used in this realm have, for the most part, reached out to building owners and created incentives for energy saving construction investments. The success of Germany's approach can be seen in the fact that absolute energy consumption is declining and facilitating the decoupling of building use and energy consumption. In addition, the increase in the share of renewables in final energy consumption has and will continue to significantly reduce carbon emissions in Germany's buildings sector. Despite these advancements further measures and instruments are needed to meet the ambitious goals. The challenge Germany faces is to successfully meet its *Energiewende* targets while at the same time addressing increased demand for affordable housing and ensuring that the solutions implemented are feasible and affordable.

The Energy Efficiency Directive and the German Energy Service Law (EDL-G) confer a special role in the improvement of energy efficiency to the public sector. Therefore, economic energy efficiency measures, which lead to comprehensive energy savings in the shortest possible time, have to be implemented by the public sector. Although the public sector accounts for a relatively small share of the total final energy consumption, there are considerable energy savings potentials, for example, in the areas of energy efficient renovation of public buildings. In Germany, which is comprised of 16 federal states and some 11,000 municipalities, along with the Confederation, the former are of great importance in increasing energy efficiency. All sub-national units combined account for about two-thirds of the total energy consumption of the public sector. In 2011, the public sector was responsible for 11.6% of investment in buildings (BfEE 2017a).

[11] More detailed analyses on how to address barriers can be found at http://www.bigee.net/, or Ecofys, Wuppertal Institut, Ifeu (2017): Weiterentwicklung der Energieeffizienzpolitiken zur Erreichung der Klimaschutzziele der Europäischen Union bis 2050. For Umweltbundesamt.

The following table gives an overview of the main policy instruments in the building sector and indicating the type of measure. The measures are further described below:

Table 6: Overview of policy measures in the building sector

Type	National-level Instrument
Regulatory	Energy Conservation Act (EnEG) / Energy Conservation Ordinance (EnEV)
	Renewable Energies Heat Act (EEWärmeG)
	Heating Cost Ordinance
	Tenancy law (rent increases allowed following modernisation)
Financial	Energy efficient buildings: CO_2-Building Renovation and New Build Programme – KfW support programmes and "Renewable energy" Market Incentive Programme KfW-Programme: Energy efficient building and refurbishing (non-residential buildings)
	"Energy Efficiency" Market Incentive Programme
	Tax deductibility of craftsmen's bills
	Subsidies for Informational measures: On-site consulting, energy check
Informational	Energy Performance Certificates
	National heating label
	"Energy-saving meters" pilot programme
Research & Development	The "Energy in buildings and neighbourhoods" research network
	The Energy-Optimised Building (EnOB) research initiative
	The EnEff:Stadt/Wärme (energy-efficient city/heat) research initiative
	The "Energy in buildings and neighbourhoods" research network

Regulatory instruments

Energy Conservation Act (EnEG) / Energy Conservation Ordinance (EnEV): Both of these pieces of legislation are key instruments of the German government's energy efficiency policy and address state of the art energy-savings requirements for buildings. The revised version of the EnEV entered into effect on 1 May 2014. One of the requirements contained in this legislation is the decrease in the maximum allowed primary energy demand for new buildings by 25% on average, which is effective as of 1 January 2016. The allowed primary energy demand is compared to a "reference house" with a specific floor area, window size etc. For example, primary energy consumption of a one family house is approx. 56-96 kWh/m²a, of multi-family house ca. 60 kWh/m²a. This requirement is a transposition of EU's Energy Performance of Buildings Directive and represents a step towards the nearly zero-energy building standard, which according to the EPBD, will be standard for new public sector buildings in 2019 and all buildings in 2021.[12] Through the implementation of the EnEV it is expected to achieve final energy savings of 103 PJ (cumulative for 2014-2020) for new buildings and 316 PJ for existing buildings (see NEEAP 2017). The effectiveness of the EnEV requirements for new buildings is considered as high.

Renewable Energies Heat Act (EEWärmeG): Since coming into effect on 1 January 2009, the EEWärmeG has required building owners to meet a portion of the heat demand of new buildings with any form of renewable energy. The public sector is required to use renewables in large-scale renovations of its building stock. Through this law the share of renewable energy in heating and cooling should be increased to 14% by 2020. Through the implementation of the EEWärmeG it is expected to achieve final energy savings of 24 PJ (cumulative for 2014-2020) (see NEEAP 2017).

Heating Cost Ordinance: This ordinance is part of energy saving legislation and regulates the metering, distribution and accounting of heating costs and hot water between tenants and landlords. The introduction of the Heating Cost Ordinance has contributed towards an average reduction in energy consumption of around 15%. Efforts are currently underway to examine the extent to which updating and upgrading the rules for accounting and/or user information, whilst fulfilling the requirement of economic efficiency, can make a reasonable contribution towards energy savings above and beyond this level.

Tenancy law: The right to increase rents after modernisation (section 559 of the German Civil Code (BGB)) is an important economic precondition for energy-saving modernisation of existing leasehold property. A revision of the option to increase rents after modernisation must ensure that housing remains affordable for the tenants on the one hand and that incentives for landlords to invest are not reduced on the other.

Financial instruments

"Energy efficient buildings": Since May 2017, the following two programmes (CO_2 building renovation programme and "Renewable energy" Market Incentive Programme) have been combined under the programme "Energy efficiency buildings". According to the principle - the more ambitious the investment, the more attractive the subsidy, there are subsidies for the "easy entry" into energy saving measures, as well as for holistic, comprehensive renovation measures.

> *CO_2 building renovation programme:* The CO_2 building renovation programme is a central promotional instrument for energy saving and climate protection in the buildings sector. Funds from the CO_2 building renovation programme are used to finance promotional programmes of

[12] See also Example 1: Energy Savings Ordinance for further information (Figure 10).

KfW for energy-efficient building and renovation. Funds are available for new buildings and comprehensive renovation with the aim of achieving the so-called KfW Efficiency House standard as well as energy-efficient individual measures in existing buildings.[13] The promotional standards of these programmes go significantly beyond the requirements of the energy saving legislation. The CO_2 building renovation programme also provides special promotional rates for best practice projects (for instance, via model projects). The Federal Government uses the promotional lever that is available in this respect in order to speed up the dissemination of efficient and innovative projects, such as the KfW energy-efficient buildings 40 and 55.[14]

"Renewable energy" Market Incentive Programme: The Market Incentive Programme is a central instrument designed to promote renewable energy in the heat area. Since 2009, the support programme has been anchored in section 13 of the Renewable Energies Heat Act which provides for support for renewable energy for heating and cooling. The programme contributes to increasing the share of renewable energy in the heat sector to 14% by the year 2020 and is additionally making an important contribution towards achievement of the goal of a virtually climate-neutral building stock by 2050. The Market Incentive Programme promotes, for instance, solar panel installations, biomass plants, heat pumps, deep geothermal energy plants, heat grids fed from renewable energy as well as large heat storage systems for renewable energy. The amended Market Incentive Programme came into effect on 1 April 2015 and sets forth new and improved conditions for support.

KfW-Energy efficient constructing and refurbishing for non-residential buildings: KfW makes loans up to 25 million EUR available for building and renovation of non-residential buildings.

"Energy Efficiency" Market Incentive Programme: The "Energy Efficiency" Incentive Programme replaces the tax support scheme for energy-efficiency building renovation measures that was originally planned in the National Action Plan on Energy Efficiency (NAPE). The support volume totals EUR 165 million per annum. The programme supports: the introduction to market of innovative fuel cell heating systems; the installation of ventilation systems in conjunction with measures for the building envelope in order to avoid damage to the building (for instance mould); and the replacement of inefficient heating systems with efficient ones. This includes measures to optimise the heating system (heating and heat distribution) which address the entire efficiency potential of the heating system, as well as a quality, efficiency and outreach initiative. The programme is expected to achieve 18 PJ in final energy savings (cumulative 2014-2020) (see NEEAP 2017).

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[13] See also Example 2: KfW programmes, Figure 12

[14] The Energy Saving Ordinance sets the benchmark for the 'KfW Efficiency House 100'. However, it is possible to build houses that are even more energy efficient. While a 'KfW Efficiency House 100' meets all of the statutory minimum requirements; an 'KfW Efficiency House 70' needs no more than 70% of the energy a 'KfW Efficiency House 100' would need. A 'KfW Efficiency House 55' needs even less than that, namely 55% of the 'KfW Efficiency House 100'. KfW provides funding for the construction of new residential buildings that meet the 'KfW Efficiency House 40, 55 or 70' standards.

Tax deductibility of craftsmen's bills: Owner-occupants and tenants can deduct 20% of the labour costs – maximum of EUR 1,200 – of craftsmen's bills from their income tax bill (section 35a (3) of the Income Tax Act (EStG)) unless other public funds were received. Landlords can treat the costs of energy-saving renovation measures as maintenance costs and thereby reduce their tax bill, often reducing taxable income by the full amount of such costs.

Financial support for personal energy advice: 60% of the costs for personal energy advice are borne by the Federal Ministry for Economic Affairs and Energy (BMWi). The funding application is done by the energy consultant and not the building owner.

Informational instruments

Energy Performance Certificate: The Energy Conservation Ordinance (EnEV) prescribes energy performance certificates for assessing the energetic status of buildings, whenever these are sold or rented out. The certificates contain general information on the building, energy sources used for heating (e.g. gas, oil) and the energy characteristics of the building. New certificates for residential buildings also have an energy efficiency class from A+ to H. The energy performance certificate intends to allow comparisons between buildings throughout Germany. However, no direct conclusions can be drawn about the expected energy consumption and energy costs because many dependent factors are not reflected in the certificate.

Energy consulting: Various energy consulting providers are available in Germany. Among them are for example "energy checks". This is a consulting program, funded by the Ministry for Economic Affairs and Energy and run by the Federation of German Consumer Organisations, that allows tenants and house owners to bring in experts to examine their homes for energy conservation opportunities. Energy checks are free for low-income households. All consulting programmes for the building sector (including advice for SMEs) are expected to achieve final energy savings of 49 PJ (cumulative for 2014-2020) (see NEEAP 2017).

Heating label: Since autumn 2016, the EU energy label for new heaters is compulsory. The label indicates the efficiencies of the various options on sale to consumers who want to buy a new heating system. Additionally, the German government introduced a label for existing old heating systems which uses the same logic as the labelling method applied to new heaters. Supporting consumers in the application of the label, a webpage called "Heating Check" was also developed, where consumers can check the CO_2 emission and energy performance of their heating equipment. The programme is expected to achieve 23 PJ in cumulative final energy savings (see NEEAP 2017).

Main take-away messages

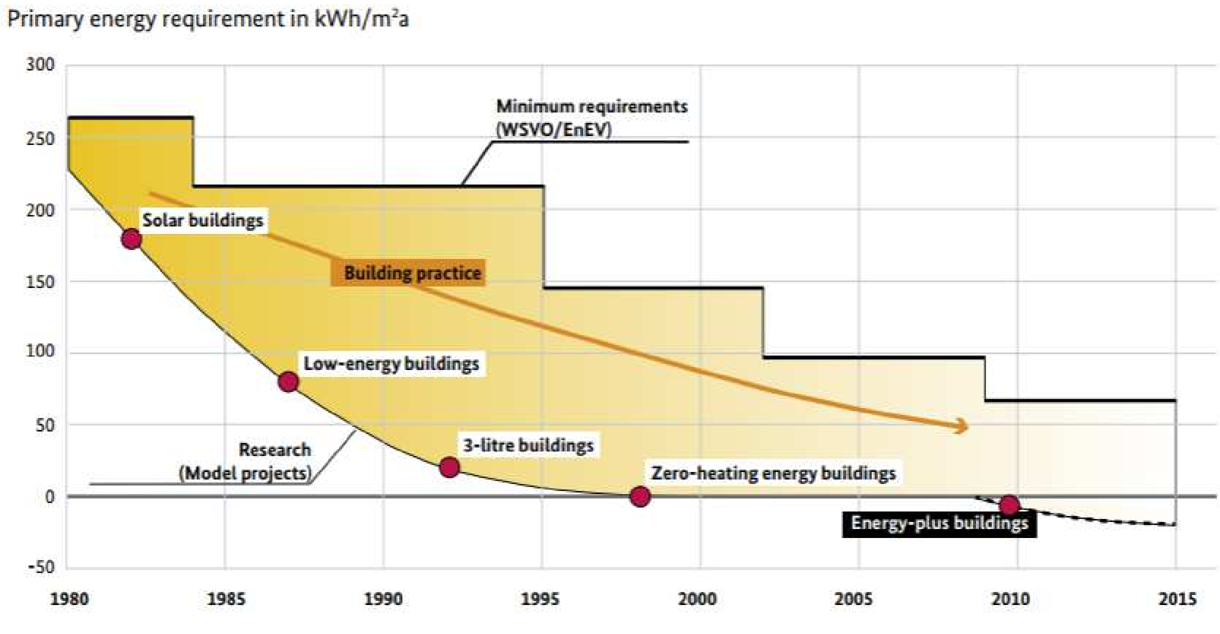
While a variety of subsidy programs and information are available in Germany, the landlord-tenant problem still represents a major barrier for the renovation of buildings especially given the high share of renters in Germany.
Additionally, given the old age and, hence, the low energy performance of the large existing building stock, deep renovations[15] are crucial to avoid a "lock in" effect of investments. Currently the renovation rate of buildings is around 1.1% per year. In order to meet energy efficiency targets, this rate needs to be increased to 2% or more. The German government has therefore introduced renovation roadmaps that outline which part of the building best needs to be renovated when. Nevertheless, in order to achieve renovation rates of 2% per year to reach the efficiency targets for the building sector, further policy implementation work is crucial.

[15] According to a study of the Global Building Performance Network (GBPN) deep renovations in Europe focus on heating, cooling, ventilation and hot water and define these "deep" renovation as retrofits with at least 75% energy savings.

Example 1: The Energy Saving Ordinance (EnEV)

Germany began to implement building codes as early as the 1970s due to pressures from the oil price crisis. These standards have been continuously tightened, while remaining technically and economically achievable, which makes it a best practice example. A comparison of the trajectories of legal minimum requirements and research activities in the building sector show that research results were successfully transferred into building practice and led to a continuous decrease in energy consumption. Already in the early 1980s solar houses were built, progressing into low-energy houses in the mid-1980s and eventually to 3 litre houses and zero-energy buildings in 1998. ENEV is expected to achieve final energy savings of 103 PJ (cumulative for 2014-2020) for new buildings and 316 PJ for existing buildings (see NEEAP 2017). The effectiveness of the EnEV requirements for new buildings is seen as high.

The following figure shows learning curves in the energy efficient buildings sector.



Sources: Fraunhofer IBP, BMWi.

Figure 10: Energy efficiency savings ordinance (Best practice example 1)

Example 2: KfW Programmes

The German state-owned Bank for Reconstruction ("KfW") manages two programmes to **improve the energy efficiency of German residential buildings**: the EEC (Energy-Efficient Construction) that targets the construction of new buildings and the EER (Energy-Efficient Refurbishment) that addresses the refurbishment of existing buildings. Both programmes offer financial products (upfront grants or soft loans, which may have a grant component) to building owners to overcome economic barriers (e.g. lack of sufficient loan financing or own upfront capital, short payback expectations) to realising energy-efficient investments.

The amount of **funding that is given out is tied to Germany's Minimum Energy Performance Standard** (also known as energy building codes).

For the refurbishment program, KfW defines six levels of support from KfW Efficiency House 115 to KfW House 55 (40 kWh/m^2a) (incl. KfW Efficiency House Monument). The figures indicate in percent how much of the maximum primary energy requirement specified by the Energy Conservation Ordinance (EnEV) the house consumes. The best standard (55) receives the highest support with a grant of up to EUR 30,000. In order to meet the high energy standard of a KfW Efficiency House, extensive investments such as the renewal of heating systems, thermal insulation and replacement of windows, are required. KfW provides funding for the construction of new residential buildings that meet the 'Efficiency House 40, 55 or 70' standards.

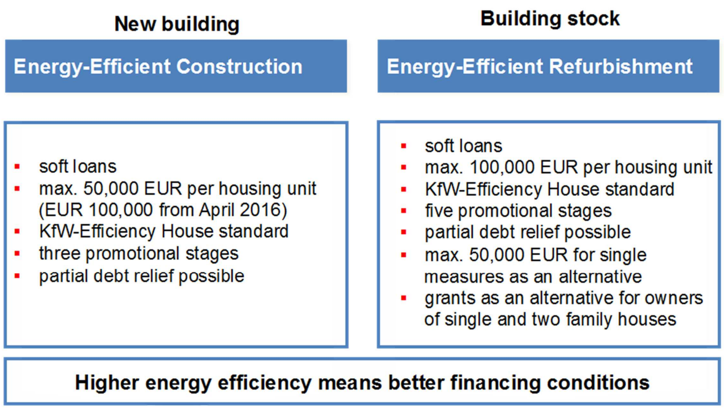


Figure 11: Overview of KfW's financing mechanisms for new and existing buildings
(Source: EEW 2016)

Due to government liabilities, KfW, an AAA-rated bank, can raise capital at low costs. In 2012, the Government allocated EUR 1.5 billion to finance the grants and reduced interest rates of loans in the scheme. Additionally, KfW raised EUR 8.4 billion for the efficiency programs. These add up to EUR 9.9 billion of loans and grants, which leverage another EUR 17.2 billion of investment. Furthermore, KfW makes use of local commercial bank offices to facilitate loans.

Between 2006 and 2014, 3.8 million homes underwent energy efficiency retrofits or were newly built in compliance with high energy efficiency standards in Germany. In 2013, the programme "Energy-efficient Construction" recorded 129,000 subsidy applications. This is more than 50% of all new residential buildings. Therewith, CO_2 savings of 94,000 tonnes of CO_{2eq} or energy savings of 1.2 PJ were achieved. The programme "Energy-efficient Refurbishment" recorded in the same period 276,000 subsidy cases, achieving savings of 650,000 tons of CO_{2eq} and 6.3 PJ of energy. In total, these two programmes save the equivalent of 744,000 tCO_{2eq}/a (BMWi 2015d; Institut Wohnen und Umwelt, Fraunhofer IFAM 2014).

Tying the funding to the Minimum Energy Performance Standard and the common availability of funds makes this a best practice example.

Figure 12: KfW Programmes (Best practice example 2)

4 Appliances

- ***The implementation of the EU Ecodesign and Labelling Directives are the main regulatory policies for appliances.***

4.1 Energy statistics and developments

In German national statistics, appliances are not listed as a separate category, hence, the information must be compiled from different sources to create a well-rounded picture of this sector. The specific electricity consumption of most major household appliances in Germany decreased considerably between 1991 and 2011. However, for TV sets an increasing trend was observed since 2006 accounting for the larger size of TV screens. Currently, nearly 7 million TVs are sold in Germany each year. More than 99% of all households have a refrigerator.

The following figure shows the specific consumption of new electrical household appliances from 1991-2010.

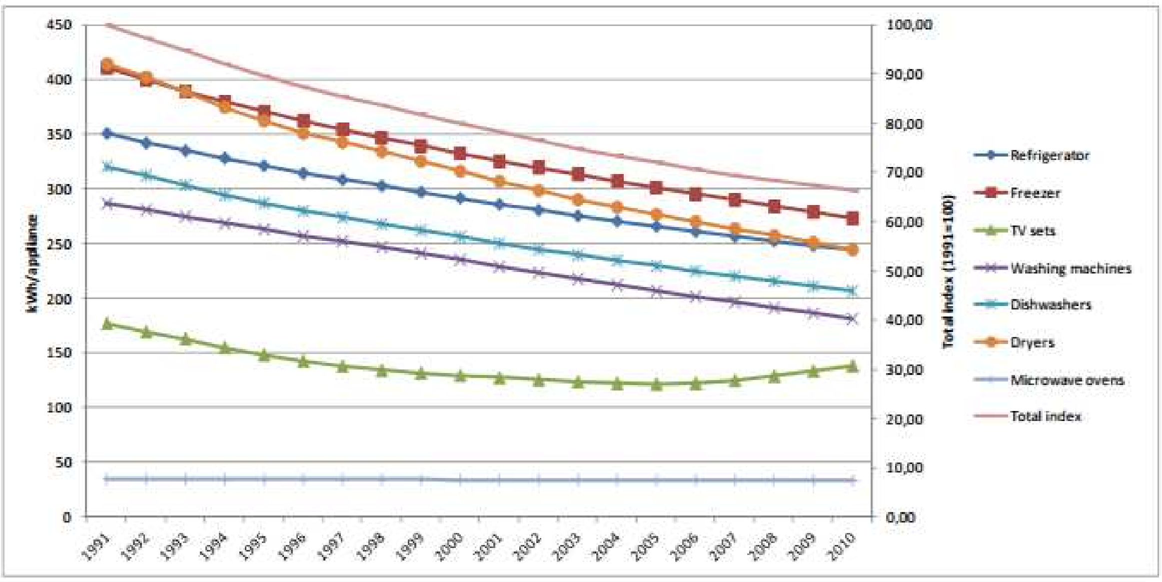


Figure 13: Specific consumption of new electrical household appliances from 1991-2010
(Source: Fraunhofer ISI 2012b, p. 19)

For the tertiary sector, large energy savings were achieved by improving the heat insulation of buildings, increasing the automation and process optimisation as well as improving the efficiency of appliances by modernising machinery and equipment used (UBA 2017).

4.2 Potentials

Looking at residential and tertiary appliances, the total savings potential for 2030 is estimated to be 244 PJ, where slightly more savings can be realised in the tertiary sector (Fraunhofer ISI, TU Vienna, PwC 2014b, p.25). The following table shows the estimated savings in the baseline scenario, the high policy intensity scenario as well as the resulting absolute and relative potentials.[16]

Table 7: Energy savings potentials in appliances until 2030

	Energy saving measures/technologies	Energy consumption Base_WM in 2030 (in PJ)	Energy consumption HPI in 2030 (in PJ)	Absolute energy savings until 2030 (in PJ)	Relative Energy Savings until 2030
Residential appliances	Various household appliances (IT appliances, non-IT electric appliances, lighting, & non-electric cooking)	422	309	113	27%
	Heating and cooling technology (electric cooking and air conditioning)	65	55	10	16%
Tertiary appliances	ICT in offices and data centres	59	56	3	6%
	Street lighting	18	12	6	33%
	Lighting	139	78	61	44%
	Cooking	25	20	5	20%
	Refrigeration	56	54	2	4%
	Ventilation and air-conditioning	53	26	28	52%
	Others	103	77	26	26%
Total				**244**	**28%**

[16] Numbers were rounded.

4.3 Barriers

Appliances are regulated EU-wide by the Ecodesign and Energy Labelling Directives. Especially the Ecodesign Directive involves a large number of stakeholders in the regulatory process, which makes it more transparent. This also means that tightening product standards takes a long time (cf. Energy Efficiency Watch 3). Also for some appliances, e.g. in ICT, technological developments are moving very fast, making it difficult to keep up with adequate standard setting. For purchasing decisions, energy and water consumption of appliances is only a secondary decision criterion for consumers and the energy label is often not well understood (BUND 2012). Additionally, the mind-set of consumers has shifted over the last decades and now products are rarely repaired, but substituted by new often even bigger appliances (INER 2015). Financial incentives for product replacements for poorer households are in place, yet further push and pull strategies are to a large extent absent.

Table 8: Barriers for energy efficiency in appliances

Barrier type	Individual barrier	Relevant	Actors
Informational	Lack of product-related consumer advice	very high	Government, manufacturers, associations, consumers
	Classification of energy labels not very well understood	very high	Government, consumers
	Poor reputation of EU energy efficiency standards caused by negative media coverage	Medium	Media; individual politicians, consumers
Financial	Product replacement schemes are largely absent[17]	very high	Government, manufacturers, consumers
	Financial limitations for poor households to busy energy efficient appliances	very high	Government, consumers
Behavioural	Tendency to buy larger, more energy-consuming products before end of lifetime	high	Government, manufacturers, consumers
	Tendency not to repair products, but buy new ones	high	Government, manufacturers, associations, consumers

[17] In the tertiary sector, several product replacement schemes for appliances are in place (e.g. for heat pumps).

4.4 Policies

Although, as already mentioned, the public sector accounts for a relatively small share of the total final energy consumption in Germany, considerable energy savings potentials can also be achieved in this sector with more efficient appliances. Around 4.5% of investments in efficient machinery, equipment and vehicles came from the public sector in 2011 (BfEE 2017a). Public purchasing decisions can therefore promote energy-efficient technologies and services and improve their overall market position. In order to overcome the large number of barriers, a policy package is necessary. A policy package combines a governance framework including strategies, concepts, institutions and all types of policies (regulatory, financial, information, capacity building, research and development).[18]

Table 9: Policy instruments for energy efficiency in appliances

Type	National-level Instrument
Regulatory	Energy Consumption-Relevant Products Act (EPPG), Energy efficiency Labelling Act (mandatory information measure)
	Top-Runner Programme
Financial	Heating pump replacement scheme
Information	Information campaigns: e.g. "Deutschland macht's effizient" (Germany does it the efficient way)

Description of key instruments

Energy Consumption-Relevant Products Act (EPPG), Energy efficiency Labelling Act: The label has turned out to be an effective consumer information tool. These two instruments are combined within the scope of the EU's top-runner strategy. The EPPG represents the national implementation of the Ecodesign Directive (2005/32/EC). The EU Ecodesign directive, for instance, with its staged increase in minimum requirements, fosters the gradual displacement from the market of products with relatively high energy consumption, and energy consumption labels for products support the market penetration of efficient products. These two tools in tandem create incentives for manufacturers to develop innovative, energy-efficient technologies and make energy consumption transparent for consumers. In order to strengthen energy efficiency even further, the German government supports the introduction of ambitious requirements for the respective product groups. At the same time, it must be ensured that the requirements are designed in a technology-neutral manner and that they are ecologically sensible and economically reasonable. This will enable a further reduction in energy demand.

[18] More detailed analyses on how to address barriers can be found at http://www.bigee.net/, or Ecofys, Wuppertal Institut, Ifeu (2017): Weiterentwicklung der Energieeffizienzpolitiken zur Erreichung der Klimaschutzziele der Europäischen Union bis 2050. For Umweltbundesamt.

National Top-Runner-Initiative (NTRI): The National Top Runner Initiative (NTRI) bundles measures to speed up the market penetration of high-quality services and products (top runners) that contribute to reducing energy consumption. The NTRI aims to mobilise energy efficiency improvements along the entire value chain. Besides facilitating a continuous stakeholder dialogue to identify further potentials for energy savings and to develop products to meet consumer needs, the EU Energy Star will also be integrated into NTRI. Around EUR 6 million in funding per year are provided by the German government. It is expected that 85 PJ in primary energy savings will be achieved until 2020.

Heating pump replacement scheme: Since August 2016, subsidies have been available for the replacement of heat pumps, hydraulic balancing and additional low-expenditure measures. Subsides cover 30% of the total investment costs.

Germany makes it efficient: An energy efficiency campaign capturing all sectors and highlighting programmes that offer efficiency funding and advice. The aim of the campaign is to provide all consumer groups with quick and simple access to the right information. This includes details on what efficiency measures are open to them, where they can obtain expert advice, and how much government support is available to them.

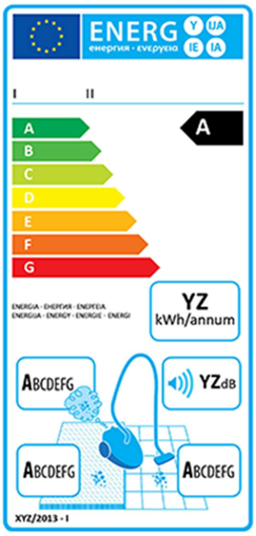
Main take-away messages

The implementation of the EU Ecodesign and Labelling Directives are the main regulatory policies for appliances. As shown in the following Example box, these standards and labels have had a large effect on energy savings - in Germany, both instruments are responsible for 80% of electricity savings. However, for several appliances, further improvements in energy efficiency are limited which will reduce additional savings.

As the development of new standards is a long and iterative process at EU level that involves various stakeholders, it often takes a long time. Additionally, while benchmarks are available for absolute consumption levels, benchmarks for the operation of appliances are often absent in the tertiary sector.

Example 3: The Ecodesign and Energy Labelling Directives

The **Ecodesign Directive** (2009/125/EG, ED) sets minimum energy efficiency standards for products and appliances. These standards are EU-wide, which means that manufacturers do not have to comply with disparate national legislations. Energy efficiency standards are developed through extensive product studies by examining market data, technological status, least lifecycle-cost options, and recommendations for the European Commission.



The **Energy Labelling Directive** (2010/30/EU, ELD) introduced a multi-colour **EU Energy Efficiency Label** to inform consumers and increase energy efficiency understanding of all energy-related products. Not only home appliances are included, but also products for commercial applications and products that do not consume energy, but have significant influence on energy consumption (e.g. windows).

The aim of the coloured EU Energy Efficiency Labels is to inform the consumer and to increase their understanding of energy efficiency. The prospective buyer should gain an improved information base and be aware of energy consumption or consumption of other essential resources available. In July 2015, the European Commission proposed a return to a single **A to G** (without "A+" or "A++") label scale that will enter into force by mid-2017.

Figure 14: Energy Efficiency Label
(*Source: EU Energy Labels 2015***)**

The impact assessment of the European Commission (2015) concludes that the ecodesign and energy labelling measures adopted by March 2015 save an estimated **7,327 PJ primary energy per year in 2020**, including rebound effects. In Germany, both instruments are responsible for 80% of the electricity savings in Germany due to state regulatory law (BMWi 2017a).

As of February 2017, **31 product groups** are covered by the Ecodesign Directive.

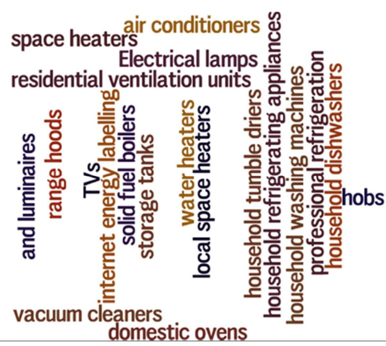


Figure 15: Ecodesign and energy labelling directives (Best practice example 3)

5 Industry

➢ ***The industrial sector does not have an explicit energy efficiency target, yet under Germany's long-term climate action plan, it needs to reduce its CO_2 emissions by 51-49% (compared to 1990) until 2030. This is equivalent to 140-143 $MtCO_{2eq}$.***

5.1 Energy statistics and developments

Final energy consumption of the industrial sector was 2,576 PJ in 2015 (BMWi 2017a). Energy productivity increased from 1991 to 2015 by 1.7% per year, totally 48.7%. In terms of application, process heat with 65% is the largest application for industry, followed by mechanical energy with 23%.

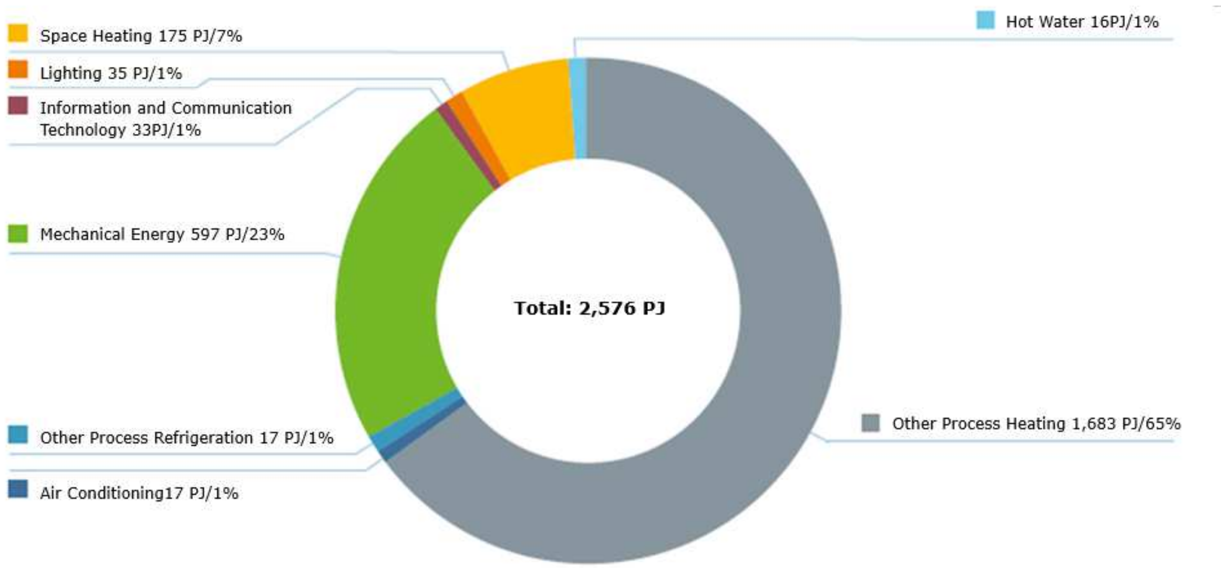


Figure 16: Final energy consumption per application in the industrial sector
(Source: UBA 2017 in BMWi 2017a, p. 21)

The final energy consumption of the different sectors varies enormously. The most energy-intensive sectors[19] in Germany are iron and steel, chemical and mineral industry as well as paper and pulp industry.

5.2 Potentials

For 2030, the total savings potentials in the industrial sector are estimated to be 222 PJ (Fraunhofer ISI, TU Vienna, PwC 2014b, p. 25). Cross-cutting electric measures (77 PJ) such as pumps, motors and lighting and cross-cutting thermal measures (73 PJ) such as waste heat recovery and cooling have the largest saving potential. This is followed by process-specific thermal measures (54 PJ). Process-specific measures for example include process optimisation by regular maintenance and modernisation of the combustion plants for non-ferrous metals as well as new drying processes in paper production, new cement grades, final dimensions in steel mills etc. (Fleiter et al. 2013). In terms of industry sector, the iron and steel sector as well as the chemical industry have the largest saving potentials with ca. 39 PJ each (ibid). The following table shows the estimated savings in the baseline scenario, the high policy intensity scenario as well as the resulting absolute and relative potentials.[20]

Table 10: Energy efficiency potentials in the industrial sector until 2030

Sector	Energy saving measures/technologies	Energy consumption Base_WM in 2030 (in PJ)	Energy consumption HPI in 2030 (in PJ)	Absolute energy savings until 2030 (in PJ)	Relative Energy Savings until 2030
Industry	Cross-sectoral electric measures	582	504	77	13%
	Cross-sectoral thermal measures	421	348	73	17%
	Process-specific electric measures	190	185	5	3%
	Process-specific thermal measures	823	789	54	7%
	Space heating	106	93	13	12%
Total				**222**	**10%**

[19] Energy-intensive industries are defined as companies whose energy intensity is more than 3%. This means that their energy costs are at least 3% or more of their total production costs (EU Directive 2008/1/EC).
[20] Numbers were rounded.

5.3 Barriers

The industry sector is confronted with a variety of barriers, of which some apply to all sectors, while each sector also has specific barriers. In smaller enterprises, information deficits play a major role in the financing of investments, whereas in larger enterprises, organisational aspects such as the distribution of responsibilities for energy efficiency or the in-house flow of information are inhibitive. The following barriers apply to the sectors (cf. Fraunhofer ISI et al. 2012):

Table 11: Barriers to energy efficiency in industry

Barrier type	Individual barrier	Relevant	Actors
Informational	Companies fear that external energy efficiency service providers do not know production processes well enough and might cause disruptions	high	Plant owner, energy efficiency service providers
Financial	High return of investment rates are expected (max. 2 years) for energy efficiency investments.	very high	Board of company
	Energy efficiency investments are in competition with other (more strategic) investments which do not have to meet the high return rates.	very high	Board of company
	Low energy tariffs for industrial companies due to tariff exemptions	very high	Government
	High transactional costs for the application to subsidy programs	high	Government, smaller enterprises
Behavioural	General fear of disruption in the production process when realising replacement of technology	high	Plant owner
Operational	Average lifetime of plants with 30 to 50 years	high	Plant owner
	Lack of dedicated energy efficiency personnel and lack of knowledge about profitability calculations and energy efficient technologies	high	Smaller enterprises
	Lack of interest in/awareness of energy efficiency, other priorities of companies´ decision makers	high	Board of company

5.4 Policies

The German energy intensive industry, which has the highest energy savings potentials in the industry sector, is covered by the EU ETS; however, the small and medium-sized companies (SMEs) are also an important part of the industry sector in Germany. In total, 3.67 million SMEs are registered in Germany, generating an annual turnover of up to EUR 500 million and representing 99.95% of all companies and employing 68% of the work force (KfW 2015d). Given this fact, SMEs play a large role in reaching the *Energiewende* targets and Germany has taken the approach of strongly supporting SMEs in realising energy efficiency potentials while at the same time ensuring their competitiveness. This is exemplified by the following policies.

Table 12: Energy efficiency policies in industry

Type	National-level Instrument
Market-based	Greenhouse Gas Emissions Trading Law (TEHG)
	Tendering model ("STEP-UP")
Regulatory	Special compensation regulation for electricity intensive companies & railways (according to §§ 63 ff. EEG 2014, electricity and energy tax law)
	Energy audits and energy management systems, implementation of Art. 8 of the EED through the Energy Services Law (EDL-G)
Financial	KfW Energy Efficiency Program – Production facilities/processes; construction and renovation and heat recovery
	KfW financing for energy efficient and climate-friendly production processes
	BAFA funding for highly efficient cross sectorial technologies
	Funding for energy management systems for SMEs
Energy service markets	Energy Services Law (EDL-G)
Informational	Energy Efficiency Networks
	Energy consulting for SMEs
	Consulting for performance contracting
	Top-Runner Strategy
	Campaign Germany makes it efficient (Deutschland macht's effizient)
Research & Development	6th Energy research framework program
	Research for an Energy Efficient Industry
	BMUB's Environmental Innovation Programme

In order to overcome the large number of barriers, a policy package is necessary. A policy package combines a governance framework including strategies, concepts, institutions and all types of policies (regulatory, financial, information, capacity building, research and development).[21]

Description of key instruments

Market based instruments

Greenhouse Gas Emissions Trading Law (TEHG): The TEHG implements the EU emissions trading system (EU-ETS) into national law. The EU's emissions trading system is generally regarded as the central economic mechanism for GHG reduction in the industry sector but only has a secondary effect on energy efficiency. The increase in the price of CO_2-intensive energy provides an incentive to implement GHG mitigation measures, which can also reduce energy consumption depending on the measure. However, the effect on energy consumption is low due to very low ETS certificate prices. In total, the ETS is expected to achieve 12 PJ in cumulative final energy savings (2014-2020) (German Government, NEEAP 2017).

Tender Model ("STEP-up"): In 2016 Germany introduced a competitive tendering scheme for energy efficiency. The initial focus is on electricity, but an extension to cover heat is planned. In a tender model, users submit projects with estimated energy savings for a given price. Measures with the most economic cost-benefit ratio are then awarded. Open auctions as well as closed auctions for specific technologies are taking place. Although it is an innovative and market-based approach, participation by companies has been rather limited up to now. The German Government estimates the final energy savings of the tender model between 29 PJ and 57 PJ cumulative in 2020 (see NEEAP 2017).

Regulatory instruments

Special exemption regulations: According to §55 EnergieStG, companies of the manufacturing industry can receive an energy tax relief of up to 90% if they fulfil certain prerequisites. If a company can provide evidence that it has operated an energy management system, it can claim an energy tax relief. As a precondition for this exemption, a voluntary agreement between the association of the manufacturing industry and the German government was concluded indicating that compensation will be granted if the manufacturing industry increases its energy efficiency by 1.3% in the years 2013 to 2015 and by 1.35% in 2016 compared with the yearly average energy intensity of the 2007 to 2012 base years. A further condition is that by the end of 2015 the companies are to introduce a certified energy or environmental management system. Small and medium-sized enterprises can also operate alternative systems to improve energy efficiency.

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[21] More detailed analyses on how to address barriers can be found at http://www.bigee.net/, or Ecofys, Wuppertal Instiut, Ifeu (2017): Weiterentwicklung der Energieeffizienzpolitiken zur Erreichung der Klimaschutzziele der Europäischen Union bis 2050. For Umweltbundesamt.

Furthermore, the special equalisation scheme under the Renewable Energy Law (EEG) demands the implementation of a certified energy and environmental management system. Companies that consumed less than 5 gigawatt hours of electricity during the previous financial year can have an alternative system to improve their energy efficiency. This compensation measure for the peak equalisation for the energy and electricity tax is expected to achieve 115 PJ final energy savings (2014-2020) (see NEEAP 2014).

Energy Services Law (EDL-G): The EDL-G implements, among other things, Art. 8 of the EED and commits all companies in Germany that are not SMEs to carry out an energy audit according to EN 16247-1 every four years, an energy management according to ISO 50001, or an environmental management according to EMAS (Federal Law Gazette 2015a). The number of affected companies for the energy audits are ca. 50,000 in Germany. Companies that have already implemented energy management systems to obtain tax breaks are not considered in this number. Given these numbers, a current evaluation shows that it is likely that only 30 PJ instead of the expected 50 PJ until 2020 can be achieved and often organisational measures or low-investment measures in lighting, heating and cooling have been realised.

Financial instruments

KfW programs: The German state-owned Bank for Reconstruction (“KfW”) manages several energy efficiency subsidy programmes. KfW's energy efficiency program "production facilities/processes" promotes investment measures that achieve energy savings of at least 10% in the production facilities and processes of commercial enterprises in Germany and abroad. This includes, among other things, the promotion of efficient electric motors for pumps, heat recovery and waste heat utilisation for production processes, and combined heat and power (KfW 2015 a, b). The KfW financing initiative ‘Energiewende’ is used to finance larger company projects in Germany in connection with the Energiewende. One focus of the program is on measures to increase energy efficiency (KfW 2015c).

BAFA (Federal Office for Economic Affairs and Export Control) state grants for cross sectorial and process technologies: Grants for the replacement or acquisition of new plants are subsidised from a net investment volume of EUR 2,000 with a funding amount of up to EUR 30,000 per project (location) (BAFA 2016). The state grants for cross sectorial technologies has been broadly accepted. A total of 35,500 subsidy applications were submitted during October 2012 to November 2015) and around 12,500 companies were supported with a total sum of EUR 73 million. As a result, over 360 GWh/a of electrical and 45 GWh/a thermal energy could be saved.

All KfW investment promotion programmes in companies including the BAFA programme are expected to achieve 139 PJ in cumulative final energy savings in 2020 (see NEEAP 2017).

Informational measures

Energy consulting for SMEs: Energy consulting is an important tool for the reduction of information deficits in SMEs through qualified and independent advice, identifying energy saving potentials in the company and ultimately realising energy savings. BAFA support a program that aims at advancing the number of energy consultations carried out in SMEs. In addition to the initial consultation, the implementation of measures is accompanied by energy consultants in order to further increase the implementation rate. The energy consulting for SME is well received by the target group. In the period from 2010 to 2013, 18,368 enterprises used this service.

Energy efficiency networks: An energy-efficiency network consists of 8 to 15 companies. These companies commit to working together to increase their energy efficiency over two to three years. An energy consultant (internal or external) estimates the energy savings potential of the participating company and helps companies identify energy saving measures. Based on this analysis, each company sets a conservation target and selects accompanying measures to implement. Additionally, the network also sets itself an overall efficiency target for the duration of the network activities. Participating companies exchange experiences and ideas during a moderated dialogue three to four times per year. The German government plans to establish 500 networks by 2020 and thereby achieve energy savings of 74.5 PJ within this timeframe. See also Example 4 for further details. Until May 2017, 123 energy efficiency network have been founded.

Main take-away messages

Germany has implemented a variety of financial instruments aiming to reduce financial barriers. However, the focus on financial incentives is not sufficient for efficiency measures to be implemented by the industry sector. Currently there is still a reduced willingness of companies to implement energy saving measures with pay-back times of more than three years. Companies that operate an energy management system and reduce their energy intensity by a defined factor will benefit from tax relief, but there is no obligation to implement identified measures to reduce energy consumption. Furthermore, no uniform consulting standard has been established in energy efficiency consulting, which has had a negative impact on the consulting firms and its perception by end users.

Example 4: 500 Energy efficiency networks by 2020

INITIATIVE ENERGIEEFFIZIENZ NETZWERKE

Energy efficiency networks allow for a goal-oriented, non-bureaucratic exchange between companies.

An energy-efficiency network consists of **8 to 15 companies**. These companies commit to working together to increase their energy efficiency over **two to three years**. An energy consultant (internal or external) estimates the energy savings potential of the participating company and helps companies identify energy saving measures. Based on this analysis, each **company sets a conservation target** and selects accompanying measures to implement. Additionally, the network also sets itself an overall efficiency target for the duration of the network activities. Participating companies exchange experience and ideas during a moderated dialogue three to four times per year.

The methodology of the energy efficiency networks aims at **strengthening energy efficiency related know-how in companies** and motivating them to **implement energy efficiency measures**. An accompanying evaluation of pilot project in Germany (Fraunhofer ISI/IREES 2009 to 2015) has shown that participating companies can significantly accelerate the reduction of their energy costs compared to the industry average. Thus**, companies increased their energy efficiency twice as fast as the industry average**. Main points of the joint work are efficiency improvements in the cross-sectoral technologies (e.g. production and distribution of compressed air, heating and cooling as well as electrical motors, lighting, waste heat) and organisational measures.

When the initiative was launched in 2015, 29 networks were set up. By the end of 2016, 76 networks were added and in April 2017 at total of 114 energy efficiency networks were registered (dena 2017). The German government plans to establish 500 networks by 2020 and thereby achieve energy savings of 74.5 PJ within this timeframe. Up to now (May 2017) 123 energy efficiency networks have been founded.

During Germany's G7 Presidency in 2015, the Federal Government and the business community began to promote the concept of energy-efficiency networks at the international level. Together with the International Partnership for Energy Efficiency Cooperation (IPEEC) a global dialogue on energy efficiency networks has been ongoing since 2016.

Figure 17: 500 Energy efficiency networks by 2020 (Best practice example 4)

6 Transport

➢ ***The transport sector needs to reduce its CO_2 emissions by 52-40% (compared to 1990) until 2030. This is equivalent to 95-98 $MtCO_{2eq}$.***

6.1 Indicators

Final energy consumption in the transport sector was 2,619 PJ in 2015 (BMWi 2017a). The transport sector accounts for 28% of total energy consumption and 17% of greenhouse gas emissions in Germany. The percentages may have fallen in recent years, but absolute traffic volume continues to rise and offset efficiency gains via technical improvements (BMWi 2017a). Since 1990, final energy consumption has increased by 16%. 90% of fuels used are fossil fuels, meaning that currently biofuels and electricity only play a minor role. The largest share in the transport sector is by far road traffic.

The following figure shows the development of final energy consumption in the transport sector.

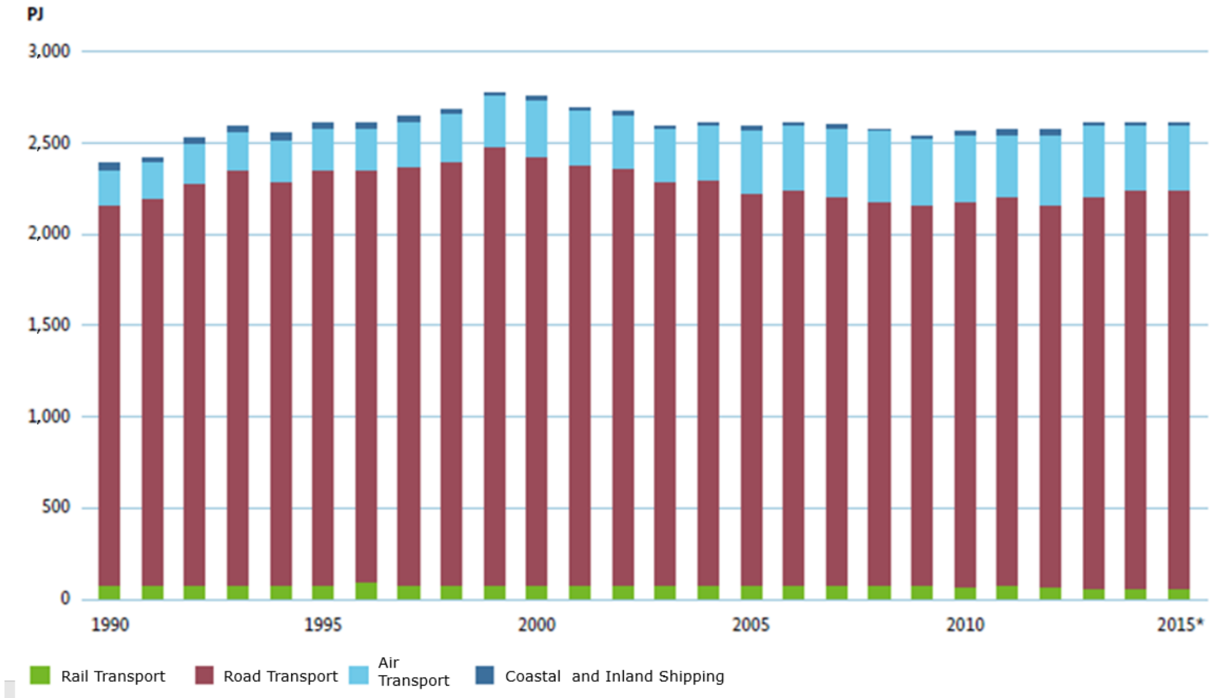

Figure 18: Final energy consumption in the transport sector
(Source UBA 2017 in BMWi 2017a, p. 27)

6.2 Potentials

The estimate of the total savings potential in the transport sector is 275 PJ for 2030. These numbers can be broken down into passenger transport and goods transport (Fraunhofer ISI, TU Vienna, PwC 2014b, p.25). The greatest potentials are in the road transport for cars and light and heavy vehicles. However, these can be tapped not only through an increase of vehicle efficiency but also via significant modal shifts that increase system efficiency. The following table shows the estimated savings in the baseline scenario, the high policy intensity scenario as well as the resulting absolute and relative potentials.[22]

Table 13: Energy efficiency potentials in the transport sector

Segment	Energy consumption Base_WM in 2030 (in PJ)	Energy consumption HPI in 2030 (in PJ)	Absolute energy savings until 2030 (in PJ)	Relative Energy Savings until 2030
Passenger transport	**1437**	**1234**	**203**	**14%**
- Road (cars/motorcycles)	1056	92	203	19%
- Road (buses)	59	49	10	16%
- Air[23]	294		-10	
Goods transport	**561**	**489**	**72**	**13%**
- Road (light & heavy duty vehicles)	506	437	69	14%
- Rail	15	14	2	11%
- Ship (maritime)	9	8.5	0.5	5%
- Ship (inland navigation)	29	28.5	0.5	1%

6.3 Barriers

Efficiency in the transport sector can be split into three areas: system efficiency (reductions in traffic performance), transport efficiency (transport shifts to energy efficient means of transport) and vehicle efficiency (improvement of energy consumption per vehicle km). Especially the first two areas require changes in the mobility behaviour and/or mobility management as well as organisational changes. The high investment costs for the expansion of the transport infrastructure constitute a

[22] Numbers were rounded.
[23] The negative values indicate that no savings potentials are presumed and air travel will increase further.

major obstacle to energy efficiency in the transport sector. On the other hand, an increase in vehicle efficiency is inhibited by a lack of technical innovations and high investment costs.

The following table summarises barriers of the transport sector (cf. Ecofys, ifeu, Wuppertal Institut 2017, UBA 2014a, UBA 2011, SRU 2005, Aral 2015):

Table 14: Barriers for energy efficiency in the transport sector

Barrier type	Individual barrier	Relevant	Actors
Governance	Conflict over responsibility/jurisdiction (financing vs. planning) for transport infrastructure	very high	Government
	Globalisation and the resulting abandonment of regional economic cycles	very high	Government
Organisational (infrastructure, planning)	Lack of holistic concept for an integrated (energy efficiency) transport policy	very high	Government
	Urban sprawl, increase in travel distance	high	Government
	Missing integration of transportation and urban development	high	Government, associations
	Lacking capacity of rail transport	high	Government, railway association
	Lacking connection between transport modes (multimodality)	high	Government, associations
Informational (behavioural)	Status symbol car	very high	Individuals, manufacturers, auto lobby
	Reduced cost awareness in transport choice	high	Individuals
	Strong automobile lobby: difficulties in enforcing restrictions against motorised transport	very high	Automobile lobby
	Scepticism over new drive technologies and alternative fuels	Very high	Individuals, automobile lobby
Financial	Inadequate internalisation of external costs and competitive difference in taxes, duties and subsidises	very high	Government
	High investment requirements for a high-quality public transport system	very high	Government
	Tendency to promote large-scale infrastructure projects rather than smaller ones	high	Government
	Higher costs of energy efficient vehicles	very high	Manufacturers, individuals
	Incentive for manufacturers to produce large and heavy cars	Very high	Manufacturers, government

6.4 Policies

The expansion of renewable energies in final energy consumption and the increase in energy efficiency also play an important role in the transport sector. Amendments in energy efficiency are expected to reduce final energy consumption in the transport sector by 10% in 2020 or by 40% in 2050 compared to 2005. In addition to the Action Plan for Climate Protection 2020, the Climate Protection Plan 2050 and the National Energy Efficiency Action Plan, sector-specific programs and strategies have been initiated for the transport sector, such as the government program for electromobility (Bundesregierung 2011) and the mobility and fuel strategy (BMVBS 2013). However, an overall strategy for the implementation of a transport policy is lacking. In order to overcome the large number of barriers, a policy package is necessary. A policy package combines a governance framework including strategies, concepts, institutions and all types of policies (regulatory, financial, information, capacity building, research and development).[24]

The following table lists selected measures:

Table 15: Energy efficiency policies in the transport sector

Type	National-level instrument
Planning	Federal road planning
	National bicycle traffic plan
	Government program electromobility
	Commitment to build up a tanker and charging infrastructure for alternative fuels > national strategy plan to 2016
Regulatory	CO_2 fleet limit values for passenger cars and light commercial vehicles
	Adaptation of European Renewable Energy Sources Act (EAG EE)
	Biofuel Sustainability Regulation
	Ordinance on Energy Consumption Labelling
	Energy labelling of car tyres
Financial	**Vehicle-related taxes:** CO_2-based vehicle tax 5-year car tax exemption for cars with only electric motors Energy tax Reduced taxation of natural gas and liquefied natural gas beyond 2018
	Other: Funding program for electric vehicles Mode-independent distance (tax) refund Air traffic tax

[24] More detailed analyses on how to address barriers can be found at http://www.bigee.net, or Ecofys, Wuppertal Institut, Ifeu (2017): Weiterentwicklung der Energieeffizienzpolitiken zur Erreichung der Klimaschutzziele der Europäischen Union bis 2050. For Umweltbundesamt.

Type	National-level instrument
	Truck toll (and further development)
Informational	Initiatives and pilot projects in the field of company/municipal mobility management
Research & Development	Innovation programme for hydrogen and fuel cell technology
	Field trials of electric motors in heavy commercial vehicles

Description of key instruments

Planning instruments:

Federal Road Planning: The Federal Road Planning is the planning instrument for transport infrastructure development at the national level (federal highways, federal railways and federal waterways).

Regulatory instruments:

CO_2 fleet limit values for passenger cars and light commercial vehicles: EU legislation sets mandatory emission reduction targets for new cars and light commercial vehicles. The current limits for passenger cars are set at 120 g CO_2/km since 2015. From 2021 they will decrease to 95 g CO_2/km. For light commercial vehicles, they are set at 175 g CO_2/km since 2017 and will decrease to 147 g CO_2/km from 2020.

Ordinance on Energy Consumption Labelling: The Ordinance on Energy Consumption provides information on the energy efficiency of passenger cars. For this purpose, a website was created where prospective buyers can get information on the most efficient car models within each class of vehicle.

Financial instruments:

CO_2-tax: The annual circulation tax for cars registered as from 1 July 2009 is based on CO_2 emissions. It is comprised of a base tax and a CO_2 tax. The base tax is EUR 2 per 100 cc (petrol) and EUR 9.50 per 100 cc (diesel) respectively. The CO_2 tax is linear at EUR 2 per g CO_2/km emitted above 95 g CO_2/km (see CO_2 fleet limit). Any car with emissions below 95 g CO_2/km is exempt from the CO_2 tax component (ACEA 2017).

Truck toll: Germany imposes distance-based tolls on motorway use by all trucks as from 7.5 t maximum gross weight. The toll amount depends on emission class, axle number and the length of the toll stretch (DKV 2017).

Funding program for electric vehicles (Environmental bonus): The purchase or lease of a new, first-approved electric vehicle is funded with EUR 1,500 - 2000 depending on the amount of CO_2 emissions per km which has to be at least smaller than 50g CO_2/km (BAFA 2017b). Until July 2017, in total

23,024 vehicles were approved for funding. This is split into 13,083 electric battery cars, 9,937 plug-in hybrid bars and four fuel cell cars.

Research & Demonstration instruments:

Electromobility program: Under the electromobility program, funding of EUR 1 billion will be devoted to technological research and development projects and a further EUR 180 million for practice-oriented (regional) demonstration and pilot projects (e.g. "Schaufenster Elektromobilität"). Additionally, the government program also includes further measures, such as education and training or financial incentives (exemption of motor vehicles for pure electric passenger cars).

Main take-away messages

While the Ministry for Economic Affairs and Energy jointly with the Ministry for the Environment (BMUB) initiates regulation for the buildings, appliance and industry sectors, the responsibility for transport policy lies with the Federal Ministry of Transport and Digital Infrastructure. Germany has implemented a variety of measures in the transport sector to overcome existing barriers. Yet, gaps in the current policy framework still lead to increasing emissions and less energy efficiency in the transport sector.

Regarding system efficiency, the federal road planning system (BVWP) consists of sectoral plans for infrastructure development and individual projects as opposed to an integrated and weighted network plan.

In terms of travel and transport efficiency, various tax-related instruments that try to incentivise a modal shift, present deficits in the regulatory framework. Since the ecological tax reform in 1999, the tax rates have not been adjusted. The steering effect of the CO_2-based passenger vehicle tax is also rather small, since the tax rate applied is too low to effect significant changes in buyer's behaviour. These taxes also focus on direct emissions and do not take the other parts of the value chain into account.

Vehicle efficiency is another area in which there are deficits in the regulatory framework. Currently, there is a lack of knowledge about the extent to which the energy consumption labelling obligation for passenger vehicles influences purchasing behaviour of consumers. Additionally, the goal to deploy 1 billion electric vehicles by 2020 was cancelled by the German government in May 2017 due to lack of supply and demand.

7 Cross-sector

7.1 Information and communication technologies

7.1.1 Potentials

According to Germany's Climate Action Plan 2050, the digitalisation of the energy system is expected to yield energy efficiency potentials through the analysis of increasing volumes of data on energy flows. Under the premise of data security and protection, modern technologies such as smart grids and smart metering shall positively impact energy efficiency.

The digitalisation of the energy system is still in an early phase. In principle, information and communication technologies (ICT) can manage considerable amounts of data needed to allow for flexible distribution of energy supply and demand. Real-time information and communication about energy supply, grid load and storage capacity opens opportunities for the optimal and efficient use of energy.

As clearly, digitalisation per se does not lead to energy savings, its energy efficiency potential will largely depend on how digitalised processes will be designed for the purpose of energy savings. The digitalisation of the energy system will to a large extent be technology-driven rather than policy-driven and hence can only be steered to some extent. These factors make it difficult to quantify the energy savings potentials of information and communication technologies.

Accurate, real-time data on energy flows can generate positive results for energy efficiency through different effects.

- Firstly, detailed monitoring and analysis of energy use coupled with user feedback allows industrial and private consumers to optimise their energy input and identify individual savings potentials (BMWi 2016c). According to estimates, the introduction of smart meters coupled with monitoring tools can account for electricity savings of 3-5%. For heating, energy savings are expected to be slightly higher (up to 6,5%) (Hoffmann et al. 2012). In particular, the visualisation of energy use has been found to be crucial as it enables the consumer to use energy more consciously. Automated energy management systems in buildings can make up for 10-20% of energy savings.
- Secondly, user information and the development of cost-effective energy advice is made possible. Innovations based on automatic energy metering may include improved, continuous, and automatic energy advice (BMWi 2016c).
- Thirdly, it allows policymakers to base energy efficiency measures on a more realistic set of data and improved forecasts.

- Fourthly, the availability of data is a precondition for demand response management and technology innovations (section 7.2) (BMWi 2016c).

A digitalised, smart grid does not only use energy supply efficiently, but also reduces the need to expand grid infrastructure. A study conducted on behalf of the BMWi suggests that the expected costs of grid extension until 2032 could be reduced by 20% as a result of new approaches to grid planning and intelligent grid technologies (E-Bridge, IAEW, OFFIS 2014). This would be in addition to the significant reduction in grid extension costs that could be induced by energy efficiency. (Prognos, IAEW 2014). As an indication for digitalisation of the grid, it can be noted that in 2015, more than 77% of installed renewable energy capacity in Germany could be remotely metered and controlled (BMWi 2015c).

7.1.2 Barriers

The potentials of ICT for increased energy efficiency cannot currently be fully leveraged due to multiple barriers that are only beginning to be understood and addressed.

Institutional barriers range from insufficient policies and a missing regulatory framework to no legal or investment certainty and not enough steering of R&D activities. Furthermore, digitalisation allows for multiple subsystems to become interconnected. This may create complications as it is unclear, to which extent the different technologies will be compatible, whether the regulator will be needed to coordinate the subsystems and whether this will increase or diminish efficiency, stability and controllability of the system (BMWi 2016a).

Knowledge barriers refer to the need for further research and development, information asymmetries, a lack of knowledge exchange and insufficient networks. Despite the considerable potential, mass-market applications are not yet economically feasible. In particular, German SMEs are hesitant to become part of "industry 4.0" as the advantages are often not clear (Deloitte 2016). On a global range, customers tend to lack a clear understanding of the value of the Internet of Things (IoT), so that there is a need to demonstrate concrete solutions and capabilities of connected appliances.

Further, there is some **disagreement about the efficiency gains** acquired through specific technologies. For instance, energy efficiency gains by smart metres and IoT may be outweighed by increased consumption of the devices. Smart meters, for instance, have been criticised for their high energy use, which may not be compensated by their efficiency gains (Theron 2015). Global standby energy consumption caused by the necessity of IoT devices to always be reachable is estimated at 130 PJ per year by 2025 in the area of home automation alone (IEA 2016).

Security barriers are a major challenge from a systemic perspective and in the context of privacy protection. ICT systems are potentially prone to hackers, viruses and even cyber-war attacks, presenting serious threats to the security of the system (BMWi 2016a). In the German context, there is particular scepticism towards open data resources and the misuse of consumer data, which are linked in part to the prominence of the right to privacy in the German constitution. It remains to be seen how detailed energy metering will be harmonised with German data protection laws (BMWi 2015c).

Market barriers to information and communication technologies include insufficient available capital and long amortisation periods. Established technologies have high returns, while new technologies are very cost-intensive and there is an insufficient demand from potential buyers.

7.1.3 Policies

The current policy landscape addressing digitalisation of the energy sector is comprised of multiple support programs and information platforms.

Table 16: ICT related energy policies

Laws
Law on the digitalisation of the energy transition
Strategies
High-tech Strategy "Innovation for Germany"
Digital Agenda 2014-2017
Digital Strategy 2025
Support programs
Smart Energy Large-scale demonstrators ('Showcases') - Digital agenda for the energy transition (SINTEG)
Technology programme Smart Data
Technology programme SMART SERVICE WORLD
Technology programme – ICT for electric mobility II
6th energy research framework programme • Support initiative "Energy storage" • Support initiative "Future-proof Power Grids"
Support measures "E-energy – ICT based energy systems of the future"
Support initiative „material science research for the energy transition"
Large-scale demonstrators ('Showcases') electric mobility
Pilot programme Savings Meter ("Einsparzähler")
Green IT initiative
Information Platforms
Platform Industry 4.0
Energy transition platform research and innovation
Digital networking in the framework of the digital agenda

Description of key instruments

In June 2016, the **law on the digitalisation of the energy transition** was passed. It determines the gradual roll-out of smart metres. In contrast to most EU members, Germany will only oblige large consumers and producers (consumers with over 10,000 kWh/year and producers between 7-100 kW installed capacity) to install smart meters in the medium term until 2024 (until 2032 for consumers with more than 100,000 kWh/year), while the roll-out for smaller consumers and producers is envisioned for the period 2020 to 2027. The law further comprises technical guidelines, protection profiles and a communication platform tool and aims to warrant data protection and interoperability (Sachverständigen Rat 2016). Only smart metering systems that adhere to very high data protection and data security standards will be awarded with the according certificate (BMWi 2016d).

The **pilot program "Savings Meter"** is scheduled to run from 2016 to 2018 (BMWi 2016a) with the aim of supporting private and industrial consumers in finding options to decrease their energy use. Innovative, IT-based pilot projects are tested with voluntary end consumers, who are enabled to identify the energy uses of individual appliances and monitor energy saving successes and associated cost savings. Besides testing innovative solutions for demand side response, co-benefits including load management for sector coupling or private financial services for energy efficiency are incentivised through the programme (BAFA 2017a).

As part of the digital agenda, the **support program SINTEG**, funded with over EUR 200 million and 200 companies, aims to demonstrate how smart grids can optimise the interplay of power generation, consumption, storage and grids. Five showcases projects, focussing on different solutions for a climate-friendly, secure and efficient energy supply with high shares of variable renewable energy, are supported. The project "C/sells" is a large-scale showcase with a focus on solar energy in southern Germany designed to test an energy system that is organised into sub-cells. "Designnetz" tests send requests for flexibility from higher grid levels to lower ones, using data from ca. 140,000 meters to generate forecasts on the grid status. "Enera" aims to showcase regional energy system services and solutions. In "NEW 4.0" flexibility options such as demand side management, storage units and sector coupling are tested in Northern Germany, and in "WindNODE" digital networking is leveraged for flexibility options at multiple levels (BMWi 2017d).

In the context of the **Green IT-Initiative**, the energy consumption of all public sector IT-appliances was to be reduced. By 2013, the energy consumption had been reduced by 40% against the 2009 baseline for peak energy consumption. The initiative is being continued with the aim to achieve further energy savings (UBA 2014b).

7.2 Demand response

7.2.1 Potentials

Demand Response refers to balancing the electricity grid through changes in electricity usage (Department of Energy 2017).[25] With increasing shares of variable renewable energy, the grid needs to be stabilised and demand response is one option for providing the needed flexibility, while at the same time reducing the need for additional back up capacities. Demand response is a promising low-cost option to balance varying electricity supply and demand, especially through levelling out load peaks and valleys, which eases the further integration of variable renewables to power systems.

However, the effects on energy efficiency are indirect and twofold. In many cases increasing the energy efficiency of an installation leads to a decrease of its flexibility. Yet, some cases have opportunities for synergies. For instance, an upgrade of control technology is likely to lead to improvements in both, energy efficiency and flexibility. As a second indirect effect demand response potentially decreases the need for back up capacities and grid extension, which increases the efficiency of the system as a whole.

Germany has a high potential for demand response. Indicative figures for the theoretical potential per sector are presented in table 14.

Table 17: Theoretical demand response potential in Germany in MW

	Potential for load reduction in MW	Potential for load increase in MW
Industry	3543	734
Commercial	3397	3671
Residential	6023	27413
Water Supply and Treatment	559	501
Total	**13522**	**32319**

(Source: Gils 2014)

In general, it is easier to implement demand response for a few large industrial consumers than to leverage the flexibility potential of many small actors. A successful example for a large consumer offering flexibility to the grid is the aluminium producer Trimet, which regularly provides grid balancing services by adjusting the electrolysis process according to extraordinary peaks and valleys in the electricity supply. This is done at 12 production sites, which employ modern technology that

[25] Note that the European Commission's definition refers only to reductions in electricity usage at times when the capacity is jeopardised (European Commission 2016a).

have proven to increase efficiency in the electrolysis process while at the same time provide flexibility to the grid (Agora Energiewende 2015). Scaling up such successful examples depends on the individual technologies and a coordinated approach of utilising them for the purpose of greater energy efficiency.

A key technology for new demand response applications is **smart metering**. Smart metres in industries and private households are envisioned to provide detailed information about energy consumption patterns. Besides enabling individual energy consumers to save energy, smart metering opens up business opportunities such as variable electricity tariffs which provide direct financial incentive for demand response. Large industrial actors could market flexible loads themselves while smaller companies could do so via demand response aggregators.

Another key technology for demand response management is the **internet of things**. The internet of things refers to things and communication networks, whose primary function is not directly related to information and communication technology, i.e. a washing machine. Those things are "identifiable, addressable and can be integrated in communication networks" (IEA 2016). The internet of things can impact the energy sector and energy efficiency using connected devices and appliances to better moderate electricity demand. In theory, appliances connected to the internet could automatically respond to fluctuations in the electricity grid, thereby helping to balance out extremes. For instance, a washing machine connected to the internet could automatically start once electricity supply is higher than demand.

7.2.2 Barriers

In principle, current regulation allows for demand response measures. However, market regulation creates considerable barriers to most forms of demand response, including programs by retailers and independent aggregators. The current configuration of the electricity market inhibits most forms of demand response services provided by both retailers and independent aggregators because of the specific regulations balancing power must meet (e.g. referring to volume and duration). Hence, actual participation is hardly possible despite increasing demand for balancing services. The wholesale market as well as re-dispatch are not available for demand response. The GJETC study on electricity market design provides more detail on this.

Aggregation of smaller actors can currently only be implemented by retailers, and there are significant barriers to entry. Intra-day markets are in principle open for consumers working through their retailer (assuming the retailer offers this service).

7.2.3 Policies

The responsibility to balance the grid lies with the system operators. Since the liberalisation of the electricity market in 2001, the system operators have been purchasing balancing power in an open and transparent market. This works through auctions, in which power plants as well as end consumers can offer flexibility. As there are specific rules for each type of balancing power (primary balancing power, secondary balancing power, minute balancing power), smaller actors have to pool their flexibility resources in order to meet those criteria. The rules and criteria of the auctions are regulated by the electricity network access directive ("Netzzugangsverordnung") and the Network Fee Regulation ("Netzentgeltverordnung"). In principle, balancing power can be traded across European borders.

The German government has reviewed the current barriers to demand response in its white paper "An electricity market for the energy transition" (BMWi 2015b). Among other things, the intended measures would open up balancing power markets for new actors, allow for modifications of the grid fees and regulate the aggregation pools of smaller actors. Consequently, the potential for demand response in Germany would be greatly improved.

There is currently no capacity market in Germany and according to the white paper, a possible capacity reserve would be closed for demand response. In the long term, daily auctions with volumes of one hour are envisioned. According to the European Commission (2016), the measures proposed in the white paper on the electricity market would, if implemented, solve the current barriers to demand response.

7.3 Impacts of Smart Cities and communities & city planning

7.3.1 Potentials

ICT, big data and the internet of things are also key for the future of smart cities and urban planning. The term "smart city" refers to the intelligent, digitalised and cross-linked city of the future. Smart cities may increase energy efficiency through smart street lights, smart grids and intelligent building systems.

The overall benefits of the smart city concept are based on a resource efficient management of the city's needs, which leads to low carbon, sustainable development. Digitalisation and data management can optimise urban mobility, living, working etc., reducing the amount of time and energy spent on many activities. Also, the sharing economy, linked via digital networks, is supporting the efficient use of resources by avoiding unnecessary production.

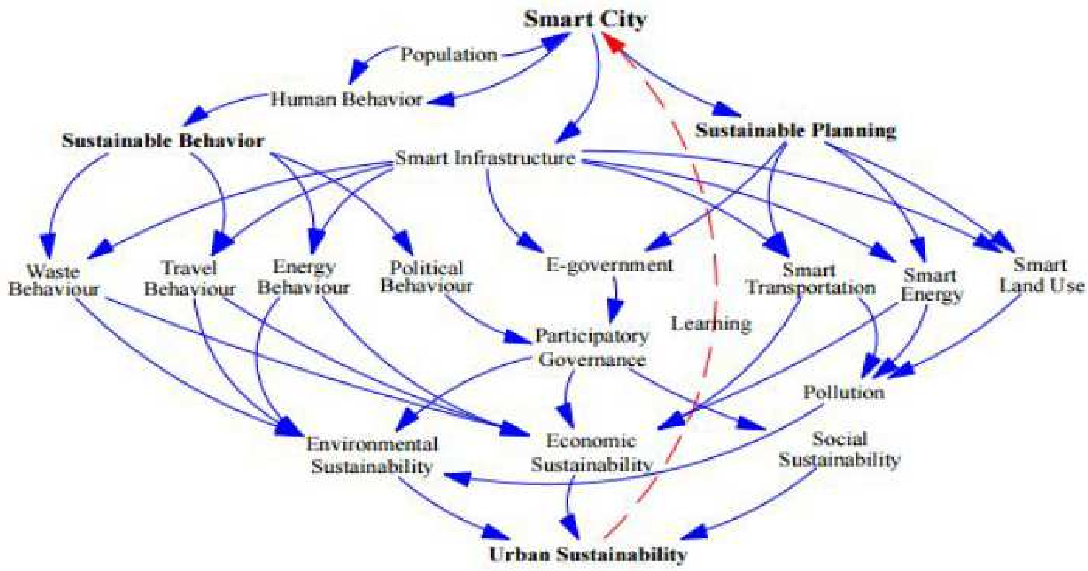

Figure 19: Relation of smart city and urban sustainability
(Source: Khansari et al. 2014)

A smart and integrated urban planning practice reduces land-use and promotes redensification of urban structures and short distances. In the urban context in particular, the optimisation of the energy infrastructure via ICT solutions and M2M (machine to machine) communication provides a high energy and CO_2-emission saving potential, connecting the demand and supply sides of all relevant sectors (heating, cooling, power, transport, water, waste, communication etc.). E.g. the report "Smart Stories, Amsterdam Smart City 2011" states that Amsterdam's projects generated projected savings of 12.7 kt CO_2 per year, which account for a reduction of 0.5% of overall CO_2 emissions of Amsterdam per year. Full up-scaling of smart city projects has not been achieved so far, but it is estimated that this would lead to a reduction of 6% and 148 kt CO_2 (Mapping Smart Cities in the EU, 2014).

Overall energy management systems on city-level (digital city models) are not yet available and the digitalisation of the urban infrastructure needs to develop in-line with a circular economy and social sustainability approach to reach its maximum potential.

The following table shows indicative energy saving potentials of smart technologies in the context of smart cities and communities:

Table 18: Energy savings potential of smart technologies

(smart) Technology	Energy saving potential
Smart urban energy system (integration of decentralised renewable energy sources – buildings as producer and consumer "prosumer")	high
Virtual power plants	high
Heating/cooling/gas infrastructure as energy storage (power to heat/gas)	medium (GHG emission reduction through flexibility of power generation via renewable energy systems)
Using e-mobility sector as energy storage – integration in smart grid	medium
Energy management system which predicts the energy production and demand in the city	medium
Combination of different sectors (recycling, heating, electricity, waste water, …)	medium
Sharing concepts for mobility (bikes, cars, …)	medium
Sharing economy in general	low
Optimisation of public transportation through big data access of users (possible, question of privacy)	medium
Smart meter (savings ~2% (Allcott and Mullainathan 2010; Van Elburg 2014), M2M~20%(GeSi and BCG 2012)	medium
Smart lighting (savings up to 60%) (Manville et al 2014)	high
Sensors for traffic (transport demand management) → optimised traffic control	medium

(Source: own assessment by Ecofys, 2017)

Currently, the smart city approach still does not have a large impact on energy and GHG-emission savings. So far, the effects of this approach are not fulfilling the expectations. Instead, conventional efficiency measures like building insulation and modal shift continue to result in higher energy savings. Nonetheless, the smart city approach has the power to fundamentally change user behaviour and therefore offers the possibility for significant energy savings.

7.3.2 Barriers

German cities are currently facing a huge challenge to adapt to technology developments and implement fundamental changes in the urban infrastructure (e.g. for e-mobility). Many cities are suffering from investment lags in conventional urban infrastructure. Due to a shift from an industrial economy to a service economy and the related demographical changes, some cities are growing rapidly while others are shrinking along with the local economy. These developments are already challenging many German cities and investment in innovation and smart technologies is lagging behind (smart lamp post, e-cars etc.).

The development towards a "smart city" requires a multi-stakeholder approach: citizens need to be involved in the planning and development process to increase the acceptance of the digitalisation of the urban infrastructure. Moreover, the smart city process should integrate all relevant technology sectors, which requires a coordinating entity within the municipal administration. And finally, private partners must be identified to invest in new smart technologies that are linked to public infrastructure. Therefore, the governance structure needs to be adapted to this challenge in order fulfil these tasks.

The municipality must make reliable decisions with positive, long-term impacts on infrastructure and the welfare of citizens. Unknown dependencies and new relationships are to be taken into account by a smart approach. Data security should also be respected while opening up new data sources e.g. via public cameras and sensors. It is crucial to decide which data could be opened up for the public (open data) and vis-a-versa. The risk of security shortcomings and cyber-attacks is increasing through the digitalisation of infrastructure. And finally, the digital revolution also impacts social divide and disruption (WGBU 2016).

It is clear that smart-city technologies will create new regulatory frameworks across all governance levels, as well as challenge existing social norms and expectations regarding privacy (Kitchin 2016). An open and broad discourse on the effects of digitalisation in the city context should therefore be conducted. This requires a strengthening of IT and media competencies within the population as well as in public and private institutions. As the technical possibilities and associated risks are rapidly evolving, an urban governance is required that is able to shape the digitalisation process associated with great uncertainties in the city and create a socially acceptable and sustainable, digitised city.

7.3.3 Smart City Policies

The function of a smart city refers to the digitalisation of all essential sectors of the urban environment. However, there is no common definition of a smart city. E.g. for the City of Vienna, the Smart City "represents the overarching framework for an innovation-driven, resource efficient and liveable city that includes an innovation strategy as well as a sustainability strategy (City of Vienna 2014)." (Radecki et al. 2015).

In recent years, the relevant institutions have been attempting to define and set standards relating to this term.

International and European standards

China, Japan and Germany founded an evaluation group under the umbrella of the International Electronical Committee (IEC SEG 1) in 2013. Eight working groups were created with a focus on smart cities and the following topics: city service continuity, planning and simulation system, facilities management, smart homes, smart education, smart cities assessment, smart cities framework, and mobility and logistics). ISO and IEC founded additional committees that deal with international standardisation of smart cities (e.g. cloud computing, identification of requirements for cities, potential interface problems). Moreover, the International Telecommunication Union (ITU, part of the UN) is currently developing studies and recommendations concerning smart and sustainable cities.

Additionally, DIN (German Institute for Standardisation) and DKE (German Commission for Electrotechnology) are cooperating in a national strategy group on smart cities, working on

- buildings and urban processes
- mobility and logistics: intelligent transport systems, navigation and use of open data
- protection and security: emergency response, reaction to crisis, civil security
- digital city: role of ICT in smart cities
- energy: production and demand (electricity, heat, gas, water) - smart grid and smart home
- production (industry 4.0) (DIN & DKE 2014).

In Europe, the CEN-CENELEC-ETSI Coordination Group on Smart and Sustainable Cities and Communities (SSCC-CG) (ETSI 2015) is defining European standards with a focus on smart cities. Further, the EU Directive 2013/37/EU on re-use of public sector information, is in place. It focuses on the economic aspects of the re-use of information rather than on the access of citizens to information. It encourages Member States to make as much of their data publicly available as possible to support innovative and future-internet-based services, new companies, transparency, and participation in urban spaces (European Commission 2017). Germany has transferred the directive into national law, but still has issues with data security referring to Open Data. The research institute Fraunhofer FOKUS, together with the Berlin-based data-portal BerlinOnline, are working on the integration of a City Data Cloud, in order to make selected data publicly available. The aim is for The Data Cloud to be available in several cities to support innovative urban processes and implement smart city solutions.

Information platforms

Another strategy to promote the smart city development is via communication and the stimulation of the multi stakeholder process. The European Innovation Partnership on Smart Cities and Communities (EIP-SCC) brings together cities, industry and citizens to improve urban life through more sustainable, integrated solutions. The partnership aims to overcome bottlenecks, co-fund demonstration projects, and help coordinate existing city initiatives by pooling its resources together.

This includes applied innovation, better planning, a more participatory approach, higher energy efficiency, better transport solutions, intelligent use of Information and Communication Technologies (ICT), etc. (European Commission 2016b).

In 2016 the German government under the lead of the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) and the BMUB created the research cluster "Smart Cities" (BBSR 2017) to understand the impact of digitalisation on urban development, the use of digitalisation and big-data for urban development, and possibilities for cities to become a digital and sustainable city. The projects range from mobility issues to citizen participation and influence of digitalisation on urban structures. In this framework the inter-ministerial working group on sustainable urban development (IMA)(BMUB 2017) offers a dialogue platform for discourse between political representatives from federal, provincial and local level to improve the cooperation between the federal government and municipalities.

To support digitalisation in Germany, the Digital Agenda of Germany's Federal Government (Digital Agenda 2014 – 2017) was developed, which represents a roadmap with goals for Germany's digital development. It aims to strengthen Germany's role as an innovative and highly productive economy and ensure that Germany takes the international lead in the digital transformation (Federal Government of Germany 2014). At the same time, the cornerstones for a "Smart City Charter for Germany" are being developed at the federal level, from the point of view of urban development policy. It is intended to showcase all aspects of a Smart City and to outline strategic paths for the digitisation of German cities and municipalities.

Various companies are also developing technologies and accompanying instruments for an intelligent infrastructure of densely populated urban areas. For example, Siemens has developed a "City Performance Tool" to help cities create their environmental balance. The aim is to identify the most efficient instruments for reducing CO_2 emissions and improve air quality, while at the same time indicating the number of jobs created in the city by the measure presented. Cisco has also entered into agreements with the city councils to advise and test different ICT applications - in Germany, for example, with the cities of Hamburg and Berlin. These examples indicate that smart cities may aim for resource efficiency or sustainability, but it is not granted that each smart city concept will, as there is no common definition.

7.3.4 CHP and district heating networks in Germany

The existing district heating networks are an important infrastructure for the integration of renewable energies and flexible sector-clustering technologies in densely populated urban areas. The Federal Government aims to increase the share of renewable energies in the heating sector to 14% by 2020.

At present, about 225 of the municipalities in Germany have large district heating areas. Over the past few years, district heating has accounted for about 9% of final energy consumption for the provision of space heating and hot water in private households and the sector of trade, commerce and services (BMWi 2016a). District heat is mainly generated by CHP plants, but there is still a clear dominance of fossil fuels with regard to the primary energy sources used. Renewable heat sources have only a share of around 10% (ifeu & GEF 2013) in the form of biomass and waste incineration. The future role of the heating networks should not be restricted to the collection and distribution of heat, but should create flexibility options for the electricity market. Hence, smart regulation of heat demand and heat supply, coordinated with the requirements of the electricity system, should be included in a smart city approach.

Existing national regulations and incentives in this field refer to the Act on Combined Heat and Power Generation (KWKG) and the Market Incentive Program (MAP), as well as the KfW programme 432 "Energetic urban regeneration - provision of investment for energy efficiency measures in urban redevelopment areas" and the KfW programme 294 on "waste heat use".

The KWKG promotes the construction and expansion of heat networks based on fossil-fuelled heat producers, which provide coupled electricity and heat generation, with certain, fixed surcharges per grid meter as well as the expansion of heat and cold storages. The MAP favours energy efficient heating plants in the building stock and additionally supports the construction of heat networks that meet specific efficiency requirements as well as heat storage within defined limits. The MAP also promotes the construction of heat production facilities, including biomass plants, large-scale heat pumps, biogenic cogeneration plants and solar thermal collectors.

The lack of "municipal heating plans" as the main coordination and planning instrument is seen as a hindrance for the further expansion of district heating. As a result, it is often not known to the municipalities which areas are suitable for large heat generation plants and how much unused waste heat potential is locally available. The promotion of local heat plans is supported within the framework of the national climate initiative (NKI). However, thus far only a few municipalities have made use of this funding.

7.4 Rebound effect and behavioural approach

7.4.1 Impact of the rebound effect on energy efficiency potentials

The discrepancy between an increase in energy productivity of the German economy by 56.2% since 1990 on the one hand and a comparatively small decrease in total energy consumption by only 10.5% (Statistisches Bundesamt 2016) on the other, shows that absolute energy savings through energy efficiency increases have diminished. This can be explained both by larger economic and societal trends such as increased GDP, production, wealth and smaller household size leading to greater energy use, and by rebound effects.

The term rebound effects describes the phenomenon of increased energy use caused by energy efficiency measures. Rebound effects can be broken down into three types. **Direct rebound effects** stem from increased demand for the more energy efficient product or service. An example is the purchase of a new, more efficient yet bigger car that will be used more than the old, less efficient vehicle. **Indirect effects** refer to an energy efficiency increase of one product or service that leads to increased demand for another different product or service, e.g. because of greater available financial resources. In the case of a new car, the fuel savings induced by greater efficiency will be partially compensated by more frequent flights as the consumer has more financial resources and/or a cleaner conscience due to the lower CO_2 emissions of their car. **Macroeconomic effects** emerge as a result of energy efficiency increases, which cause an overall increase in energy consumption. For instance, increased demand for efficient cars may lead to lower fuel prices, ultimately resulting in greater fuel demand than what was anticipated as the result of energy efficiency (UBA 2016).

It is generally agreed that the impact of rebound effects can be significant; however, there is large disagreement about the scope of the impact. The German Environmental Agency (UBA) estimates that direct rebound effects can account for a 20-30% decrease of the actual energy savings caused by an energy efficiency measure (UBA 2016). For example, in the case of motorised private transport, 10 – 30% rebound effect are a realistic assumption, although Frondel et al (2012) find that this amounts to over 50%. For space heating, 10 – 30% are estimated. For space cooling, existing studies point to a 1 – 25% rebound effect, 2 – 20% for warm water, 2 – 15% for industrial processes and 2 – 9% for residential lighting (UBA 2016, Sorell 2007). The large variation can be explained by the different data sets, evaluation periods and geographic scopes of the reports. On average, however, direct rebound effects may be in the range of 10% (Thomas 2012, Nadel 2012, Gillingham 2013).

In addition to direct ones, indirect effects are estimated at 5 – 15% under the assumption that consumers distribute their financial savings evenly over their existing expenditures (Schipper and Grubb 2000, Santarius 2014). In the case of macroeconomic effects, no reliable numbers are available.

Direct, indirect and to some extent macroeconomic rebound effects are usually taken into account in energy efficiency scenarios; however, underlying assumptions about the range of effects impedes comparability. It should be noted that rebound effects are hard to reliably quantify. This is particularly true for indirect and macroeconomic effects. Nevertheless, the existing evidence indicates that they pose a non-negligible challenge to energy savings policies.

7.4.2 Policy measures to minimise the rebound effect

The Ministry for Economic Affairs and Energy acknowledges in its Greenbook on Energy Efficiency that current policy instruments of energy efficiency do not sufficiently take rebound effects into account. Given the potential reduction in energy savings caused by rebound effects, they should be considered from the early stages of policy development onwards in order to fully reap their energy consumption reduction potential (BMWi 2016e).

The UBA has ranked different policy instruments by their susceptibility to strong rebound effects, which is presented in Table 16.

Table 19: Susceptibility of policy instruments to the rebound effect

Policy instrument	Susceptibility	Example
Subsidies	strong	Subsidies for cross-sectoral technologies
Requirements, efficiency standards	strong	Eco-design directive, CO_2 guideline for automobiles
Licenses for use	medium	Authorisation according to the Federal Emission Control Act
Voluntary agreements with the private sector	medium	Climate protection declaration of the German petroleum industry for the heating market
Public procurement	medium	Requirement for certified products, e.g. The Blue Angel certificate
Charges (taxes, fees, special levies)	weak	"EEG levy"
Traded certificates	weak	European emissions trading
Information and communication measures	weak	Efficiency labels

(Source: UBA 2016)

The ranking is a general indication, to which there are exceptions. For instance, efficiency labels as an information measure have shown significant rebound effects in the case of washing machines. Due to the definition of the energy efficiency index (EEI) label which tends to rate large machines positively, the average size of washing machines is increasing. As in many households, this is not matched by corresponding amounts of laundry, final energy consumption per unit of laundry may increase.

Charges such us energy taxes can counteract the rebound effect as they target final energy consumption. Similarly, communication measures with the aim to motivate clever use of energy as well as energy sufficient behaviour are a way to counterbalance rebound effects.

Generally, setting concrete envisioned energy savings rather than energy efficiency measures as policy targets helps to incorporate rebound effects from the indicator perspective. In spite of the difficulty to quantify rebound effects, there is an urgent need to close the evidence gap, in particular for indirect and macroeconomic effects.

7.4.3 Impact of behavioural approaches

As determined in the Climate Action Plan 2050, the German government will strive to foster participation and the development of an environmental consciousness as well as behavioural change in the context of climate protection (BMUB 2016a). Behavioural approaches can target either consumer purchasing decisions or use patterns.

The **potential for energy savings** from replacement of appliances is estimated at 60% and the savings potential from changed use routines is estimated at 20% of residential electricity consumption in Germany (Bürger 2009). The top three applications with regard to savings potential are cooling and freezing (ca. 6TWh), washing and drying laundry (ca. 5 TWh) and cooking (ca. 4 TWh). Feedback mechanisms play a central role in this context. It is generally acknowledged that they have measurable effects on behaviour change, if it is clear and easy to process. Direct feedback, such as immediate feedback from savings meters (e.g. visualised on a monitor) is expected to motivate energy savings in the range of 5-15%. Indirect feedback, such as bills may account for energy savings between 0-10%. Clearly, this varies depending on the quality of information as well as the context (Darby 2006).

Technological developments and corresponding policies such as smart meters connected to feedback mechanisms can be employed for the behavioural approach. The introduction of efficiency measures through the internet of things would also have a significant behavioural component that has to be considered both in the technical design and in complementary policy measures. Furthermore, information campaigns, energy advice and measures to incentivise energy sufficiency (see section 7.4.4) aim for a general change of behaviour. However, as discussed in the context of rebound effects (section 7.4.1), the behavioural approach is not only leveraged for positive change but can frequently have considerable adverse effects on the success of efficiency measures. Therefore, it is important to have a basic understanding of behavioural dynamics.

First, it is important to considered that pro-environmental values do not necessarily lead to pro-environmental behaviour. For example, **Information campaigns** as a policy measure implicitly assume that awareness of the consequences of a certain behaviour combined with the ascription of personal responsibility will lead to individual pro-environmental behaviour. Because of the so-called **value-action gap**, which describes the disparity between individual's concern for the environment and their consumption patterns, this is not necessarily the case. An extreme example would be environmental activists who frequently fly to their holiday destinations.

Another behavioural key is the importance of **habit**. It has been shown that individuals pay disproportionate attention to options which are readily available (Wilson and Dowlatabadi 2007). This has been leveraged in the case of electricity consumers in the city of Schönau in southern Germany. There, the standard electricity utility "EWS Schönau" provides electricity from renewable energy sources. Although this electricity is slightly more expensive than other options, most people tend to stay with their default provider (Pichert and Katsikopoulos 2008). A possible option would be, hence, to set the energy saving mode of new appliances as the default mode, as people are likely to keep this default setting (Stiftung Marktwirtschaft 2013). Interventions designed to leverage the role of habit and subconscious decision-making are referred to as **nudges** by Thaler and Sunstein, who ascribe significant energy savings potentials to this opportunity. As opposed to the Anglo-Saxon context, nudging has not played a prominent role in German policy design to date. However, in 2014, behavioural scientists were hired in the policy planning department of the German Government (FAZ 2014).

Another well-known theory with regards to the behavioural approach is the **social learning** theory (Bandura 1977), which suggests that people learn from one another. Accordingly, energy efficiency interventions based on teamwork have been shown to achieve better results than providing simple energy saving tips (Rat für nachhaltige Entwicklung 2017). An example of an initiative leveraging social learning are the "energy efficiency networks in industry". These foster social learning effects by supporting the formation of networks between different companies that exchange their approaches to energy efficiency (DENA 2017).

Individuals are also strongly influenced by **social norms**, i.e. what "ought to be done" because their peers do it (Steg et al 2013). In the American context, the energy utility Opower achieved a 2% reduction in electricity use simply by informing consumers about their energy use relative to their neighbours in so-called "Home Energy Reports" (Rat für nachhaltige Entwicklung 2017).

Another aspect refers to people's **self-identity,** which is forged, negotiated and affirmed by material goods or status symbols (Noppers et al 2014). Therefore, trends play an important role. In the case of the large consumer base for organic food in Germany, it seems that organic food has become part of the self-identity of a social group because it is possible to ascribe status with green product choices.

In conclusion, further research on the behavioural dimension is needed. Pro-environmental behaviour cannot be easily achieved by straightforward information campaigns. Rather, it is a complex issue, for which there is certainly no perfect solution. While low-cost behavioural change might be induced by information provision, costly or problematic behaviour changes require other, more sophisticated interventions. Civic engagement, public dialogue and social networks need to be employed particularly for progressive scenarios of sustainability, as those require profound changes in values, norms and identities.

7.4.4 The role of sufficiency in current energy efficiency policy

The concept of sufficiency adds an additional dimension to the discourse on energy savings. Rather than seeing it in contrast to efficiency, it should be considered an alternative path towards the end goal of energy savings. Sufficiency is closely intertwined with behavioural change and all its complications and potentials. Policies aimed at a shift towards sufficiency must therefore be informed by the behavioural approach discussed in section 7.4.3. Notwithstanding the complexity of changing human behaviour, sufficiency can make an impact in the short term as unlike energy efficiency, it does not require that old devices be swapped out over time.

The Öko-Institut defines sufficiency as a modification of consumption patterns that respect the Earth’s ecological limits, while aspects of consumer benefits change (Öko-Institut 2013). The sufficiency approach is helpful in providing a different perspective on energy savings than the efficiency discourse offers: it puts needs and desires into the focus of attention and poses a question about how these can be transformed (Wuppertal Institut 2015).

Policy instruments can enable sufficiency action through framework conditions, infrastructures and service offerings. **Supporting, regulating and informing instruments** touch on device design, the purchase and use of devices. Investing in sufficiency-related infrastructure in households belongs to this category of instruments. These instruments aim to make energy sufficiency more acceptable and practical in everyday life. For example, supporting communal laundry facilities or pick-up and delivery laundry services, or even changing housing regulations to allow for a common drying room, can foster less individual clothes drying and thereby sufficiency.

Examples of **special cross-applications instruments** is the idea to make electricity suppliers responsible for the reduction of electricity consumption in households (via a cap and trade scheme on the electricity consumption of all customers of a supply company together) and the support of municipalities in reducing or stopping the growth of living space per person. As part of this, the federal and state governments would need to finance the development of municipal living space agencies that combine consultations, moving assistance and the transfer of grants or subsidies. In addition, in the medium term, alternative living forms would need to be expanded (Wuppertal Institut 2015).

Ifeu et al. (2016) calculated the hypothetical case of complete implementation of measures in what they refer to as the ‘sufficiency spectrum’ in combination with maximum exhaustion of energy efficiency potential, which would theoretically result in electricity savings of up to 77% for the households sector in Germany. This correlates with a reduction of up to 360 PJ/a, of which at least in the short term two-third stems from energy sufficiency. In the medium to long term, efficient appliances would take over a larger share of these savings.

7.5 Energy service market

7.5.1 Potential of the energy service market

The energy service market in Germany comprises the product groups information, consulting, energy management and contracting (ESCO models). These products of the energy service market defined in more detail in the following figure:

Energy Services			
Information	**Consulting**	**Energy Management**	**ESCO models**
• Energy Performance Certificate residential buildings • Energy Performance Certificate non-residential buidlings	• On-site consulting residential buildings, non-residential buildings, process and system technologies, SME • Energy checks • Energy audits • Implementation support for energy efficiency measurs • Stationary energy consulting • Energy and Climate concepts for municipalities	• Energy Management (ISO 50001, ISO 14001, EMAS) • Energy Monitoring & Controlling	• Energy Performance Contracting • Operation Management Contracting • Energy Supply Contracting

Figure 20: Own illustration based on BfEE 2015

Figure 20 shows the range of energy services that are provided by energy service companies. They are characterised by a different service intensity: from solely information-based Energy Performance Certificates to complex Energy Performance Contracts, which can include a package such as energy concepts, implementation of energy efficiency measures, financing, training, and MRV. Energy-related investments typically require technical and economical expertise and experience. Therefore, a dynamic market for professional energy efficiency services is an important prerequisite for a sustainable increase in energy efficiency.

Compared to other European countries, the German energy service market is particularly well developed on the supply side and is characterised by a high competition. Energy suppliers as well as craftsmen, planners, architects, manufacturers of building equipment and measurement and control technology, and energy consultants are operating on the market. For the demand side, however, the benefits of energy efficiency services cannot often be clearly identified since information procurement is still associated with excessive transaction costs. To facilitate a higher uptake of energy services and the associated energy savings on the customer side, it is necessary to activate and incentivise demand more specifically.

A recent study for BfEE (2015) on the energy services market concludes that the service markets for energy consulting / energy audits, energy management and energy contracting have developed positively in recent years. Despite different market situations for the different products, around 77% of energy service providers see growth potential or strong growth potential for the energy services market. In 2015, approximately 535,000 people were employed in the energy efficiency market. The total turnover was about EUR 135 billion or 10% higher than in the previous year (DENEFF/PwC 2016).

Energy Performance Certificates provide **information** about the energy performance of a building for the owner or potential buyers and tenants of an object. As laid down in the EU Energy Performance of Buildings directive (EPBD), Energy Performance Certificates are mandatory for all buildings that are newly constructed, sold or newly rented-out. All public buildings of more than 250m^2 need to display their Energy Performance Certificate. In 2015, more than 250,000 Energy Performance Certificates had been registered in Germany.

According to the findings of the above-mentioned research, **energy consulting** is the most offered and demanded energy service product. Around 14,000 companies are estimated to provide a variety of energy consulting services. The market has increased from a volume of EUR 270 to 460 million in 2012 to EUR 480 to 520 million in 2015. Energy consulting is often an entry point for further energy efficiency services and investments. A high potential on demand side is estimated, while currently only around 1% of objects have been subject to energy consulting. Positive expectations dominate the market as around 73% of energy service providers expect a market growth in terms of turnover in the coming three years.

In the European Union, it is a prerequisite for non-SME companies to have a certified **Energy Management** System in place or carry out energy audits every four years. Since 2016, in Germany, all companies – which are not SMEs – need to have a certified Energy Management System in place or an energy audit. For SMEs, this can alternatively be an energy audit or alternative systems to improve energy efficiency. The market volume for energy management services is estimated around EUR 250-500 million per year with a growth tendency.

Energy Performance Contracting (EPC) and Energy Supply Contracting have the highest market volume of around EUR 7.2-8.4 billion with a steady annual increase (BfEE 2017b). The market volume has increased from EUR 3.5-5 billion (2012) and EUR 1.7-2.4 billion (2010) (JRC, 2014). More than 60% of energy service suppliers expect growth or even strong growth of the ESCO market until 2020 (BfEE 2017b).

The market research conducted by BfEE finds around 500 specialised ESCOs and utilities providing ESCO models while only around 10-15 ESCOs provide EPC in their portfolio. And while utilities only generate 17%, ESCOs generate almost two thirds of their turnover from energy services (BfEE 2017b). ESCOs mainly originate from utilities, energy companies and independent energy service companies (e.g. provider of building automation). Other market participants are energy consultants, engineering firms, crafts businesses and planners. The following figure shows their share in the market.

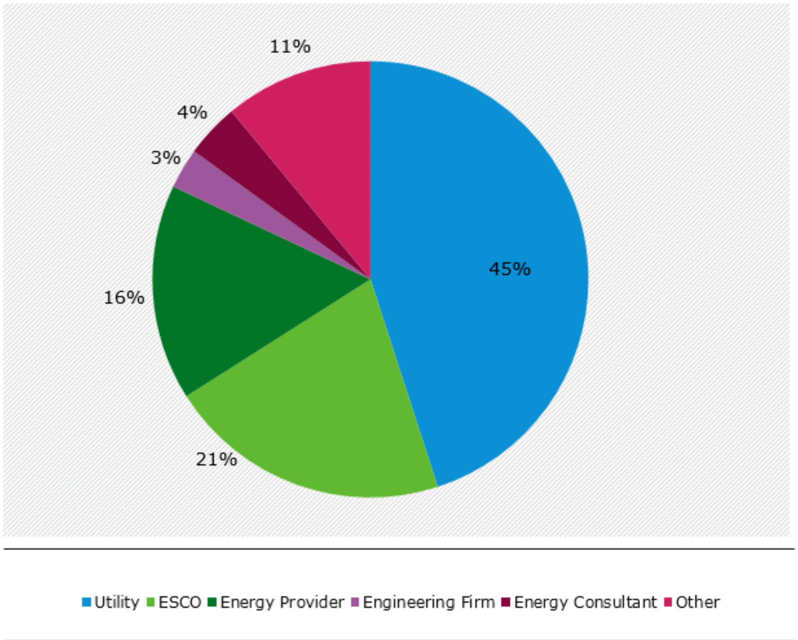

Figure 21: Origin of ESCO model provider
(Source: based on BfEE 2017b)

Approximately 80-85% of all ESCO projects are energy supply contracts, while only 8-10% of the market is covered with EPC (JRC, 2014). The remaining projects are other ESCO services which are of less relevance in the market, e.g. operation contracting.

Energy supply contracts are usually smaller than Energy Performance Contracts. Energy supply contracts target the supply of energy to the customer by fuel switching, the installation of renewable energies, or efficient technologies such as small CHP plants. They are focussed on carbon emission reduction rather than end-use energy consumption reduction. However, contracts may also include such elements and can achieve savings of 15-20%. Energy Performance Contracts, on the other hand, are larger in size and are often in the public sector. These contracts target energy savings, e.g. through efficiency measures in the heating system, lighting, ventilation but can also include measures targeting behavioural aspects of the users of a building. Some EPC contracts also include measures with longer payback periods such as windows or building insulation if additional financial resources are provided by the building owner. EPCs provide savings of usually around 20-25%.

7.5.2 Barriers in energy service markets

Various barriers slow the development of the energy service markets in Germany. Among them are (cf. BAFA 2013):

- Uncertainty regarding investments
- Capital shortages
- Investor-user dilemma
- Information and motivation deficiencies of the final customer

While an uncertainty regarding investments especially applies for measures with long return rates, uncertainty also exists over the transaction burden as well as the cost-benefit ratio of measures. Capital shortages exist in particular for private households and the public sector, but industry and commerce also experience these shortages when energy efficiency investments compete with investments in their core business. Given the large share of renters in Germany (cf. Chapter 2), the investor-user dilemma remains a large barrier. This means that the person investing in energy efficiency measures is not necessarily the beneficiary of the measure. ESCO models were originally discussed as a potential way to overcome this barrier, in case the landlord agrees for the tenants to pay the contracting fee, however in practice this remains uncommon.

Furthermore, an excess of information and no targeted attempts to address the information deficits by consumers slows the uptake of efficiency measures. In addition, specific barriers can be found in the energy service market. These include a lack of transparency for energy consulting, a mixing of different energy services and the low willingness of consumers to pay (HRW, IFEU, Prognos 2013).

With regard to contracting as an energy service, barriers are the investment risks for the contractor, information deficits of the customer and the complex legal set-up of contracting models, accompanied by regulations on energy and electricity taxes. Small and medium sized companies in particular are reluctant to take up energy services because energy costs only represent a small fraction of total costs. Therefore, they lack incentives to invest outside of the core business and are often also lacking dedicated energy efficiency staff.

The identification of suitable and innovative technologies in Germany is primarily the task of the market actors. In the long run, technological solutions are only financially viable if there is a matching demand. It is expected that digitalisation will create new opportunities for the development of the energy market.

7.5.3 Policies supporting energy service markets

Regulatory development as well as economic and social trends set the framework for the energy service market. The development of energy prices and the environmental consciousness of consumers play a large role and regulatory frameworks are important to provide investor confidence, both for the supply and demand sides. Market transparency, quality standards and availability of professionals jointly increase the attractiveness of the market for suppliers and consumers (DENEFF/PWC 2015).

Important policies have promoted energy consultations for residential buildings (renters and owners) as well as for SMEs and industry (buildings and processes). Additionally, the availability of tax relief for companies that have implemented an energy management system has led to increased demand since 2011. While in 2011 only 40 energy management systems were certified, in 2014 over 6,000 energy management systems were certified. Yet, so far it is not mandatory that energy saving measures recommended by the energy management system certification process are implemented.

Furthermore, the German government has implemented two policies to improve the qualification of professionals in this field ("Qualifizierungs- und Weiterbildungsoffensive" and "Qualitätssicherung am Bau bei der Sanierung"). These policies are seen by 60% of energy service companies surveyed annually by DENEFF as an important policy to expand their business (DENEFF/PWC 2015). However, almost the same amount of survey companies sees further improvements as necessary. This is due to the fact that different energy consultations (e.g. for industry or residential buildings) are not a circumscribed product with limited transparency for customers. Therefore, no competition over quality is currently taking place.

Two policies promoted by the National Action Plan Energy Efficiency, namely raising the ceiling of the existing loan guarantee scheme for energy performance contracting and the tendering scheme for energy savings, are not yet seen as important drivers for business development on the energy service market (DENEFF/PWC 2015). Given their recent introduction, this could very well be attributed to limited publicity of the measures and a small funding volume at present.

It is expected that digitalisation will create new opportunities for the development of the energy saving contracting and will also help develop new business models (e.g. accounting, measurement of energy savings, cost allocation) (BMWi 2016e).

Example 5: Energy Performance Contracting

Energy Performance Contracting (EPC) is a concept in which an Energy Service Company (ESCO) invests in energy efficiency measures in several buildings of a similar kind (pool of buildings) or a single large building and obtains returns on its investments through the achieved energy efficiency gains. In Berlin, this concept was introduced in the mid-90s mainly for public buildings and is known as "Energy Saving Partnership". The state's energy agency acts as a facilitator for the process and supports the public administrations of the districts in implementing the concept.

The public authority selects the buildings and looks for the best offer through a public tender procedure. The winning ESCO is selected by elements such as:

Quantifiable criteria	Non-quantifiable criteria
Volume of investment	Evaluation of concept of measures
Guaranteed energy cost savings	Energy management concept
Reduction of CO_2 emissions	Maintenance concept
	Evaluation of user motivation concept

After the best proposal is selected, the ESCO implements the proposed measures and validates its energy savings compared to a baseline. An important aspect of the contract are the guaranteed energy cost savings which means that if the ESCO does not achieve the amount of savings guaranteed in the contract, it either needs to implement additional energy efficiency measures or pay the difference to the contracting authority. The following figure shows the development of energy costs over time within an EPC contract. The "contracting rate" represents the achieved energy costs savings by the ESCO. After the end of the contract, the building owner is the beneficiary of the cost savings.

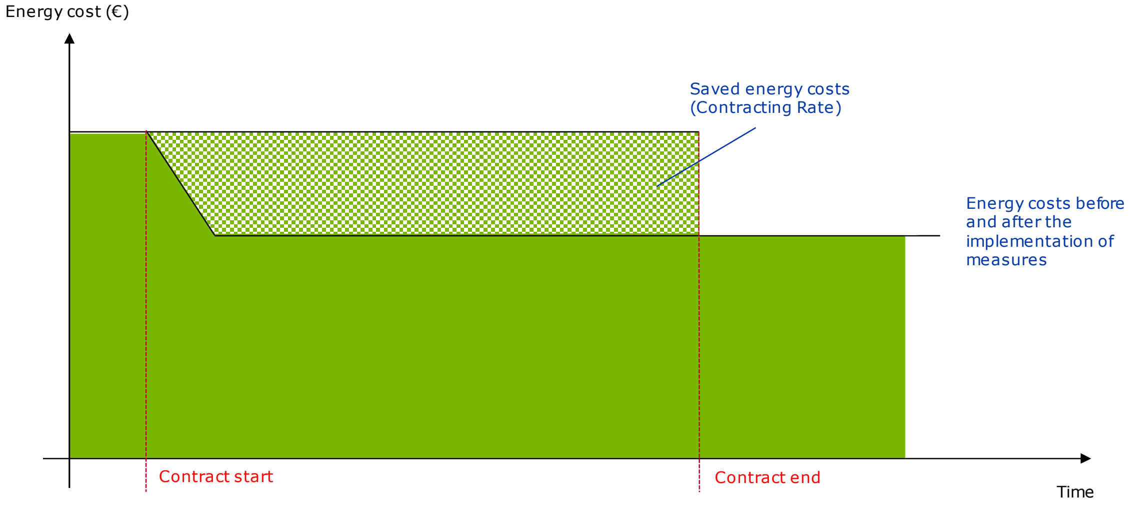

Figure 22: Simplified presentation of an EPC model
(Own figure)

In Berlin, more than 27 building pools, including more than 1,600 buildings have been modernised through this concept since 1996. On average, the projects achieved energy savings of more than 25%, creating energy cost savings of around EUR 2.8 million per year which makes this a best practice example. Overall EUR 55 million have been invested.

Figure 23: Energy performance contracting (Best practice example 5)

8 Outlook

In Germany, significant steps have been taken to promote the *Energiewende*. At the same time, considerable efforts will still be needed to reach the target path and tap the existing energy savings potentials. Currently, the renewable energy targets for 2020 are expected to be achieved, but presumably there will be a significant gap (~8%) in the climate protection target and also in energy efficiency targets. The achievement of German energy efficiency targets depends also on ambitious policies on EU level. These are currently not overly ambitious but the European Commission proposed a binding 30% energy efficiency target for 2030, which would consequently result in additional efforts. However, not all European Member States support a more ambitious energy and climate policy and try to create loopholes to water down energy efficiency targets and obligations.

The German *Energiewende* has been focused on power generation and the development of renewable energies so far. But the heating and transport sector will be crucial in the future to show the way to reach the energy transition. On the one hand, a climate-neutral building stock can only be reached by significantly increasing the renovation rate, promote deep renovation of the existing building stock and setting ambitious requirements for new buildings. In the transport sector, on the other hand, the efficiency of vehicles needs to be drastically increased but reducing the total fleet and improving modal shift are considerable challenges as well. Here, current developments move in the other direction, e.g. the target of 1 million electric vehicles in 2020 was dropped by the government, the share of road freight transport still ranges by three-quarter of the entire freight transport and both, passenger and freight vehicles have constantly increased in total numbers in the last years.

Consequently, the existing policy mix which comprises in particular subsidy and energy advisory programmes is not sufficient to meet the challenges also in the longer run towards 2030 and 2050. The government has substantially build up capacities (staff and finance) in energy efficiency in recent years but the demand for many subsidy programmes is rather low. About one third of the funds, which were made available for energy savings measures by the Energy and Climate Fund in 2016 and which would have added up to 2.4 billion EUR, were not drawn down. This means that other barriers need to be removed and further policies and instruments be developed in order to achieve the required energy savings. Climate protection and energy efficiency considerations need to be mainstreamed through all policy and investment decisions, e.g. by consequently implementing the 'energy efficiency first' principle. Thus, even stronger interfering instruments as regulatory or price control measures as well as planning measures need to be considered.

In addition, the co-benefits deriving from the energy efficiency actions must be clearly stressed, e.g. improved air quality, health, comfort of living as well as macroeconomic impacts. According to model calculations, additional investments of more than 100 billion $Euros_{2005}$ are needed by the year 2020 which need to be triggered by the energy efficiency policy. A large part of these investments are in the construction sector. Co-benefits of an ambitious energy efficiency policy will also materialise in terms of employment. The model calculations also show a positive effect on employment of almost

190,000 full-time jobs in 2020 (BMWi 2016e, p.12/13). Finally, resource and energy efficiency will become increasingly important international competitive advantages in the next few years.

The Climate Action Plan 2050 and the Green Book Energy Efficiency introduce a paradigm shift which aims to rethink renewable energies and energy efficiency. While until now both have been considered as technologies which need to be integrated as climate technologies into the established fossil fuel based markets they now become the standard for investments. This includes firstly the “energy efficiency first” principle. The energy demand in industry, buildings and transport has to be significantly and sustainably reduced. Then, secondly, renewable energies meet the remaining energy demand and, thirdly, where appropriate and possible, renewable electricity is used for heating, transport and industry (sector coupling). Renewable fuels such as biomass are used where electricity cannot be used, especially in the aviation and shipping sectors, as well as in parts of the industry. In the future, however, it will be necessary to clarify to what extent the sector coupling and ongoing digitalisation influence the development of energy efficiency.

Digitalisation affects all levels of the energy value chain. The analysis of increasingly large amounts of data is used to identify new efficiency potentials. Electricity networks, for example, can be linked intelligently to each other and to electricity generation and consumption through the use of modern technologies. New actors (prosumers) will be involved in it. In the area of energy and resource savings, digitalisation will also open up great potential. This applies in particular to intelligent buildings, transport optimisation and intelligent production systems. Digitalisation has the potential to revolutionise our lifestyles and brings great possibilities for energy efficiency. However, acceptance and timing are still uncertain and data security issues have to be solved.

Ultimately, the *Energiewende* is based on societal consensus and can only be implemented together with all stakeholders. The Government has launched a broad-based consultation processes with the *Energiewende* platforms (energy efficiency, buildings, etc.), the dialogue process on the Climate Action Plan 2050 and the consultation on the "Green Paper on Energy Efficiency". The government will need to continue along this path to ensure that the *Energiewende* is accepted and supported by society as a whole.

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The Institute of Applied Energy

Part II: Country Report Japan

By: Atsushi Kurosawa

1 Introduction

1.1 About this study

This country report of Japan is the summary of Work Package 1 'Analysis' in the strategic topic 4 'Energy end-use efficiency potentials and policies and the development of energy service markets' of German-Japanese Energy Transition Council (GJETC).

Looking back at history, two oil shocks in the 1970s were the initial milestones that influenced energy efficiency improvement in Japan. After the shocks, various energy saving technologies have been widely disseminated through energy efficiency improvement in production processes and end-use energy equipment developments by businesses and institutions for energy management and energy efficiency. They resulted in the decrease of final energy consumption per activity as well as the improvement of energy security on the supply side. From other perspectives, the issues raised after the 1990s, such as the global environmental agenda and the Great East Japan Earthquake, were the influential factors in energy efficiency improvement in Japan.

In this report, Japanese energy efficiency potential and policies are surveyed and new energy market opportunity is discussed.

1.2 End-use energy consumption trends

It is essential to know the current status of end-use energy before discussing end-use efficiency potentials and policies. Energy White Paper 2016 (METI 2016) reported the energy supply and demand overview in Japan. The sectoral share of final energy consumption in Japan in 2014 was 44.8% in industry, 17.8% in commercial, 14.3% in residential and 23.1% in transportation. Following a trend of roughly 40 years, Japan's industrial energy consumption has remained almost unchanged since the oil crisis in the 1970s, but consumption and share of residential, commercial, transportation are expanding (see Figure 24).

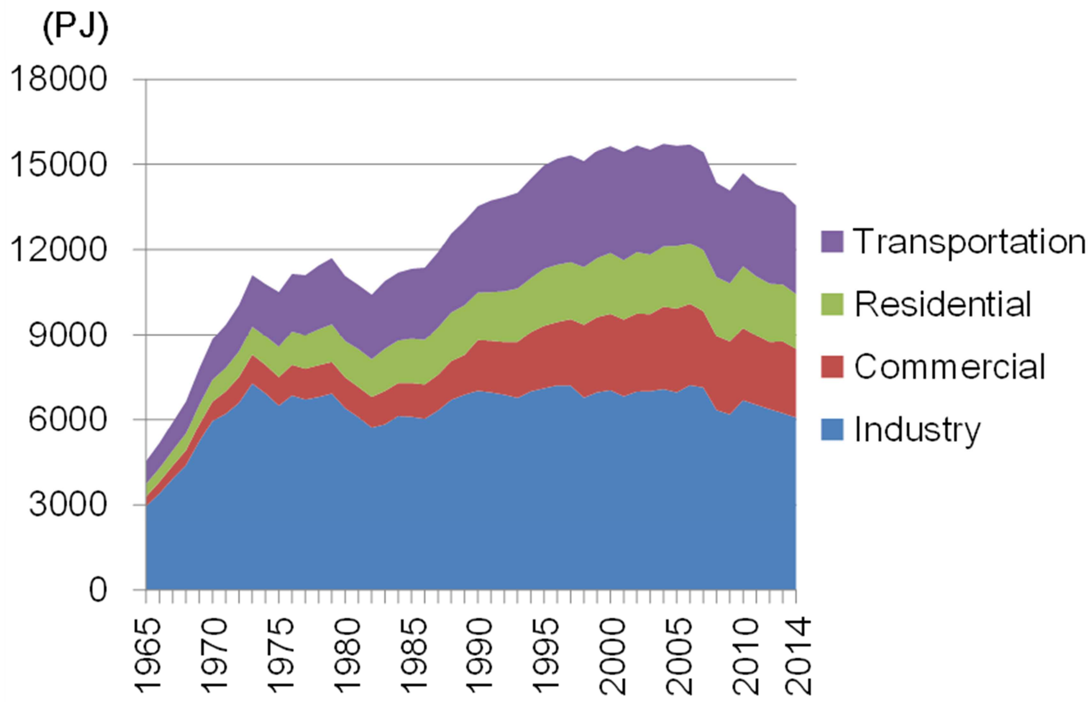

Figure 24: End-use energy consumption in Japan

1.3 Long-term energy supply and demand outlook

Figure 25 shows the transition of final energy consumption in the Long-term Energy Supply and Demand Outlook. Both the reference case and the aggressive conservation case are shown for 2030 figures, and the difference between the two corresponds to the energy saving potential.

The Paris Agreement of United Nations Framework of Climate Change requested mid-century target for parties. Currently, some Japanese government ministries discuss mid-century low carbon social system but comprehensive energy package plan with policy initiatives has not shown. Therefore, we limit the policy related discussion up to 2030 in Japan report.

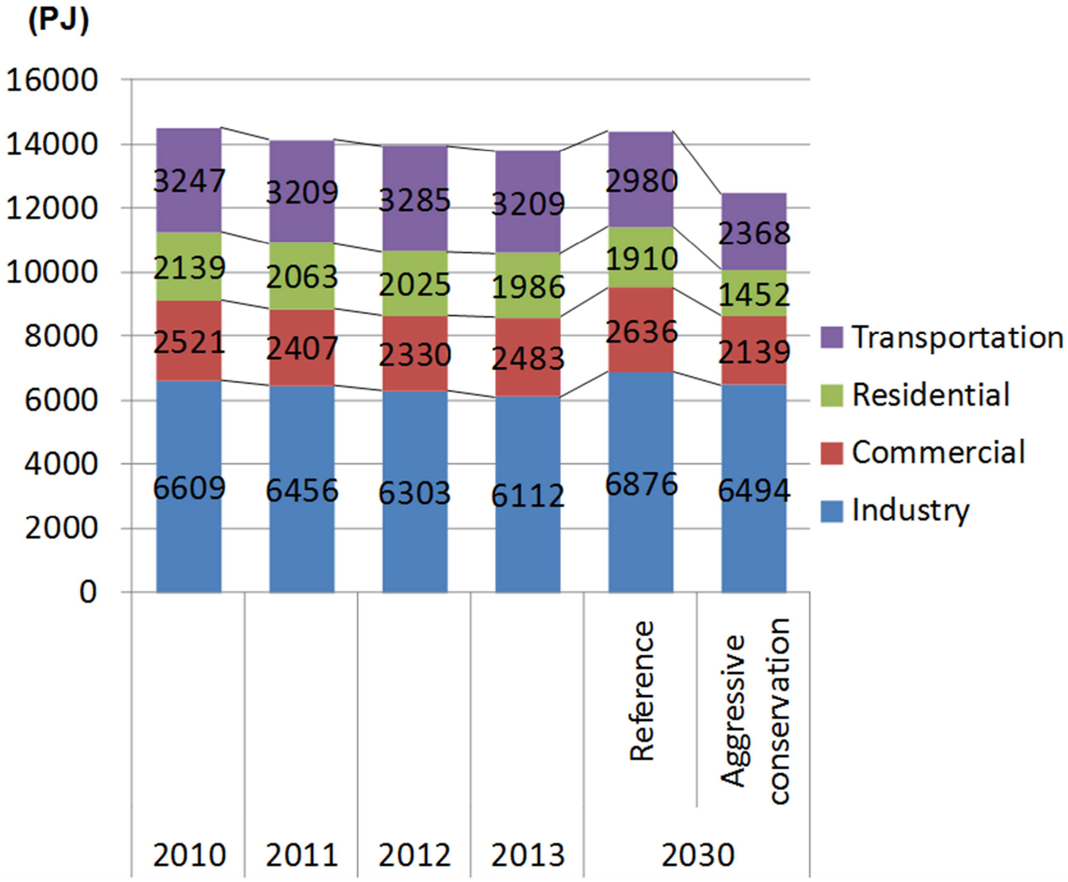

Figure 25: End-use energy transition in Long-term energy supply and demand outlook[26]

1.4 Energy saving potential in 2030 and 2050

In February 2015, the Energy Conservation Division of Agency of Natural Resource and Energy reported a provisional estimate of energy saving potential in 2030 as a material for the Energy Conservation Subcommittee of Advisory Committee for Natural Resources and Energy (ANRE 2015a). Through the formulation of the long-term energy supply and demand forecast for 2030, the estimate is also the basis of the greenhouse gases reduction target of 2030, which the Japanese government submitted to the UN Framework Climate Change Convention in July 2015 as an Intended Nationally Determined Contributions (INDC) document.

[26] Original Unit is Million kL oil equivalent. Numbers are converted using conversion factor Million kL oil equivalent = 38.2 EJ.

Provisional energy saving potential is defined as the differences between reference case and aggressive conservation case. Total potential is 14% of reference energy demand, and 6% for industry, 19% for commercial, 24% for residential and 21% for transportation.

A breakdown of an estimate for provisional energy saving potential in end-use sectors is summarized in Figure 26. Detailed breakdown is discussed in the following sections. It should be noted that the original figures in the sectoral assessment tables are oil equivalent units. These numbers are converted to PJ for comparison with German numbers. There was no description of methodology of energy saving potential calculation. However, policy packages for energy efficiency improvement are shown. In this sense, it is considered as policy-driven energy saving potential.

Figure 26 provides two kinds of energy saving potential for industry. One is end-use energy saving, another is energy savings including primary energy efficiency improvement in conversion sector such as recycled material thermal use, heat recovery and high efficient boiler, etc.

The Institute of Energy Economics Japan publishes a global energy outlook every year. The latest version IEEJ Outlook 2018 (IEEJ 2017a) extends its assessment time horizon to 2050. It prepares a reference scenario and an advanced technology scenario by global region. Japan is one of the global regions, and the demand difference between reference and advanced technology can be regarded as energy saving potential of Japan in 2050.

Advanced industrial demand technology examples are best practice technology global diffusion in iron&steel, cement, and paper&pulp processes. Building energy saving technologies assumed are home appliances (refrigerator, television, etc.), hot water supply (heat pump etc.), illumination, thermal insulation of buildings. In addition, transportation sector energy saving technology examples are clean energy automobile (fuel efficient cars, hybrid cars, plug-in hybrid cars, electric vehicles and fuel cell vehicles).

The estimated potential is estimated for 42 PJ in industry, 419 PJ for buildings and agriculture, and 377 PJ for transportation. These numbers are smaller than ANRE assessment targeted in 2030, and further saving opportunities should be elaborated.

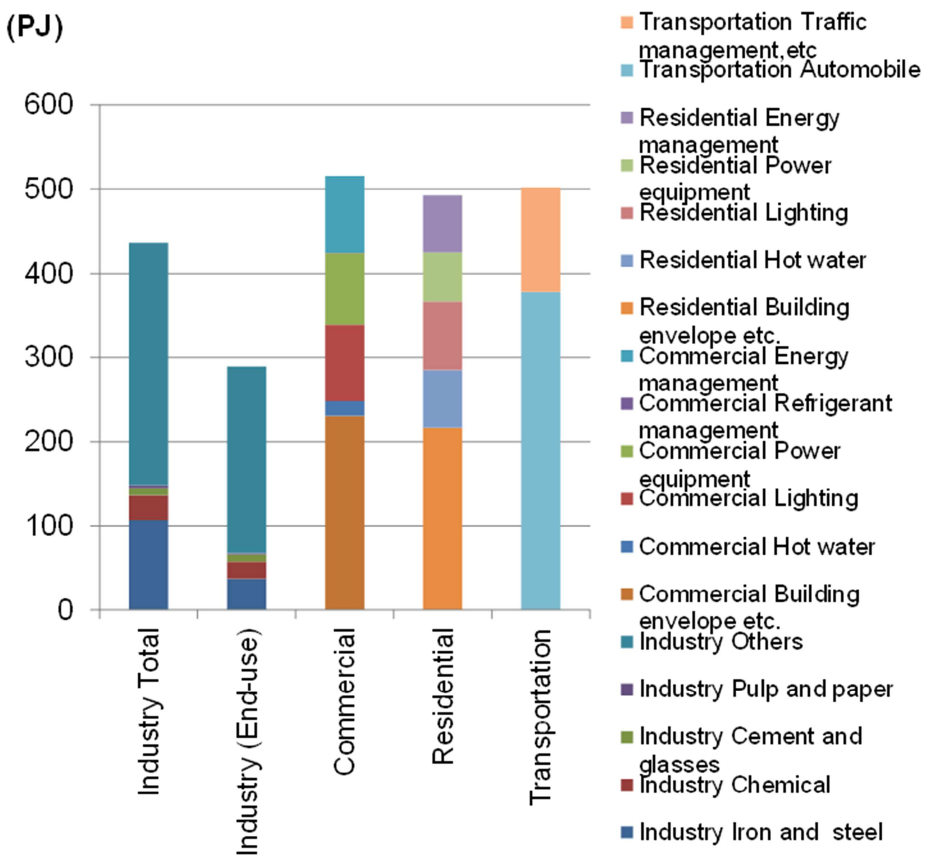

Figure 26: Japanese energy saving potential in 2030[27]

[27] Original Unit is 10,000 kL oil equivalent. Numbers are converted using conversion factor 10,000 kL oil equivalent = 0.382 EJ.

2 Industry sector

2.1 End-use energy consumption

Regarding the composition of industrial energy consumption, iron and steel, chemicals, ceramics, and pulp and paper account for about 80% of the whole industry, which is characterized by the high ratio of primary material industry consumption. In recent years, the growth rate of primary material production has been saturated, and energy consumption as well as energy consumption intensity per Indices of Industrial Production (IIP) has remained almost constant. On the other hand, looking at non-primary material industries, the energy consumption intensity per IIP and the production indices have not increased. As a result, the energy consumption of the industrial sector as a whole has been flat or decreasing in recent years.

2.2 Energy efficiency indicators

The efficiency indicator trend after the 1970s for the end-use sectors are reviewed in the following sections, using the energy and related statistics data provided by the Energy Data and Modelling Center of the Institute of Energy Economics Japan (IEEJ 2017b).

In the industrial energy consumption, manufacturing dominates the consumption, as non-manufacturing (i.e. agriculture, forestry, fishing, mining, and construction) share was around 10% in the 1970s and has gradually fallen to its current level of about 5%. Therefore, the manufacturing industry trend should be discussed. The major primary material industry (i.e. iron and steel, chemical, ceramics, and pulp and paper) is energy intensive in general in their production process, and it is called energy intensive manufacturing in the following descriptions. Other manufacturing industries are aggregated to non-energy intensive manufacturing.

Long term trend is summarized in Figure 27 in energy intensive manufacturing (orange), non-energy intensive manufacturing (green) and manufacturing in total (red). The typical activity index for manufacturing is IIP (hashed lines) and intensity is defined as energy consumption per IIP (solid lines). This results in a relatively stable trend of energy consumption (dotted lines) with contribution of energy efficiency improvement, especially in energy intensive manufacturing. We can find that energy intensity has fallen to around half compared to the intensity at the beginning of the 1970s. It is the dominant factor in manufacturing intensity improvement, because within manufacturing, energy intensive manufacturing’s share of energy consumption is high.

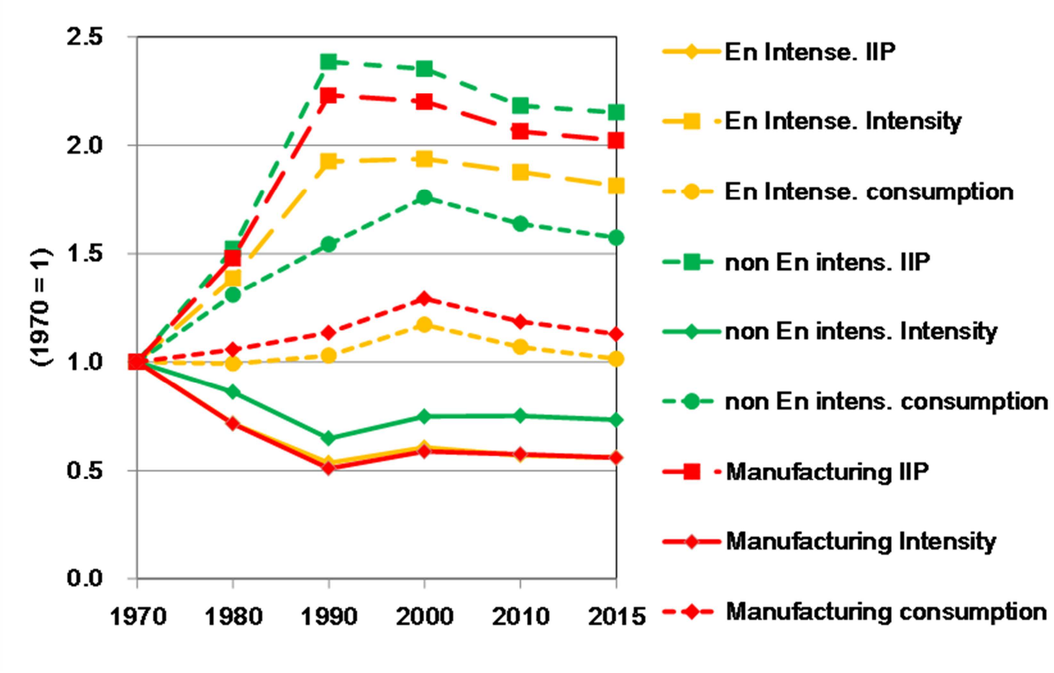

Figure 27: Manufacturing energy consumption trend and factor decomposition in Japan

2.3 Potentials

As for policy measures concerning energy conservation in the industrial sector, about 90% (energy-base) of industries are regulated by the Energy Conservation Act (IEA 2016, see Annex 1), requesting approximately 1% or more conservation on annual average. In addition to that, energy intensive manufacturing, with 60% of the energy share, sets benchmark targets. For small and medium-sized enterprises that are not covered by the Energy Conservation Act, diagnostics on energy-saving potentials are also being implemented.

The industrial sector energy saving potential is summarized in Table 20 (ANRE 2015a). It should be mentioned that some total 'potential' numbers with asterisks in the table include energy savings in conversion process, such as recycled material thermal use, heat recovery and high efficient boiler, etc. End-use energy saving is final energy saving.

Among energy intensive industries, the energy saving potential of the iron and steel and chemical industries is relatively high. Technologies such as electric power supply from waste heat recovery, use of waste plastics, coke (i.e. coal pre-treatment, low grade coal and low-grade iron ore combination), hydrogen reduction, etc. are the technology candidates in iron and steel. In chemistry, most of the potential is occupied by the use of energy efficient processes. In ceramics, the potential of low temperature sintering clinker is high. In other areas, the potential contribution of highly efficient industrial furnaces, electric motors, boilers and lighting are the main candidates.

Energy management at the factory is mentioned as an item, but its potential has not been quantitatively shown.

Table 20: Energy efficiency potential in conversion and industry in 2030[28]

Type	Potential, (PJ)	End-use potential (elec.), (PJ)	End-use potential (fuel), (PJ)	Technology options
Iron and steel	106.9(*)	16.4	21.2	Power supply (incl. heat recovery power generation), plastic waste recycle, advanced coke, ferro coke (combined material of low-grade coal and low-grade iron ore), hydrogen reduction
Chemical	29.4(*)	5.0	15.3	New process, membrane distillation, CO_2 utilisation, non-edible biomass, bio-catalyst, vegetation factory
Cement and glasses	8.8	0.0	8.8	Conventional energy-saving process (milling, cooling, waste heat power generation, etc), waste recycle, low-temperature firing clinker, advanced glass melting process
Pulp and paper	3.6(*)	1.4	0.0	Recycled paper pulping, advanced black-liquor boiler
Others	287.8(*)	127.1	94.4	Efficient air conditioning, industrial heat-pump, LED lighting, industrial furnace, efficient motor, efficient boiler, direct use of recycled plastic flakes, hybrid construction machine
Energy management	-(unknown)	-(unknown)	-(unknown)	Factory energy management system, etc.
Subtotal	436.5(*)	149.9	139.7	

(*) including primary energy efficiency improvement in conversion sector

2.4 Barriers

The actual level of market penetration of cost-effective energy efficient technologies is often below optimal level. It is recognized as the energy efficiency gap by various bottleneck factors and energy efficiency barriers. The results of literature surveys and general findings are summarized in the following sections.

[28] Original Unit is 10,000 kL oil equivalent. Numbers are converted using conversion factor 10,000 kL oil equivalent = 0.382 EJ.

In August 2015, the Energy Conservation Subcommittee of the Advisory Committee for Natural Resources and Energy consolidated bottlenecks and required energy policies on energy conservation by the energy demand sector as a reference material together with present policies (ANRE 2015b).

Several barriers in the industrial sector are noted. They include stagnation of energy efficiency improvement as a result of energy conservation efforts so far, aging of large facilities due to the length of investment payback period, lack of positive co-action evaluation among multiple enterprise businesses, and lack of funds, human resources, and know-how for small and medium companies.

3 Commercial sector

3.1 End-use energy consumption

Energy consumptions in nine commercial subsectors were estimated by business type. This includes office buildings, department stores, lodging facilities, theatres, entertainment venues, schools, hospitals, wholesale and retail stores, restaurants and other services. Among them, the share of office buildings, wholesale and retail stores in 2013 is relatively large; 21.6% and 19.5% respectively. A representative activity indicator for energy consumption of the commercial sector is the total floor space, which has increased by 40% from 1990 to 2013. However, the energy consumption has remained almost unchanged since 2010, and energy consumption per floor space has been continuously decreasing. It is thought that this is due to the improvement of energy efficiency of equipment and heat insulation improvement of buildings, but there are also factors which are increasing, such as an increase in the number and size of equipment and an increase in cooling demand due to equipment heat generation.

3.2 Energy efficiency indicators

Commercial sector intensity per floor space by category in the past 45 years is summarized in Figure 28 (IEEJ 2017). We can find heating, cooling, hot water, cooking, and appliances intensities in the figure. The share of appliances increased in the long-term portfolio. Total intensity was stable till 2000, but started decreasing in 2000. Intensity changes from combined effects of equipment efficiency, heat insulation, size and number of appliances, as well as additional cooling demand from appliance heat source. But a 3.3 times floor space increase in 45 years, as shown in the line graph, exceeds the decrease of intensity effect. It resulted in an increase in total commercial demand.

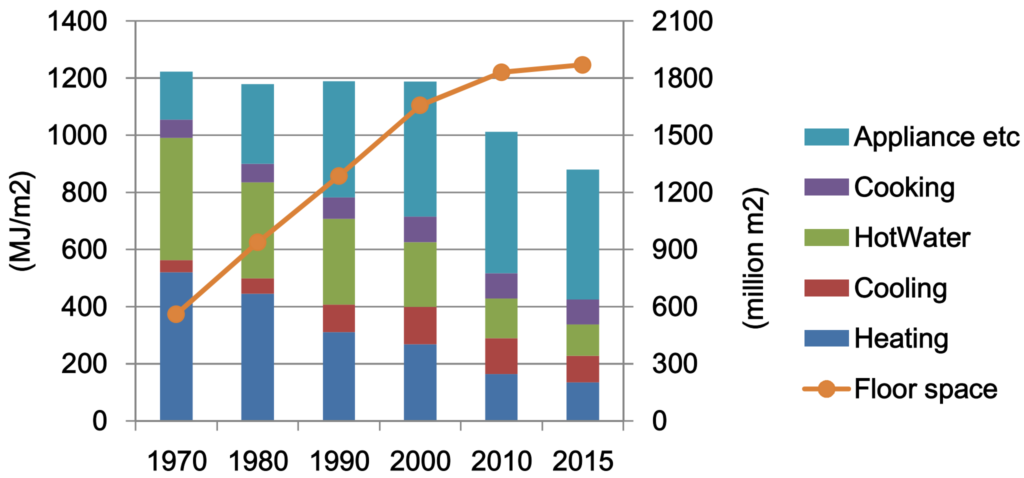

Figure 28: Commercial energy consumption intensity and floor space in Japan

3.3 Potentials

Large-scale enterprises in the commercial sector are subject to the energy consumption restriction of the Energy Conservation Act, and in terms of energy consumption, the coverage rate is about 40%. In addition, it is said that incentives for energy conservation are unlikely to work because the energy input per production value is lower than that of the industrial sector. New policy measures in energy conservation for the commercial sector include mandating compliance with energy conservation standards in the Building Energy Conservation Act, preliminary review of the benchmark system defined by energy saving indicators for each industry, and demonstrating projects on net zero energy building with subsidies.

Table 21 summarizes the energy-saving potentials of the commercial sector (ANRE 2015a). The largest one is due to improvements in the building envelope performance, etc. and the energy-saving potential is high for both electricity and fuel. The potential of power reduction of lighting and electric equipment is also estimated to be large.

Energy management other than the Building Energy Management System (BEMS) such as lighting standards, air conditioning load reduction by clothing adjustment, and energy utilisation management across multiple business establishments are also mentioned as items, but the potential is not quantitatively identified.

Table 21: Energy efficiency potential in commercial in 2030[29]

Type	Potential, (PJ)	End-use potential (elec.), (PJ)	End-use potential (fuel), (PJ)	Technology options
Building envelope etc.	230.9	117.3	113.6	Heat insulation material, thermal insulation windows, etc.
Hot water	17.0	5.6	11.4	Heat pump, latent heat recovery boiler, etc.
Lighting	90.9	90.9	-	LEDs, organic ELs
Power consumption equipment	85.4	85.4	-	Copy machine, printer, router, server, storage, refrigerator, autonomous vending machine
Refrigerant management	0.2	0.2	-	Refrigerant management in air conditioner
Energy management	91.3	46.5	44.8	Building energy management system, etc.
Subtotal	507.1	338.2	168.9	

3.4 Barriers

The commercial sector barriers raised in the material are: lack of sharing good practice, insufficient diffusion of energy management in small and medium enterprises due to energy cost non-consciousness, and low energy efficiency in buildings in spite of their long life (ANRE 2015b).

[29] Original Unit is 10,000 kL oil equivalent. Numbers are converted using conversion factor 10,000 kL oil equivalent = 0.382 EJ.

4 Residential sector

4.1 End-use energy consumption

A representative activity indicator for energy consumption of the residential sector is the number of households. The number of households has increased about 1.3 times from 1990 to 2013, while the energy consumption per household has continued to decline in recent years. Factors related to the decrease of energy consumption per household include decrease in household size, energy efficiency improvement of equipment, building insulation improvement, etc. At the same time, there are also factors related to increase in the number and size of equipment. After these activity indices and intensity factors are comprehensively taken into consideration, it resulted in a decreasing trend.

Japan is long from north to south and has a high mountain area ratio. They create various local climate condition, and local heating and cooling demand represented by heating degree day (HDD) and cooling degree day (CDD) in Figure 29 and Figure 30 (IEEJ 2017b). For example, it is observed that large HDD and small CDD for far northern city Sapporo, medium HDD for other cities, medium CDD for Sendai and Toyama located in relatively northern latitude, large CDD for other cities. We must pay attention to inter-annual variability and heat island effects to judge the values. This tendency affects regional heating and cooling demand differences in Japan.

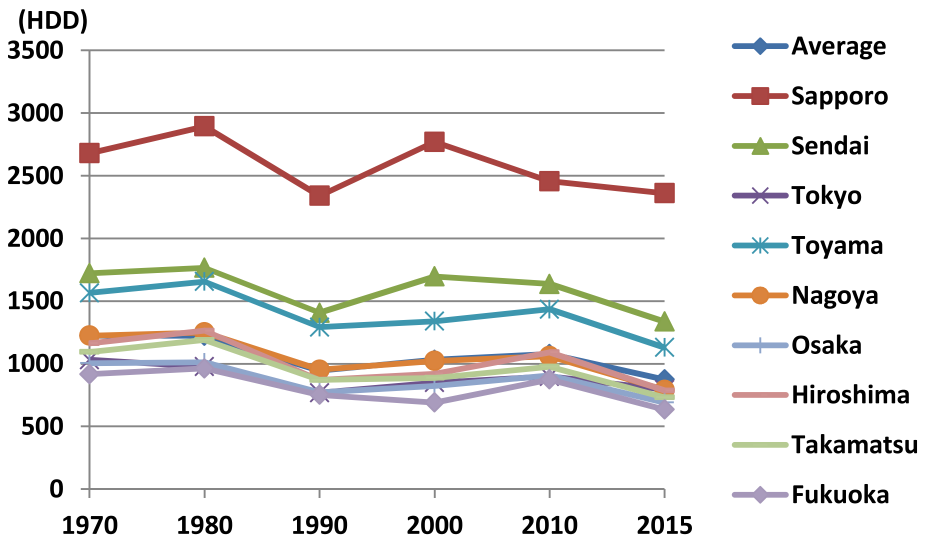

Figure 29: Heating Degree Days of representative cities in Japan

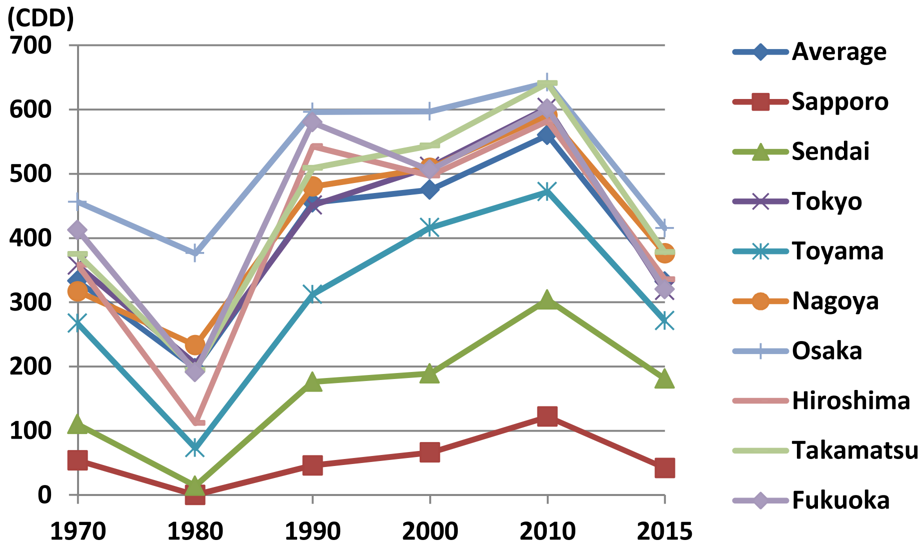

Figure 30: Cooling Degree Days of representative cities in Japan

4.2 Energy efficiency indicators

Residential sector intensity per household by category and energy source is summarized in Figure 31 (IEEJ 2017b). You can find the same categories as that of the commercial sector. The share of appliances increased in the long-term portfolio and total intensity increased till 2000 but started decreasing in 2000. Intensity changes from combined effect of household size, equipment efficiency, heat insulation, size and number of appliances, like the commercial sector. A 1.9-fold increase in the number of households, shown in the line graph, cancels out intensity effects. As a result, total residential demand has been saturated in recent years.

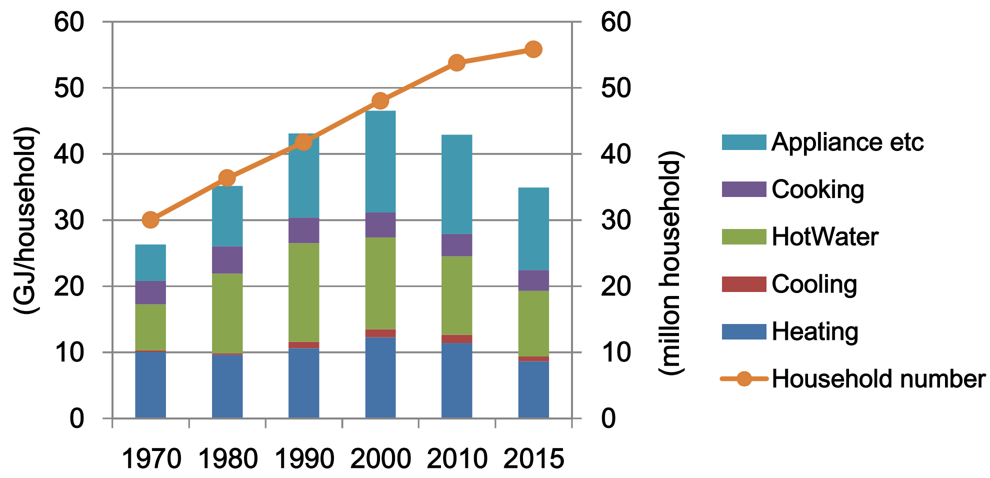

Figure 31: Residential energy consumption intensity and household number in Japan

4.3 Potentials

Regarding the energy consumption of the residential sector, the percentage of regulation covered consumption satisfying energy performance standards, called "top runner" products, is said to be 70% of the consumption in 2009 (see Annex 2) (IEA 2016). Gas water heaters, gas cooking appliances, electric refrigerators, lighting equipment, oil heaters, televisions, oil water heaters, air conditioners, etc. have a high share.

Also, in recent years, as a policy measure, the net zero energy house (ZEH), which combines solar power generation and high-performance thermal insulation construction, has technically matured. It is considered to have entered the diffusion stage. The ZEH subsidy system was developed and the ZEH numbers cumulatively reached a scale of tens of thousands.

The energy saving potential of the household sector is summarized in Table 22 (ANRE 2015a). The largest one is due to improvements in building envelope performance, etc. and its energy saving potential is high for both electricity and fuel. The potential of power reduction of lighting and electric power equipment is also estimated to be large.

In addition to the BEMS, energy management options such as the reduction of air conditioning load by clothing adjustment, energy diagnosis, etc. are also mentioned as items, but the potential is not shown quantitatively.

It also should be noted that high insulated homes could reduce the excess winter mortality in Japan. One of the Japan Revitalisation Strategy 2013 (Prime Minister Office 2013) targets is promotion of smart wellness housing and cities. Residential building envelope heat insulation improvement will bring multiple benefit in terms of energy savings and public health improvement.

Table 22: Energy efficiency potential in residential in 2030[30]

Type	Potential, (PJ)	End-use potential (elec.), (PJ)	End-use potential (fuel), (PJ)	Technology options
Building envelope etc.	216.6	107.8	108.8	Heat insulation material, thermal insulation windows, etc.
Hot water	68.8	-0.3	69.1	Heat pump, latent heat recovery boiler, fuel cell, etc.
Lighting	81.0	81.0	-	LEDs, organic ELs
Energy consumption equipment	58.2	45.8	12.4	Air conditioner, TVs, refrigerator, DVD recorder, computers, magnetic disk, router, microwave, rice cooker, gas cooker, hot water toilet seat, gas stove, kerosene stove
Energy management	68.1	68.1	-	Home energy management system, etc.
Subtotal	473.0	291.0	182.0	

4.4 Barriers

In the residential sector, non-achievement of a lifestyle with energy saving while maintaining comfort, different incentive approaches which is not employed in business, low energy efficiency in buildings in spite of their long life, and lack of energy saving consciousness are listed as major barriers (ANRE 2015b).

A technology improvement in electric heat-pump air-conditioners saves primary energy consumption if its technology performance index COP (coefficient of performance) exceeds the inverse of power generation efficiency. Current COP numbers exceed its break-even numbers and can save fuel consumption in power generation plants.

CRIEPI (2009) investigated the heating equipment unit numbers and heating technology (e.g. electric heat-pump, gas stove, and oil stove) in 2500 households in Japan. It identified heating technology preference by house owner/rent, heat insulation, oil price, etc. and discussed 6 barrier factors based on categorisation by Sorrell et al. (2004). Barriers embedded in the replacement of oil/gas heating equipment with electric heating equipment are calculated. The barrier is defined as the difference between economic potential and market potential. Breakdown of each barrier's contributions to CO2 reduction was assessed in the cost range of less than 3000JPY/tonCO2. Contribution factors are: imperfect information, split incentives, bounded rationality, access to capital, hidden costs, and risk.

[30] Original Unit is 10,000 kL oil equivalent. Numbers are converted using conversion factor 10,000 kL oil equivalent = 0.382 EJ.

It concerns the reduction of CO_2, but also provides suggestions for energy conservation. Total CO_2 reduction barrier was 33%. The largest factor was imperfect information (21%), followed by hidden cost (8.1%), and risk (5.2%). As for imperfect information, consumer prediction of the increase of utility expenses is discussed. Hidden cost is noted as utility loss by changes in heating technology, significant especially in cold regions. Risk is mentioned as investment risk in terms of initial cost and payback time.

5 Transportation sector

5.1 End-use energy consumption

Energy consumption in the transportation sector begins to decline around 2000. The composition in 2013 is 35% freight and 65% passenger. In the modal composition of vehicle, rail, navigation and aviation, the vehicle share is about 80%. Consumption intensity is indicated in terms of per passenger-kilometre for passengers, or per ton-kilometre for freight. Both indicators begin to decline around 2000, and together with the saturation of service demand in passenger-kilometres and ton-kilometres, it leads to a reduction trend in transport energy consumption.

5.2 Energy efficiency indicators

Passenger transport energy intensity by mode (solid lines), transport volume in passenger-km (hashed line), and energy consumption (dotted line) are summarized in Figure 32 (IEEJ 2017b). It seems that average intensity has gotten worse because of the complex background behind it. The most influential point is the shift in modal share. Private passenger vehicle and rail are two dominant modes in Japanese passenger transportation. At the beginning of the 1970s, the share of both modes is around 40%, but recent share in 2015 is 56% for private passenger vehicle and 30% for rail, respectively. Because the energy efficiency of rail is better than private passenger vehicle by a factor of 10, relative shift in modal share has affected aggregated transport efficiency. Another point is the size of passenger cars. It is obvious that its exhaust volume and dimension has affected fuel efficiency.

However, there are good indicators in passenger vehicles. The fuel efficiency of the new passenger vehicle has roughly doubled in 45 years and the share of the hybrid in new car sales is around 35% in the recent statistics.

Freight transport energy intensity by mode (solid lines), transport volume in ton-km (hashed line), and energy consumption (dotted line) are summarized in Figure 33 (IEEJ 2017b). It seems that average freight energy intensity is relatively stable from 1970 to 2015, in spite of efficiency improvement in all freight transportation modes. The influential factor is a shift of modal share as seen in passenger transport. Vehicle (30%), rail (20%) and navigation (49%) are the dominant modes in 1970. Absolute intensity of rail and navigation is 7 to 10 times better than that of vehicle at that time. In 2015, ton-km based modal share has shifted to 50% for vehicle, 5% for rail, and 44% for navigation, and absolute intensity of rail and navigation is 10 to 20 times better than that of vehicle. Because of the above reasons, aggregated average intensity of freight transport followed a flat trend.

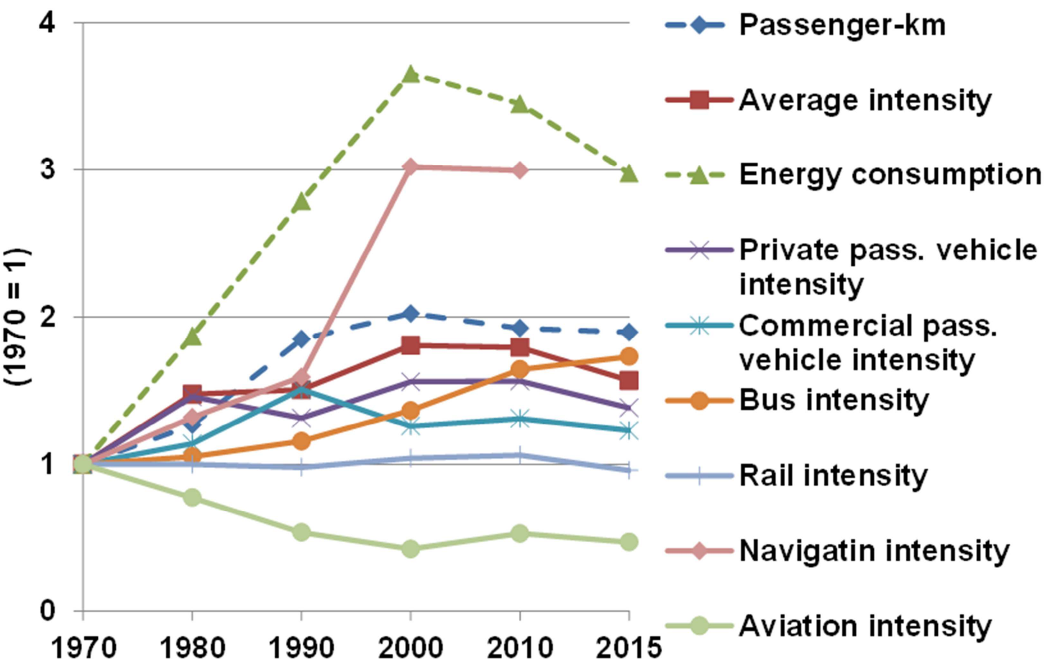

Figure 32: Passenger transportation: energy intensity by mode, transport volume, and energy consumption in Japan

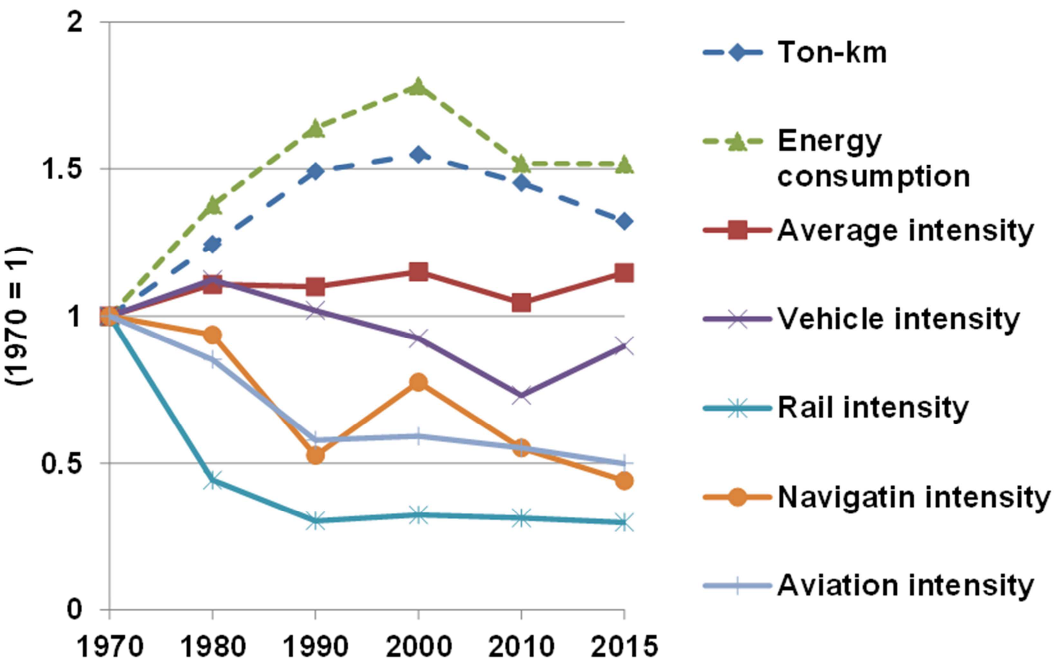

Figure 33: Freight transportation: energy intensity by mode, transport volume, and energy consumption in Japan

The fuel efficiency of new freight transport vehicles has been continuously regulated and total average freight transport energy should decline after a model shift to vehicles completed in the future, with implementation of other non-vehicle countermeasures such as traffic control and reduction of the number of trucks running with empty loads through joint operations, etc.

5.3 Potentials

The energy saving potential of the transportation sector is summarized in Table 23. Both passenger vehicles and freight vehicles are the above-mentioned top runner target products, and fuel efficiency standards have gradually been strengthened. Furthermore, along with the diffusion of next-generation vehicles such as hybrid cars, electric cars, plug-in hybrid cars, and fuel cell cars, fuel consumption is estimated to be greatly reduced. It is also estimated that the reductions in energy consumption are due to traffic flow control, modal shifts, and the improved energy efficiency of railways, ships and aircraft, but the breakdown of them is not clearly stated.

Table 23: Energy efficiency potential in transportation in 2030[31]

Type	Potential, (PJ)	End-use potential (elec.), (PJ)	End-use potential (fuel), (PJ)	Technology options
Automobile	377.6	-45.1	422.7	Next generation vehicle (hybrid, electric, plug-in hybrid, fuel cell, clean diesel), fuel efficiency
Traffic management, etc.	124.4	0.1	124.3	Traffic management, model shift, efficiency (rail, ship, airplane)
Subtotal	502.0	-45.0	547.0	

5.4 Barriers

In the transportation sector, continuation of fuel economy improvements including next-generation vehicle diffusion and traffic flow control are the main barriers, because the share of automobiles in the consumption of transport energy is about 80% (ANRE 2015b).

[31] Original Unit is 10,000 kL oil equivalent. Numbers are converted using conversion factor 10,000 kL oil equivalent = 0.382 EJ.

6 Cross-sectoral approach

There are many assessments of energy efficiency related literatures. Recent examples in Japan are picked up to understand the situation of energy efficiency in Japan.

6.1 Information and communication

Information and communication technology in the past decades changed the daily life and business drastically in Japan. We can find energy conservation related application examples in individual equipment and independent buildings with limited space. Digitalisation of the energy business in recent years will change the energy conservation business model through direct interaction between end-use energy customers and various stakeholders. Energy saving information delivery via smart phones with economic incentives is under demonstration by Kansai Electric Power Company and other business partners (KEPCO 2017). The system delivers local area information and power saving opportunities with incentives. It is regarded as one of results of demand response project in 7.2.

6.2 Demand response in smart community

The main interest of demand response (DR) in Japan is the peak-cut or peak-shift of the electric power system. It should be mentioned that peak-shift does not provide end-use energy savings because it only shifts the demand to a different time.

There are many energy management system (EMS) demonstration projects in Japan. Some of them are dedicated to buildings, factories or homes. This integrated system is called community EMS. A smart community concept is summarized in Figure 34 (NEDO 2015). It is a community with an Information and communication technology (ICT) infrastructure to exchange energy and other information, with the involvement of the energy demand side and distributed energy sources.

Four large scale demonstration projects were started in fiscal year 2010 and completed in fiscal year 2014 through the initiatives of government ministries. Demonstration sites are located in Yokohama city, Toyota city, Kansai Science city, and Kitakyushu city.

DR experiments in these projects provided valuable information to judge the feasibility and economic benefit of future grid-scale smart-grid operation. There are two categories in the demonstrations. One is tariff based DR, another is negawatt trading. Tariff based DR changes the power retail price by time of use (TOU) contract or critical peak pricing (CPP) noticed in advance.

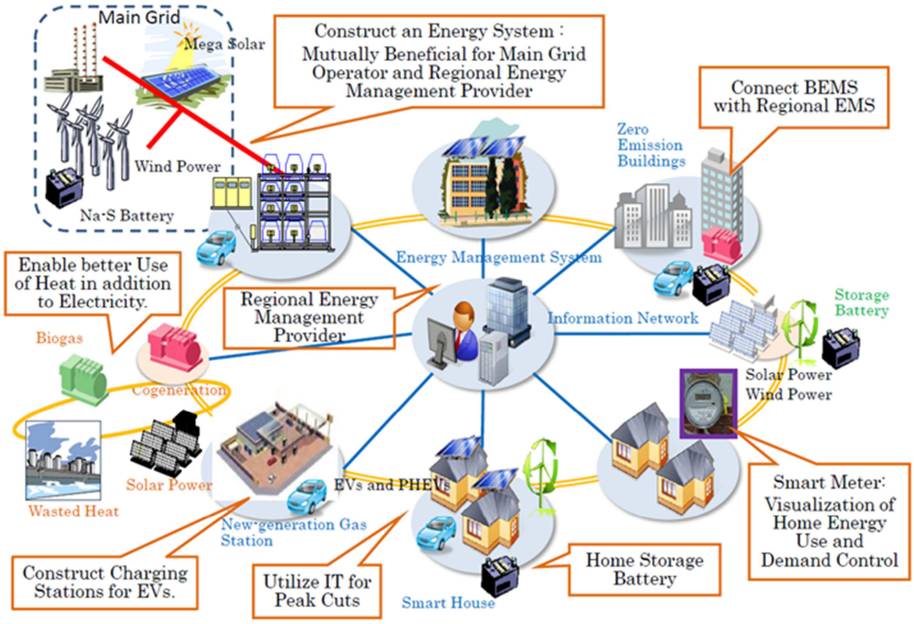

Figure 34: Smart community concept

DR experiments in two areas are categorized in tariff-based type (METI 2016). They changed the critical peak price during summer and winter peak hours. In the Kitakyushu CPP experiments, TOU effect is included, because of the existing TOU contracts between customers and power suppliers. TOU plus CPP reduction ratio is around 20% in Kitakyushu (Table 24). Keihanna had both TOU and variable price CPP experiments, and around 20% reduction was found in the experiments (Table 25). In the summer, a day-ahead CPP announcement is delivered to households if the maximum temperature of the next day is forecasted to be above 30 degree Celsius. It should be noted that the average temperature in 2013 is higher than that of 2012, and adjustment should be made.

Table 24: Kitakyushu DR experiment

Kitakyushu	Summer FY2012 (Jun-Sep)	Winter FY2012 (Dec-Feb)	Summer FY2013 (Jun-Sep)
Tariff			
TOU	Not evaluated	Not e evaluated	Not evaluated
+CPP=50JPY/kWh	-18.1% (#)	-19.3%(##)	-20.2% (##)
+CPP=75JPY/kWh	-18.7%(#)	-19.8%(##)	-19.2% (##)
+CPP=100JPY/kWh	-21.7% (##)	-18.1%(##)	-18.8% (##)
+CPP=150JPY/kWh	-22.2%(##)	-21.1%(##)	-19.2% (##)

(notes)

Samples: 180 in FY2012, 178 in FY2013

Summer peak hours: 13:00-15:00, Winter peak hours: 08:00-10:00, 18:00-20:00

TOU effects cannot be evaluated because TOU tariff was applied before CPP experiments.

(#)Significance level 5%, (##)Significance level 1%

Table 25: Keihanna DR experiment

Keihanna	Summer FY2012 (Jul-Sep)	Winter FY2012 (Dec-Feb)	Summer FY2013 (Jul-Sep)
Tariff			
TOU(+20 JPY/kWh)	-5.9% (##)	-12.2% (##)	-15.7% (##)
+CPP(+40 JPY/kWh)	-15.0% (##)	-20.1% (##)	-21.1% (##)
+CPP(+60 JPY/kWh)	-17.2% (##)	-18.3% (##)	-20.7% (##)
+CPP(+80 JPY/kWh)	-18.4% (##)	-20.2% (##)	-21.2% (##)

(notes)
Samples: 681 in FY2012, 635 in FY2013
Summer peak hours: 13:00-16:00, Winter peak hours: 18:00-21:00
(##)Significance level 1%

Asano and Yamaguchi (2014) compared the price sensitivity of three experiments in 2013, with the Kyushu electric power DR experiments shown in Figure 35. It should be mentioned that in the Kitakyushu experiment numbers are showing CPP effect and exclude the TOU effect. Estimated TOU effect is around 10% based on the Tokyo-Yokohama area experiment in the summer of 2010 and 2011. CPP demand reduction effects were concluded in the range of 10 to 15 percent in manual DR.

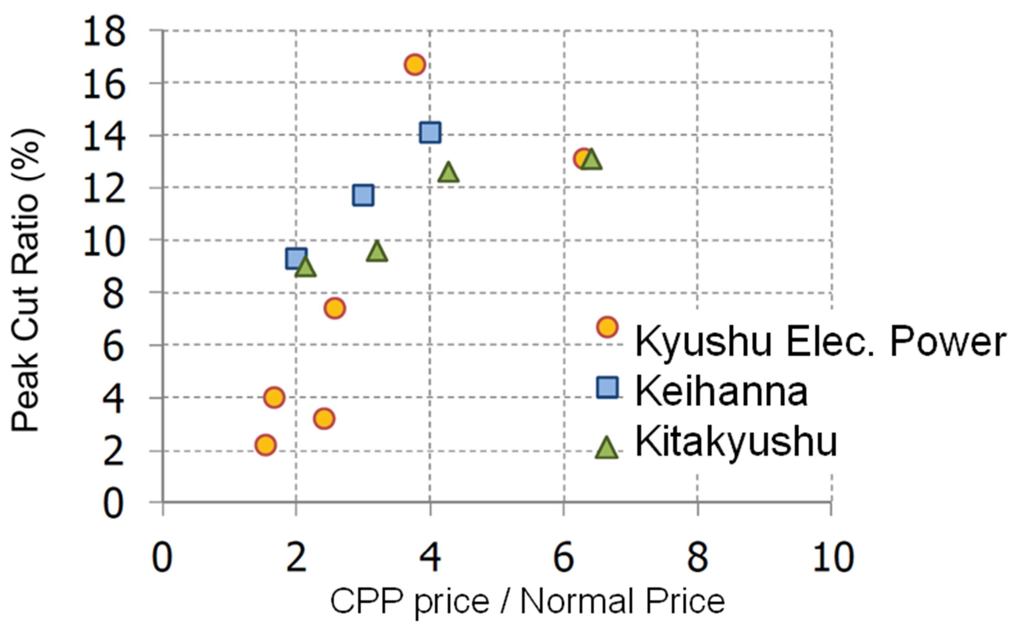

Figure 35: CPP pricing effects in DR demonstration projects

There are remaining discussion points in the tariff based DR such as price sensitivity, announcement effect, and weakening effects due to habituation. In the future, automated DR (ADR) could be employed in the power system and DR-embedded consumer electrical appliances. Original intention of DR is peak-shift or peak-cut. It could change energy consumption behaviour, but influences on energy efficiency improvement is still unclear.

Energy management systems play important roles through information exchange. Systems can be managed smartly through system learning (e.g. demand forecasting, virtual aggregation of storage devices, weather information based renewable power output forecasting and other operation experiences). We need more evidence to know the realistic impacts of these technologies.

6.3 Building energy management system

BEMS aims to appropriate energy management by combining information infrastructure such as demand information visualisation, control, data collection and storage, and communication. The estimated amount of energy saved by office buildings and stores by introducing BEMS was shown in the report of Japan Electronics and Information Technology Industries Association (JEITA) (JEITA 2015). In the report, through the case study of BEMS introduction, Japanese energy conservation potential through BEMS function was estimated. It also assumes BEMS penetration rate and number of buildings by scale. The assumed conservation rate through BEMS function is 10% in energy use diagnosis, 2% in visualisation of usage information, 10% in air conditioning, 10% in lighting and 15% in equipment installed after completion of buildings (Table 26).

Table 26: Energy saving assumptions by BEMS

Functions		Objects	Reduction rate in cases	Reduction rate assumed	Notes
Diagnosis	Energy saving service / diagnosis	All	7-15%	10%	Additional opportunities
Monitoring	Visualisation	All	2-10%	2%	For all buildings
	Central A/C	Heat source and heat transport	5-20%	10%	Large buildings
	Individual A/C	A/C control	10%	10%	Small buildings
	Lighting	Illuminance control etc.	10%	10%	For all buildings
	Power outlet	IT devices consumption data display control	15%	15%	Rate in best practice
Demand response / peak cut	Peak cut	All	5-28%	- (N.E)	- (N.E)
	Time shift	All	60% or more	- (N.E)	- (N.E)

For office buildings, the energy saving potential of both large-scale buildings (floor space: 10,000 m^2 or more) and small-scale buildings (floor space: less than 10,000 m^2) is estimated at 10%. Regarding the penetration rate, it is assumed that the BEMS adoption rate in small-scale buildings is quite low currently, but that the penetration rate in 2030 will reach 80%, except for small-scale buildings with less than 500 m^2 floor space (Table 27).

Table 27: BEMS diffusion assumption for office buildings

Scale				BEMS diffusion rate	
	Floor space	Current Share in number	Energy consumption share	Present	2030
Large	30,000 m^2-	2%	31%	50%	80%
	10,000-30,000 m^2		20%	27%	80%
Small and Medium	2,500-10,000 m^2	3%	19%	4%	80%
	500-2,500 m^2	11%	13%	4%	80%
	-500 m^2	85%	17%	4%	4%

The power reduction potential through BEMS is shown in Figure 36 for office buildings and stores. As BEMS for office buildings has already been adopted, the energy saving effect in 2012 is estimated to be 2.3TWh. However, it will increase to 4.1TWh in 2020 and 5.4TWh in 2030. Similarly, the energy saving effect of BEMS for stores is estimated to be 0.5TWh in 2012, 2.2TWh in 2020, and 3.5TWh in 2030 respectively.

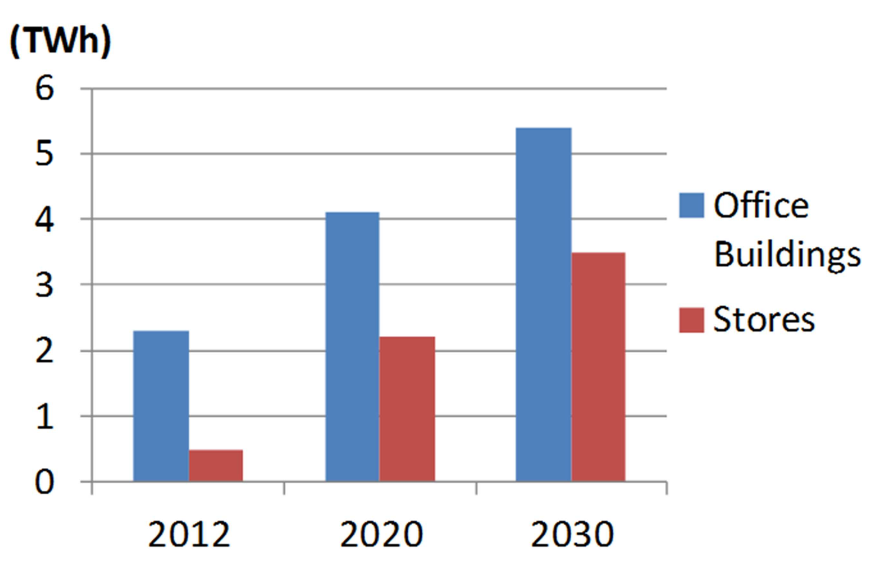

Figure 36: Energy saving potential of BEMS

6.4 Big data

There have been many business model proposals of big data in Japan. One example is Denki Kakeibo of Tokyo Electric Power Company (TEPCO). Denki Kakeibo is a visualisation tool of billing and demand information (Figure 37) (TEPCO 2017). This system depends on the framework of Opower (currently Oracle), the global leading cloud-based software developer for the utility industry. For example, we can compare monthly power consumption data embedded in big data management systems with those of averaged similar residential customers (i.e. same contract of power tariff). It aims at energy consumption behaviour change through visualisation of energy consumption data. These kinds of business proposals are quite active in Japan especially after power market liberalisation in 2016, coupled with replacement of conventional power measurement meters with smart-meters.

In general, digitalisation through smart meters, sensing technology, Internet of Things (IoT) connected appliances and autonomous driving cars, etc. will change daily life and energy consumption behaviours. However, the aggregated impact on energy efficiency is still uncertain at this point, because it allows optimal use of energy, but it will also increase convenience of life as discussed in the autonomous vehicle rebound effect.

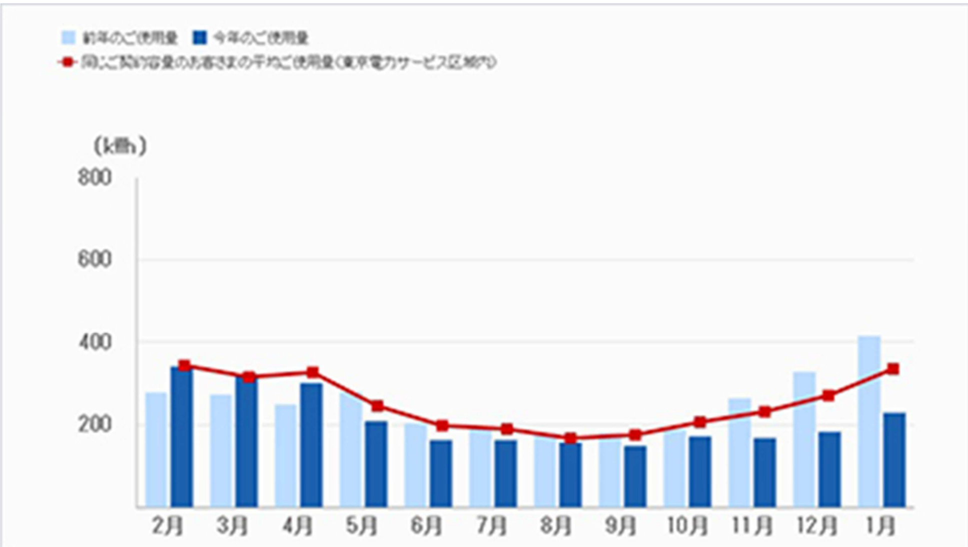

Figure 37: Sample screen image of Denki Kakeibo

(note)

dark blue bar: monthly power consumption in this year
light blue bar: monthly power consumption in previous year
red line: average monthly power consumption of same tariff customers

6.5 Energy service provider and energy service companies

Since the 2000s, services to undertake energy conservation measures at buildings, business establishments, etc. are expanding. The service has been called energy service company (ESCO), a business that proposes an energy conservation plan, provides technology, facilities, human resources, funds, etc. It recovers its investment from the reduced cost after ESCO system implementation. The contract method is divided into two types. If the customer provides funds, it is called a guaranteed-savings contract, and if ESCO operators procure funds, it is called a shared-savings contract.

Meanwhile, in recent years, there is also a business in the market for the comprehensive engagement of energy related business called an energy service provider (ESP). ESP utilizes energy management methods based on continuous monitoring and analysis of energy usage status to provide diverse services and policies that contribute to energy cost reduction and business management, etc.

In Japan, an industry organisation named Japan Association of Energy Service Companies (JAESCO) has been organized. JAESCO has 33 regular members and 44 supporting members. JAESCO estimates that the annual market scale of the of member companies on a new order basis has been in the range of 20 to 30 billion JPY per year (Figure 38) (JAESCO 2016).

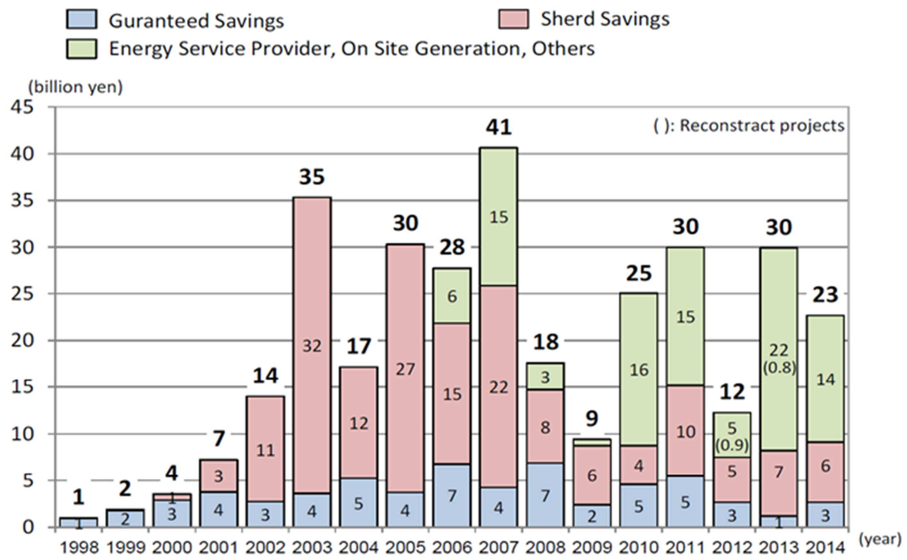

Figure 38: ESCO market size in Japan (by JAESCO members)

Jyuukankyo Research Institute estimated energy saving potential of the ESCO business in the commercial sector in Japan (Figure 39) (Jyuukankyo Research Institute 2014). Nine types of businesses (office, hospital, hotel, meeting facility, sports facility, welfare facility and store) are evaluated in terms of heating source retrofit, combined heat and power, and others. Total potential is

174PJ/yr, with a large contribution from offices (62.5 PJ/yr), hospitals (24.0 PJ/yr), hotels (41.9 PJ/yr) and stores (41.4 PJ/yr).

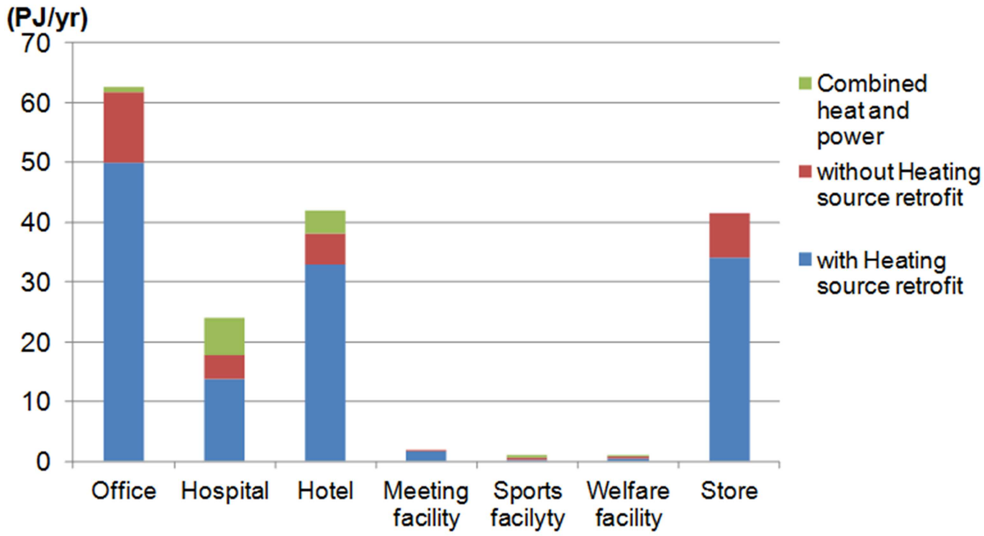

Figure 39: Energy saving potential of ESCO business

6.6 Rebound effects

The energy rebound effect is defined as a phenomenon in which the energy service increases through energy service price reduction due to energy efficiency improvement. Three types of definitions in the rebound effect are introduced in Greening et al. (2000). The first is "direct rebound effect", the second is "indirect rebound effect", and the third is "embodied energy". In addition, the combined effect of the three types is called the economy-wide rebound effect.

The potential energy savings expected by replacement are reduced by the rebound effect. A reduction in energy costs due to replacement results in a reduction in the associated energy service price. This decline in energy service prices generates new energy service demand. This effect is called the self-price effect or direct rebound effect. Indirect rebound effect is generated by directing money saved by replacement to the consumption of other goods. This household expenditure change is called the secondary effect or indirect rebound effect. This indirect effect bounces off the economy as a whole. By turning the money that households no longer use for energy to consumption of other goods, the sector supplying that good will be influenced (by the change in the final demand), further spreading to other sectors. Therefore, this mechanism affects energy consumption of all sectors. Embodied energy refers to energy consumption required for energy saving investment, and refers to the amount of energy required for the production process and installation stage. Products using new technology would consume more energy to produce than conventional products. However, there are also cases in which they consume less energy than conventional products.

Mizobuchi and Takeuchi (2016) examined the direct effect. They measured the changes in monthly household electricity consumption, which might be caused by the replacement of air-conditioners, thorough 733 household surveys. The result suggests that the replacement by energy-efficient air-conditioners might decrease power consumption, especially in spring and summer. They also calculated the size of the rebound effect monthly, and found positive rebound in summer (8% to 22% in August) and winter (134% to 192% in December and January). On the contrary, negative rebound, implying that the actual power saving effect is greater than expected saving effect, was found in mild-climate seasons (-3% to -129%). On the average, the size of the rebound effect is positive and ranges between 45% and 58%.

6.7 Setsuden initiative

Immediately after the Great East Japan Earthquake, the supply capacity of power sources temporarily dropped drastically, and the consciousness of energy saving increased, especially the energy conservation campaign that was held mainly in the summer, which is the annual power peak period. In general, it is said that the decline in electricity demand for commercial and residential use is particularly significant. In the following, examples of electricity demand analysis using time series data are described, and the energy saving effect through consciousness of electricity saving (Setsuden) is discussed.

CRIEPI (2015) reported the household electricity saving situation in Tokyo Electric Power Company and Kansai Electric Power Company during the summer of 2014. As a result, the electricity consumption after removal of the temperature effect is about 10% lower than the 2010 level before the earthquake disaster, but the conservation of electricity consumption and the action rate of energy saving measures are gradually decreasing. It is shown that the cumulative impact on savings of purchasing or replacing equipment is up to 4% in the summer of 2014, patience and ingenuity at the time of use (behaviour factor) is keeping tendency, and there is a power saving effect through the price rise in electricity tariffs.

CRIEPI (2016) also reported a time series analysis of power demand changes. For example, with regard to electricity demand for small-scale customers, data from 2000 to 2014 is analysed and classified to factors of price, income, habit, household size, climate factor of cooling, climate factor of heating, and others. The result suggested that the contribution of habit factor was recognized. It was reported that national average power consumption decline by habit factor compared to 2010 is 2.4% in the year 2014. The possibility of habitualisation of electricity saving was pointed out.

To summarize the above, it can be said that there is a trend toward a decline in electricity demand, especially in the commercial and residential sectors after the Great East Japan Earthquake. The background of this trend may be due to the increase in consciousness of power saving. However, for example, in light-emitting diode (LED) light bulbs, diffusion could be the result of home appliance eco-point institution between 2009 and 2011. Eco-point system is the institution to stimulate sales of energy saving products such as televisions, air conditioners, and refrigerators. With a rewards point system, the consumer could purchase LED light bulbs at half price if he/she used points awarded. Such special factors cannot be neglected in equipment purchase or replacement behaviour. Although the consciousness of electricity saving itself has gradually declined, it is recognized that there was a certain positive effect of the energy saving campaign. In that sense, energy conservation behaviour has been established to some degree.

7 Policy analysis

ANRE (2015b) consolidated information on energy efficiency policy packages both in regulation and supporting measures as summarized in the sections below.

7.1 Regulation measures

The Act on the Rational Use of Energy (known as the "Energy Conservation Act") was enacted in 1979 (enforced in October 1979). The Act is the foundation of Japanese energy efficiency and conservation policy. There were a series of major revisions in 1993, 1998, 2002, 2005, 2008, and 2013 (IEA 2016). The Act on the Improvement of Energy Consumption Performance of Buildings (Building Energy Efficiency Act) was newly established in 2015 and enforced in 2016 (MLIT 2016). Energy efficiency requirements for buildings are now regulated under the new act. The target sectors are all major sectors in Japan, such as industrial, residential, commercial, and transportation. The coverage of the Energy Conservation Act is estimated to be about 90% for industry and 40% for commercial.

Current regulation measures are summarized in Table 28 by the end-use sector (ANRE 2015b). Rational use of energy is requested for all sectors. Other multi-sectoral requests are intensity target and reporting (industry and commercial), and building energy efficiency (commercial and residential).

There are several regulations for industries. For the energy intensive industry, a benchmark index and its level setting are mandated. For products, buildings, vehicles, appliances, and construction materials, they are obligated to comply with performance standards. There is a labelling mandate for wholesalers and retailers.

For the transportation sector, there are intensity targets and reporting for transport operators. Shippers should also make efforts for energy savings as well as reports, such as energy reporting for large scale shippers.

Tokyo metropolitan government introduced emission trading scheme to reduce greenhouse gas emissions. Energy saving is expected as one of co-benefits.

Table 28: Overview of regulation measures in energy conservation policy

<table>
<tr><th>Act</th><th>Target</th><th>Industry</th><th>Commercial</th><th>Residential</th><th>Transportation</th></tr>
<tr><td rowspan="5">Energy Conservation Act</td><td rowspan="3">Business Activities, etc.</td><td colspan="4">Rational use of Energy (efforts)</td></tr>
<tr><td colspan="2">Intensity target setting and annual consumption reporting</td><td></td><td>Transport operators: Intensity target and its reporting</td></tr>
<tr><td>Benchmark target and its reporting</td><td rowspan="2"></td><td rowspan="2"></td><td>Shippers: Intensity target setting and annual reporting</td></tr>
<tr><td rowspan="2">Products</td><td>Top runner program</td><td rowspan="2"></td></tr>
<tr><td>Performance labelling</td><td></td><td></td></tr>
<tr><td>Building Energy Conservation Act</td><td>Building</td><td colspan="3">Energy performance target for new buildings</td><td></td></tr>
</table>

7.2 Supporting measures

Current supporting measures are categorized into economic incentive (e.g. subsidy for equipment cost, and interest or loan), demonstration, energy saving diagnosis, research and development (R&D), and tax system (Table 29). Both loan subsidy and interest subsidy is attractive institution when high cost energy saving facilities or equipment is planned. Loan subsidy reduces initial cost itself, while interest subsidy reduces interest payment of residual loan.

Economic incentives are found in all sectors for energy systems or individual equipment. Equipment examples include the home energy management system and residential fuel cell (residential), lithium batteries and high-performance building material (commercial and residential), and clean energy vehicles (transport). Demonstration is underway with subsidies in net Zero Energy Building/Home (ZEB/ZEH, commercial and residential). Energy efficiency improvements for trucks, taxis and ships are another area of demonstration. Energy saving diagnosis for small and medium enterprise (SME) is also one of the energy conservation policy portfolios, because of the lack of capacity in finance, human resources, and know-how in SME as described in the previous section. Industrial production process is a strategic area of R&D, while a broad range of energy efficiency R&D has been conducted covering all sectors.

Tax reduction or credit are other tools to accelerate energy efficiency in building retrofit, as well as tax credit for eco-friendly cars.

Table 29: Overview of supporting measures in energy conservation policy

<table>
<tr><th>Scheme</th><th>Industry</th><th>Commercial</th><th>Residential</th><th>Transportation</th></tr>
<tr><td rowspan="7">Subsidy</td><td colspan="2">Subsidy for equipment or system</td><td rowspan="3"></td><td>Subsidy for equipment or system</td></tr>
<tr><td colspan="2">Interest for equipment</td><td>Interest for equipment</td></tr>
<tr><td colspan="2">Loan for equipment</td><td>Loan for equipment</td></tr>
<tr><td rowspan="5"></td><td colspan="2">Lithium Batteries</td><td>Clean energy vehicle</td></tr>
<tr><td colspan="2">High performance building material</td><td rowspan="3"></td></tr>
<tr><td rowspan="2"></td><td>HEMS</td></tr>
<tr><td>Fuel cell</td></tr>
<tr><td>Demonstration</td><td colspan="2">Net zero energy building (ZEB/ZEH)</td><td>Truck & taxi, ship</td></tr>
<tr><td>Monitoring</td><td colspan="2">Energy conservation diagnosis for small and medium enterprise</td><td colspan="2" rowspan="2"></td></tr>
<tr><td rowspan="2">R&D</td><td>Industrial process</td><td></td></tr>
<tr><td colspan="4">Energy conservation related R&D</td></tr>
<tr><td>Tax</td><td></td><td></td><td>Tax reduction or credit of building retrofit</td><td>Tax reduction for eco-cars</td></tr>
</table>

(notes)
green: subsidy for specific product, blue: other schemes

7.3 Best practices

We have identified the best practices in energy efficiency policy in Japan through the review above. The selected five best practices in energy efficiency policy in Japan are: Top runner program (Annex 2), Energy reporting for large scale energy consumers (Annex 3), ZEB/ZEH program and labelling system for buildings (Annex 4), Tax breaks for eco-cars (Annex 5), and Voluntary actions in industrial associations (Annex 6). Top-runner program is selected because it affected same name German government policy.

7.4 Cross-sectoral governance framework

Japanese national level cross-sectoral governance structure is summarized in Table 30 for comparison with German system. About the targets and concepts, energy supply and demand outlook 2030 and Nationally Determined Contribution of UNFCCC are the major government initiatives. Energy Conservation Act and Building Energy Conservation Act are legal basis.

National level infrastructure and funding for energy efficiency improvement is mainly conducted by Agency for Natural Resource and Energy, while Ministry and Ministry of Land, Infrastructure, Transport and Tourism covers transport and building issues.

There is distortion eliminating measures. Energy taxes are applied to fossil fuels and electricity. From 2012, tax proportional to carbon contents is added to coal, oil and natural gas. However, there is no national level emission trading scheme. Local government such as Tokyo metropolitan government has own emission trading market, but it is not common in Japan.

Table 30: Major cross-sectoral governance framework for energy efficiency

Targets and concepts	Infrastructure and funding	Eliminating distortions
* Energy supply and demand outlook 2030 * Nationally Determined Contributions of UNFCCC in 2030 * Energy Conservation Act * Building Energy Conservation Act * Japan Revitalisation Strategy	* Agency for Natural Resource and Energy * Ministry of Land, Infrastructure, Transport and Tourism (especially for transport and building) * Energy Conservation Center Japan (Promotion of energy conservation in the industry, households, local communities, international cooperation, human capacity building, public outreach, conservation qualification examination, etc.) * Sustainable open Innovation Initiative (Distribution of subsidy)	* Energy taxes (tax proportional to carbon content is added from 2012) * No national level emission trading scheme.

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Annex 1 Revision history of the Energy Conservation Act

After initial establishment about 40 years ago, there have been frequent revisions in the Energy Conservation Act. Revision overview is summarized as following (IEA (2016), MLIT (2017)).

[1] Energy Conservation Act (in 1979)

The Act introduced energy conservation and management regulation targeting factories with a large amount of energy consumption, with requirements of appointment of energy manager and annual energy consumption reporting. The Act also introduced energy efficiency standards for vehicles, refrigerators, and air conditioners.

[2] Revisions in 1993, 1998, 2002, 2005, 2008

(1) Revision in 1993

The revision of the Act in 1993 adopts a mandatory periodic report to be made by the designated energy management factories.

(2) Revision in 1998

The revision of the Act concerns the four key new energy efficiency policy and measures as follows:

a. Creation of “Type 2 Designated Energy-Management Factories”

The revision of the Act introduced a new designation of factories and business establishments. These factories are those annual fuel consumption is less than quantities stipulated in initial act of 1979, with same requirements on energy managers and reporting.

b. New Obligation for “Type 1 Designated Energy-Management Factories”

For the "Type 1 Designated Energy Management Factory", a new obligation was introduced by the revision. As a new obligation, the submission of a medium- to long-term report on energy conservation measures was introduced. Also, “an average of 1% reduction of energy intensity in annual base during the mid and long term plan” was introduced as a regulatory energy management and efficiency target.

c. Creation of Top Runner Program

The revision of the Act also introduced the "Top-Runner Program". This is a regulatory standard program targeting the improvement of energy efficiency of electrical appliances. The concept of the program is that the target standard is set at the weighted-average energy efficiency of each manufacturer's and importer's shipment to achieve the level of the most energy-efficient model in each category of the current market.

d. Stricter Penalty for Noncompliance

The level of the penalties was increased for noncompliance. New penalties were: a publication of the name of the manufacturers and importers and an issuance of the administrative order for not meeting the standards.

(3) Revision in 2002

The revision of the Act in 2002 concerns the key new energy efficiency policy and measures as follows:

a. The category of the type 1 Designated Energy Management Factory that had targeted five manufacturing industries was expanded to all industries.

b. The revision obliges the type 2 designated energy management factories to make periodic reports.

c. The revision obliges the designated buildings to report energy conservation measures.

(4) Revision in 2005

The revision of the Act in 2005 concerns the four key new energy efficiency policy and measures as follows:

a. Creation of Regulation for Transportation

The revision of the Act concerns the promotion of energy efficiency in the transportation sector, targeting consigners and carriers (transportation enterprises, for both goods and passengers, and goods owners) for the transportation sector. Regulated consigners and carriers are called "Designated Consigners and Carriers" and the set of obligations is to submit a periodic report, to promote eco-driving and to appoint an energy manager

b. New Concept of Total Management of Heat and Electricity

By this revision of the Act, a new concept of management of energy source was introduced. Before, the amount of used energy of electricity and heat used was counted respectively, but after the revision total amount of the energy consumption of heat and electricity was counted.

c. New Obligation for Energy Supplier and Retailer

By this revision of the Act, a new obligation was introduced targeting equipment retailer. By this obligation, retailers became imposed on an information provision for consumers.

d. Unified Energy Conservation Label

A new labelling was introduced of which label shows a star-rating. This is a comparative performance rating labelling of a product with the cost information such as expected electricity cost during the use of the product.

e. Creation of Regulation for Housing and Building

The revised act strengthened energy conservation measures for residential buildings and the construction sector. Owners of buildings larger than 2,000 m2 floor space must prepare efficiency plans when applying for renovation permits, as must contractors planning to build entirely new structures. The reporting on maintenance and preservation of energy conservation measures to prefectures or other building authorization officials became mandatory.

f. Expansion of Top Runner Program

Newly, microwave oven, electric rice cooker, and DVD recorder became the Top Runner target products.

(5) Revision in 2008

The revision of the Act in 2008 concerns the key new energy efficiency policy and measures as follows:

a. Industry and Commercial Sectors

- The revision introduces a system for energy management obligation per whole enterprise.

- The revision treats a franchise chain such as convenience stores and restaurants also as a single enterprise, and applies the same regulation on the enterprise. (This revision imposed not only on in manufacturing factories but also on business sectors such as offices, convenience stores, etc.)

b. Building, Houses

- This review strengthens measures for large residences and buildings
  (Introduction of orders in addition to instructions and notices)

- This revision adopts a report on energy-saving methods by owners of small-medium-sized residences and buildings above a certain size.

- This revision adopts energy-saving measures by businesses engaged in the construction and sales of residences (recommendations and orders for those who are engaged in the construction and sales of a large number of residences).

- This revision promotes of indication of the energy saving performance of residences and buildings.

(6) Revision in 2013

The revision of the Act in 2013 was conducted for the purpose of enhancing energy conservation measures in the housing and building sectors. The key measures are as follows:

a. Top Runner Program for Building Materials, etc.

The Top Runner Program has so far been applied to machinery and equipment that consume energy. This revision newly adds building materials, such as windows and heat insulating materials as Top Runner Program target products. Also, three phase induction motor and LED lamp were included for the revision.

b. Positive Evaluation of Action to Reduce Peak Demand Electricity

The current evaluation and rating system of the report submitted by designated energy management factories, etc., required by the Energy Conservation Act was amended. Under this new evaluation and ratings system, the procedure was revised to positively evaluate and rate the electricity consumer' efforts to reduce the use of power from utility grids during peak demand hours by using storage batteries, energy management systems (BEMS or HEMS), or private power generation, in addition to their conventional measures to save energy.

c. Abolition of the Rational Use of Energy and the Utilization of Recycled Resources

By this revision of the Act, the "Energy Conservation and Recycling Assistance Act" was abolished. Because this part was established as temporary legislation.

[3] Current development

In 2016 and 2017, Japanese government has decided to introduce new energy efficiency measures. The key components of new measures are as follows:

a. Thermal power generation facilities

In order to improve efficiency of thermal power generation facilities, Japanese government set new Judgment of Standard for new power generation facilities and new energy efficiency benchmarks for electric power generation business.

b. SABC evaluation system (ranking evaluation system)

The government established new evaluation system for all Specified Business Operators, which categorizes business operators in accordance with the progress of energy efficiency. Under this evaluation system, the names of the excellent companies are publicized by the government.

c. Expansion of benchmark objects

Commercial sector is included in benchmark objects in order to promote energy efficiency. Benchmark objects used to be limited in industry sector.

d. Exploitation of unused heat sources

Calculation method for evaluation of energy efficiency has changed so as to promote effective utilization of heat. In the case of using waste heat, business operators get special consideration in evaluating energy efficiency.

e. Act on the Improvement of Energy Consumption Performance of Buildings

Act on the Improvement of Energy Consumption Performance of Buildings (Building Energy Conservation Act) was newly established in 2015 and enacted from 2016. Energy efficiency requirement for buildings is now regulated under new act. This Act provides 1) regulatory measures for mandatory compliance with energy efficiency standards for large-scale non-residential buildings (new building with floor space 2,000m2 or more), and 2) incentive measures such as a labelling system displaying compliance with energy efficiency standards and exception of floor-area ratio regulation for certified building.

Regulatory measures include mandatory compliance/evaluation of compliance, notification system, minister-approval system for special structures/equipment and housing top-runner program. Incentive measures are performance improvement plans (exception of floor-area ratio regulation) and labelling system.

Annex 2 Top runner program

Top runner program is mandatory program in the Energy Conservation Act from 1999, for new products. It encourages competition among companies by setting the efficiency targets for next 3 to 10 years. It also affected German top-runner program. Program has contributed to the significant energy efficiency improvement. List of target products is as follows.

1. Passenger cars
2. Trucks
3. Air conditioners
4. Television receivers
5. Video tape recorders
6. Lighting apparatuses
7. Copying machines
8. Computers
9. Magnetic disk devices
10. Electrical refrigerators
11. Electrical freezers
12. Heaters
13. Gas cooking appliances
14. Gas water heating appliances
15. Oil water heaters
16. Electric toilet seats
17. Vending machines
18. Power transformers
19. Jar rice cookers
20. Microwave ovens
21. DVD recorders
22. Routing equipment
23. Switching equipment
24. Multifunction office machines
25. Printers
26. Heat pump water heaters
27. AC motors
28. LED lamps
29. Heat insulating materials
30. Sashes
31. Multi-Paned glazing

Annex 3 Energy efficiency institution for large scale energy consumers

The Act on the Rational Use of Energy (Energy Conservation Act) sets the foundation for industrial energy efficiency and energy management regulations.

Designated energy management companies are regulated to develop and submit mid-and long-term energy management plans which include the company's energy conservation goal of reducing energy intensity by an annual average of 1% or more, and to submit annual report to government on energy consumption and investment plans (Table 31).

In addition, the Act was revised to establish new national energy efficiency benchmarks for selected sectors. Sectors covered include iron and steel, cement, and thermal power plants, pulp-papers, petroleum refinery, petrochemicals and soda chemicals. The benchmarks are set and used as the target standard of the best performing companies (top 10%–20%) in each subsector. Companies in these subsectors are subject to annual mandatory reporting on the status of their performance on the benchmarks. This has to be included in the mid-term reporting to the government required by the Act. In 2016, the benchmark system was expanded to the commercial sector,

As for evaluation, survey forms sent in advance to factories are completed by them, and on-site survey is carried out at each factory and cross-check the evaluations. If the evaluation shows results are below a certain level, an on-the-spot inspection is carried out, and if the situation is not satisfactory, the factory will be instructed to draw up a rationalization plan.

Table 31: Examples of company obligation under the Energy Conservation Act

1. Business operators overall

Annual energy consumption (crude oil converted amount kl)		At least 1,500kl	Under 1,500kl
Classification of business operator		Specified business operator or specified chain business operator	—
Items to be observed		Judgment standards for manufacturing plants, etc. (standards components) ・Set management standards, operational standards based on management standards, measurement records, maintenance inspections, etc.	
Target		Judgment standards for manufacturing plants, etc. (target components) ・Reduce energy unit consumption by 1% or more in the medium to long term ・Attain benchmark indices (only for applicable business lines), etc.	
Obligations	Person to be appointed	Energy Management Control Officer and Energy Management Planning Promoter	—
	Documents to be submitted	Medium to long term plans, periodical reports and notification on appointment of energy management control officers, etc.	
Administrative checks		Guidance and advice, collection of reports and onsite inspections.	
		Instructions for preparation of rationalization plan (failure to follow such instruction resulting in public disclosure or issuance of an order), etc.	—

2. For each manufacturing plant of installation

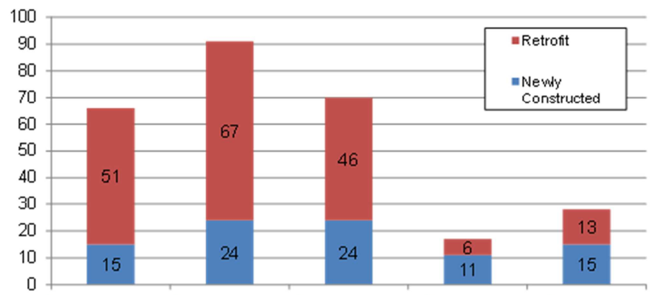
Annual energy consumption (crude oil converted amount kl)	At least 3,000kl		At least 1,500kl to under 3,000kl
Type designation	Type 1 Designated Energy Management Factory, etc.		Type 2 Designated Energy Management Factory, etc.
Obligations and persons to be appointed	Manufacturing business, mining business, as well as electric power supply, gas supply and heat supply businesses	Other than those described on the left (hotels, schools, etc.)	All business lines
	Energy Manager	Energy Management Officer	

Source: METI web page (http://www.meti.go.jp/english/policy/energy_environment/energy_efficiency/pdf/121003.pdf

Annex 4 ZEB/ZEH program and labelling system for buildings

ZEB or ZEH is acronym of net zero energy building or house, assuming annual net energy consumption is nearly zero. It will be achieved by energy conservation and renewable energy integration, but criteria of certain degree of energy conservation should be satisfied.

There exists strong policy initiative in Japan Revitalization Strategy (Cabinet decision on June 14, 2013) as phased obligation to comply with energy-saving standards for housing and buildings. The government introduced phased obligation to comply with energy-saving standards for newly constructed housing and buildings with the regulation. As a result, total number of subsidize ZEH could reach around 10,000 for only in FY2016. In addition, ZEB demonstration program is in operation for with reduction requirement target new or retrofit buildings as shown in Figure 40.



		FY2012	FY2013	FY2014	FY2015	FY2016
Reduction Requirement	Newly Constructed	30% or more	30% or more	30% or more	50% or more	50% or more
	Retrofit	25% or more	25% or more			

Source: Courtesy of Energy Efficiency and Conservation Division, ANRE/METI

Figure 40: Numbers of FY2016 ZEB Demonstration Project

Building-housing Energy-efficiency Labelling System (BELS) is new energy efficiency labelling system in Japan. BELS display for building is the obligation, notification or efforts, depending on category. Cumulative numbers of BELS acquisition are shown in Figure 41.

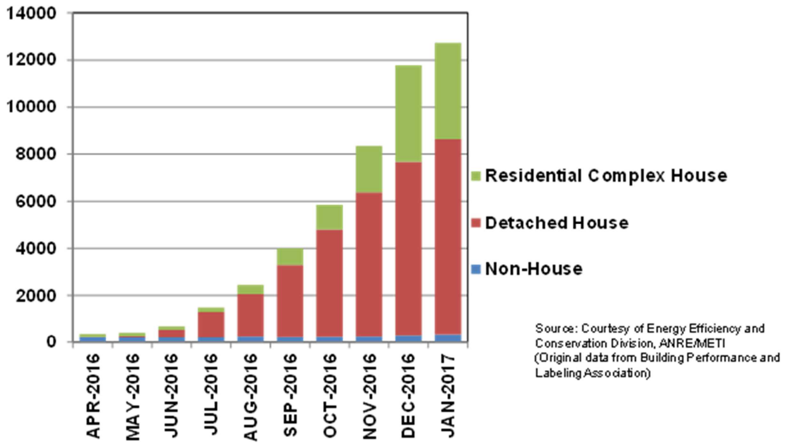


Figure 41: Numbers of cumulative BELS acquisition

The Institute of Applied Energy

Annex 5 Tax breaks for eco-cars

Tax exemptions are available for three automobile taxes: tonnage, acquisition, and ownership. Hybrids, plug-in hybrid electric, electric, fuel cell, clean diesel, and natural gas vehicles qualify for tax breaks. In addition, tax reductions are available for gasoline (including hybrid) and LPG fuelled vehicles, depending on the energy efficiency requirement achievement levels (Table 32). Current fuel efficiency standard base year is 2015, but 2020 efficiency level has been determined already to prepare the automobile production. So both 2015 and 2020 level is considered in the tax rate.

Passenger cars, buses and trucks are the target products and this institution works for one of the economic incentives to replace the automobiles.

Table 32: Summary of national tax reduction for passenger cars in fiscal year 2017

Target vehicle type		Tax items		Contents							
Electric vehicle Fuel cell vehicle Natural gas vehicle Plug-in hybrid vehicle Clean diesel vehicle		Acquisition		Exemption							
		Weight	New car	Exemption							
			First inspection	Exemption							
	Fuel efficiency / Exhaust performance			Achievement level compared to FY2015 efficiency standard			Achievement level compared to FY2020 efficiency standard				
				Less than + 5%	+5%	+10 %	Less than + 5%	+10%	+20%	+3 0%	+40%
Gasoline vehicle or LPG vehicle (incl. hybrid)	75% or less compared to 2005 regulation OR 50% or less compared to 2018 regulation	Acquisition				20% reduction		40% reduction	60% reduction	Exemption	
		Weight	New car			25% reduction		50% reduction	75% reduction	Exemption	
			First inspection								Exemption

Part III: Mutual Review and recommendations: Germany and Japan

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1 Introduction

This section presents the third part of the study on Energy end-use efficiency potentials and policies and the development of energy service markets for the German-Japanese Energy Transition Council. The first section of this part undertakes a mutual review of the two individual country reports with a focus on similarities and differences in potentials as well as the regulatory frameworks. It also aims to explain the historical, political and cultural background of differences where relevant. The second section formulates policy and business recommendations for both countries, highlights opportunities for mutual learning, and identifies areas for further research.

In accordance with the respective national sector divisions for monitoring energy demand, the two country reports follow a different structure. In order to allow for better comparability, the structures were harmonised for the purpose of the mutual review. The Japanese distinction between commercial and residential buildings was discontinued. Similarly, the German distinction between buildings and appliances was not perpetuated in this study. As a consequence, the present section on *buildings* refers to the sections "Commercial" and "Residential" of the Japanese country report, which also includes appliances policies, and the sections "Buildings" and "Appliances" of the German report. In addition, information and communication technologies are treated together with the section on demand response as well as smart cities and communities. Similarly, rebound effects and the behavioural approach are addressed together.

It should be noted that a full comparability of potentials was not possible due to the difference in underlying assumptions and definitions. Although both country reports refer to **policy-induced potentials** rather than techno-economic potentials, conclusions based on such comparisons can therefore only be understood as tendencies and indications.

1.1 Indicators

The final energy demand per capita is almost exactly the same in both countries (see Table 33). However, there are differences in levels per sector. In Japan, especially the energy use for transportation is more energy efficient while the energy intensity of the German industry is significantly lower by about 40%. Table 34 shows the energy demand structure in both countries. The reasons for such differences would deserve future analysis, which was however beyond the scope of this report.

Table 33: Key indicators

Sector	Germany	Japan
Population (2016)	82.7 million	127.1 million
GDP in billion $US	3,364	4,383
Final energy demand per capita in GJ	107	107
Energy intensity in industry (per 1,000 $US added value)	4.05 (MJ/$US)[32]	6.99 (MJ/US$)
Motor vehicles (cars, trucks, buses, motorcycles)	55.6 million	88.9 million

Sources: BMWi 2017a, Statistics Bureau 2016a, World Bank 2017a, World Bank 2017b, ANRE 2017, METI 2016, Destatis 2017, statista 2017, JAMA 2016

Table 34: Final energy demand by sector in PJ

Sector	Germany (2015) Total by sector in PJ	Germany (2015) Per capita in GJ	Japan (2015) Total by sector in PJ	Japan (2015) Per capita in GJ
Industry[33]	2548	30.8	6139	48.3
Buildings	3730[34]	45.1	4333	34.1
Transport	2621	31.7	3077	24.2
Total	**8899**	**107.6**	**13,549**	**106.7**

Sources: ANRE 2017, AGEB 2016a, AGEB 2016b

1.2 Energy efficiency potentials

For the depiction of energy efficiency potentials in both countries, policy-driven scenarios were used. However, while the assumptions of the efficiency potential scenario for Germany have been discussed in WP 1, no description of the assumptions and the methodology of the calculation of the energy savings potentials is available for Japan.

The following two figures show the energy efficiency potentials in Japan (Figure 42) and Germany (Figure 43) respectively. Both figures show the baseline year of the respective scenario (2010 in Japan and 2008 in Germany) as well as the reference scenario and the aggressive conservation

[32] Calculated with the exchange rate from 31 December 2015
[33] Excluding trades and services
[34] Excluding buildings in industry but including trades and services

scenario[35]. Additionally, the absolute savings potentials, which are the difference between the aggressive conservation scenario and the reference scenario, and the relative saving potentials, which are equivalent to division of the conservation and reference scenario, are depicted below.

Even though an exact comparison is not possible, it can be noted that the relative share of the savings potential in the buildings sector is the highest, with more than 20%. This is followed by the industry and finally the transport sector in both countries.

[35] It should be noted that these scenarios are based on the assumption that even strong (‚aggressive') policies will not fully implement the economic potential for energy efficiency, let alone the technical potential (cf. Figure 7 in the part on Germany).
Furthermore, it was beyond the scope of this study to analyse why the reference scenario for Germany already has much higher absolute energy savings compared to the reference scenario for Japan (and the reference scenario for Germany from another study shown in Figure 7). We kindly refer the reader to the GJETC study ST1, which compares a number of scenarios in more detail.

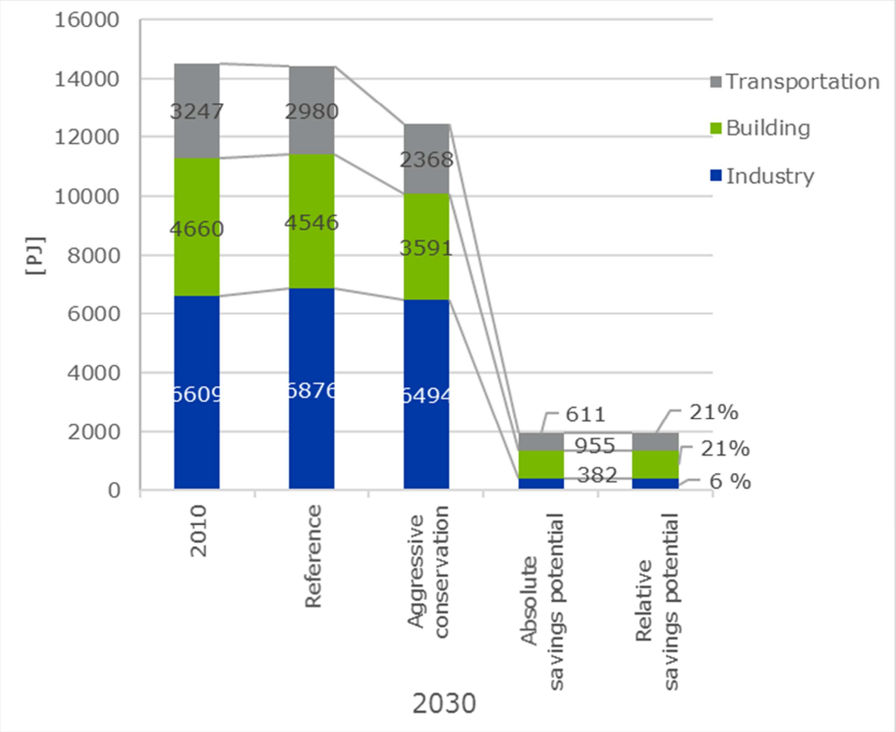

Figure 42: Energy efficiency potentials per sector in Japan

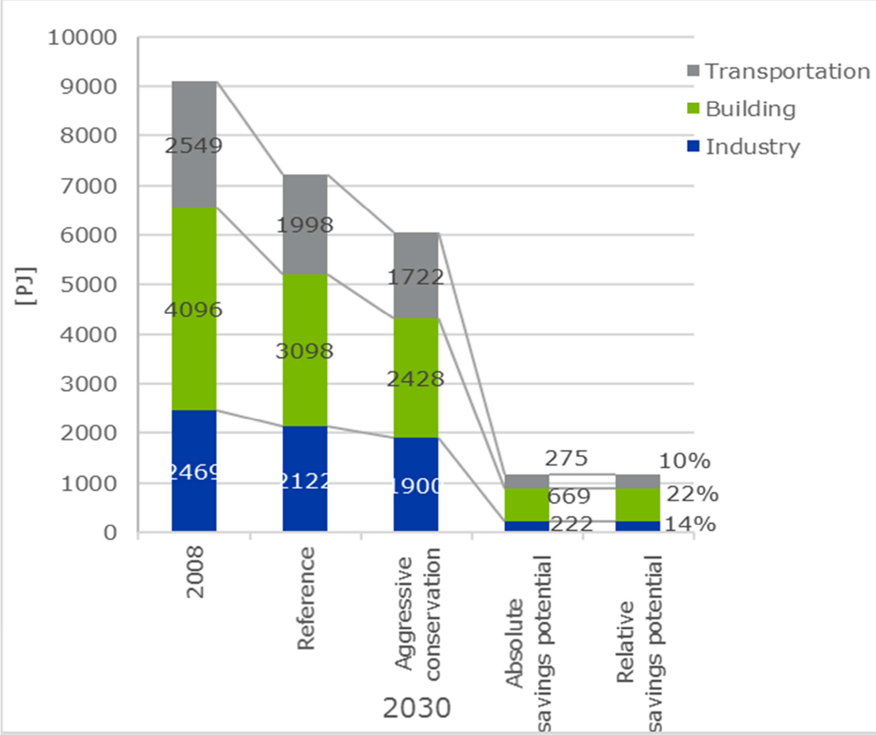

Figure 43: Energy efficiency potentials per sector in Germany

1.3 Cross-sectoral governance framework

In Japan as well as in Germany, **multiple ministries have relevant jurisdiction** influencing the regulation of energy efficiency. In Germany, the Federal Ministry of Economic and Energy (BMWi), the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and the Federal Ministry of Transport and Digital Infrastructure (BMVI) are the most relevant actors while for Japan, quite similarly, these are the Ministry of Economy, Trade and Industry (METI), Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and the Ministry of Environment (MOE).

In Germany, **federalism** on the one hand and the **membership in the EU** on the other create two additional governance layers. While the sixteen states (Länder) have regulatory competences for e.g. land-use planning, the EU releases comprehensive policy packages (e.g. directives, guidelines, targets) that mostly have to be implemented on the national level. The Ecodesign and energy labelling requirements are directly valid in all Member States. In Japan, significantly more regulatory competences lie with the **central government**. One exception to this are construction permits, which are issued by local authorities, as is the case in Germany.

In Germany, **targets and concepts** for a transition to a more sustainable energy future are subsumed in the overarching political strategy *Energiewende*. Within the *Energiewende*, long-term and binding targets are mainly derived from the Energy Concept which sets targets for climate protection, renewable energies and energy efficiency for 2050. The Energy Concept is supported by the Climate Action Plan 2050, the National Action Plan for Energy Efficiency as well as the 2020 and 2030 targets and 2050 objectives of the EU. For Japan, the energy supply and demand outlook 2030 and the Nationally Determined Contribution (UNFCCC) contain the most important targets.

In Germany, the Federal Office of Economics and Export Control (BAFA) and the German Energy Agency (dena) are important institutions making up the overall regulatory **infrastructure.** The state-owned KfW bank provides major **funding** for the implementation of the *Energiewende*. Besides this, often regional energy agencies and consumer advice centres offer energy efficiency advice. In Japan, energy conservation centres fulfil similar functions.

To eliminate market **distortions**, Germany is part of the European emission trading system (ETS) and charges energy taxes, but does not have a CO_2 tax in place. In Japan, a CO_2 tax charging carbon content for coal, oil and natural gas and energy taxes applying to fossil fuels and electricity are in place as well. Furthermore, some local governments have own emission trading markets. However, both countries continue to provide environmentally harmful subsidies. In Germany, this for example includes tax reductions for certain energy-intensive processes and techniques, a free allocation of CO_2 emission trading allowances and a flat-rate taxation of privately used company cars to name a few.[36]

Table 35 compares the cross-sectoral governance frameworks in detail of policies that are existing. However, a more detailed analysis of e.g. energy tax levels was beyond the scope of this study.

[36] A detailed analysis of environmentally harmful subsidies in Germany is provided by UBA (2014) https://www.umweltbundesamt.de/sites/default/files/medien/376/publikationen/environmentally_harmful_subsidies_in_germany_2014.pdf.

Table 35: Cross-sectoral governance frameworks

	Targets and Concepts	Infrastructure and funding	Eliminating distortions
DEU	• **Energy Concept:** By 2050 Germany wants to cut CO_2 emissions by 80-95%, boost renewables to a share of 80% in electricity and reduce primary energy consumption by 50% until 2050 (compared to 2008) (cf. BMWi/BMU 2010). • **Climate Action Plan 2050:** 55-56% GHG emission reduction by 2030 (baseline 1990) • **National Action Plan on energy efficiency (NAPE):** 20% reduction in primary energy consumption until 2020, 50% reduction by 2050 and increase in energy productivity by 2.1% per year; building stock should be virtually climate-neutral by 2050 (NAPE is part of the Climate Action Program 2020) • **Green paper on energy efficiency:** "energy efficiency first" principle • **"Energy of the future"**: monitoring process for the energy transition • **All targets embedded in EU 2020 and 2030 targets**	• **Energy Agencies**: dena (federal agency) and local energy agencies support the energy transition with expertise • **KfW** (German development bank) and **BAFA** (federal office for export control): issue grants and loans to investors of energy efficiency projects • **Energy Efficiency Funds:** Energy and Climate Funds are financed by the ETS allowances and state taxes • **Energy services**: energy service law, advice, loan guarantees	• **Energy taxation:** Energy Taxes, Fuel taxes • **Emission Trading:** EU Emissions Trading Scheme (ETS)
JPN	• **Official energy supply and demand outlook:** published by the Agency for Natural Resource and Energy since 1967, revised approx. every three years • **Nationally Determined Contributions (UNFCCC)**: 26% reduction of GHG emissions by 2030 (baseline 2013) • **Energy Conservation Act**: Basic legal framework of energy conservation in Japan which has been modified several times to increase its coverage of industry, commercial, residential and transport sectors • **Building Energy Conservation Act**: established to accelerate improvements energy efficiency in buildings	• **Agency for Natural Resource and Energy**: national government agency covering most of the energy and national resources related issues) • **Ministry of Land, Infrastructure, Transport and Tourism:** national government, especially for transport and building efficiency • **Energy Conservation Center:** promotes energy conservation measures in industry, households, international cooperation, fosters capacity building and public outreach, conducts the conservation management qualification examination, etc. • **Sustainable Open Innovation Initiative:** Distribution of energy efficiency related subsidies	• **Energy / CO_2 taxation:** tax proportional to carbon content introduced in 2012 • No national level emission trading scheme in place

2 Buildings

About 35% of the Japanese residential building stock was built in or before 1980 according to the Statistics Bureau (Statistics Bureau 2016b). In Germany, even 65% of residential buildings were built before 1980 (Landesamt für Statistik Niedersachsen 2014). Hence, in addition to standards for newly constructed buildings, incentives for energy-efficient renovation measures are of great importance in order to tap the efficiency potential of the entire building stock. In particular, the building envelope has a high potential for improvements in both countries. In Germany, it is estimated that in the next 20 years, 50% of residential houses will have to be renovated (BMWi 2017a).

The amount of living space in Germany has increased steadily since 1990. Between 2000 and 2014, the living space per capita has increased from 39.5 to 46.5 m^2, due to an increase in one-person households and the tendency to remain in larger homes at old age (Eurostat 2016). In Japan, a similar development took place. Between 1968 and 2013, the living space per house has increased from 73.68 to 94.42 m^2 (Statistics Bureau 2016b). The average household size has decreased from about 3.5 to about 2.5 persons while floor space per capita has increased from 36 (2003) to 39.4 m^2 (2013) (Statistics Bureau 2016b). In addition, the Nationally Determined Contribution of Japan has a challenging target of 40% GHG reduction for buildings relative to 2013.

Regulatory instruments

In Germany, there are push and pull measures for energy efficiency in buildings, i.e. regulations (push) and support programs and informational measures (pull). The programs support building efficiency levels and renewable energy technology applications going beyond the regulations. Germany has a long history of building regulations, dating back to the seventies, which have continuously been updated.

For **new buildings in Germany**, the Energy Saving Ordinance (Energieeinsparverordnung - EnEV) requires a maximum primary energy demand of the building in question to not surpass the primary energy demand of the reference building. Since 2016 this requirement has been tightened by 25% in order to follow a stepwise approach to *nearly zero energy buildings* by 2021 (public buildings: 2019). The primary energy demand calculation comprises requirements for heat transition coefficients of the building shell and for technical building systems (HVAC). The building shell requirements for residential and non-residential buildings are in the same range for residential and non-residential buildings whereas the requirements technical building systems differ significantly. Mandatory energy certificates indicate the building's energy performance.

As for new buildings, renovation measures in **existing buildings in Germany**- applied to a share of more than 10% of a building component - have to meet certain heat transition coefficients that are in the same range for residential and non-residential buildings. Alternatively, building owners are also allowed to prove the conformity with component requirements with a whole building requirement, which is 140% of the energy performance level for new buildings. Energy performance certificates declare the energy efficiency standard of any given building or apartment and is a prerequisite for selling, buying or renting a property.

For **non-residential buildings in Germany**, the standard to evaluate envelope performance is calculated according to the annual thermal load coefficient of perimeter zone[37]. For standards to evaluate the primary energy consumption of equipment and office automation devices (i.e. air-conditioning, ventilation, lighting, hot water, elevators, etc.), energy produced in the building is subtracted from total energy consumption.

In Japan, in contrast to the large number of specific instruments in Germany, **one comprehensive regulatory instrument**, namely the Building Energy Conservation Act was introduced. Incentive measures defined by the act became effective from April 2016 and regulatory measures from April 2017. **Regulatory measures** target new construction, extensions and renovation measures of buildings at or over a certain size. This means that certification is mandatory for 2,000 m^2 or larger non-residential buildings and for 300 m^2 or larger residential buildings. After the implementation of the regulatory measures in 2017, large-scale non-residential building that are not compliant with energy efficiency standards will become ineligible for certification.

Incentive measures in Japan are in place for all **newly constructed buildings**, extensions, renovations, improvements, remodelling and pre-installation or repairs of cooling system equipment that contribute to the improvement of overall energy performance. If plans for such measures are compliant with certification standards, they may receive certification from the administrative agency with jurisdiction in the construction area. By acquiring certification for the performance improvement plan, construction clients are eligible to receive benefits. Additionally, pre-existing buildings can receive certification of conformity with energy efficiency standards.

In Japan, there are two types of **labelling systems** in place. (1) For **new buildings**, labelling for the energy efficiency performance of buildings works as an incentive for building owners and emphasizes the energy efficiency performance as being at or higher than standards during new construction of residential and non-residential buildings. (2) **For existing buildings**, the labelling system to display compliance with energy efficiency standards lets owners emphasize the compliance of an existing residential or non-residential building with energy efficiency standards during renovations. Floor space energy intensity is implicitly evaluated when calculating primary equivalent net energy consumption of the buildings. Standard software is open to the public for standard building energy consumption estimates. Builders should comply with the energy performance at their design stage to obtain approval. Small residential building with less than 300m^2 are exempted from

[37] The perimeter zone is defined by the interior space that is within 5 horizontal meters of all walls that are in contact with the outside air, the interior space of the floor directly below the roof, and the interior space that is directly above the floor in contact with the outside air.

the regulation. In contrast to the German energy performance certificate, labelling for new and existing buildings is encouraged, but in most cases not mandatory in Japan.

In Germany, there are **long-distance heating and cogeneration units/systems**, whereas in Japan this is not widely spread because it is not economical in most regions. Further, in accordance with the German heating pump replacement scheme, since August 2016, 30% of investment costs for heating system circulators, hydraulic balancing and other low-expenditure measures are covered by subsidies.

The **implementation** of building regulation in Germany is relatively successful as the absolute energy consumption of commercial and residential buildings is decreasing. However, the current renovation rate - and especially that of deep renovations - is too low to meet the energy efficiency targets. Remaining **barriers** include the landlord/tenant barrier which refers to the share of 60% of the population renting rather than owning houses. As the legal rights of tenants are quite strong in Germany, renovation measures have to be coordinated carefully. Further barriers are of financial and informational nature.

In the case of Japan, mandatory building performance standard regulation has just recently come into effect so that it remains to be seen to what extent implementation will be successful.

Appliances

Both countries regulate appliances with regards to their energy efficiency. In Germany, appliances are regulated by the **EU directives on Ecodesign and Energy Labelling**. The Ecodesign directive sets standards for individual appliances, a process that can be challenging especially for products undergoing a fast development, such as ICT appliances. The directive was transferred into national law with the Energy Consumption-Relevant Products Act, making energy labelling mandatory. Another policy measure are financial incentives for poor households to replace old products for more efficient ones. Germany has lobbied the top runner approach on the European level for about 5 years, but there is no mandatory regulation with the top runner approach in place. Instead, Germany has implemented a National Top Runner Initiative (NTRI) on the national level, which bundles measures to speed up the market penetration of high-quality services and products (top runners) that contribute to reducing energy consumption. For example, it is facilitating stakeholder dialogues and promoting the EU Energy Star. In general, there is a tendency that national approaches are becoming harder to implement in the face of detailed European legislation.

The **Top Runner program in Japan** is the country’s primary instrument for energy efficiency and appliances. It bundles energy performance standards and labelling programs that set efficiency targets for the next 3-10 years. It applies to 31 target products including passenger cars, trucks, air conditioners, heaters, computers, LED lamps and multi-paned glazing. It promotes competition in the area of energy efficiency as the most efficient products set the standard for the respective product. The program covers ca. 70% of residential end-use energy consumption (2009).

The key difference is that the current regulatory system in Japan operates with mandatory benchmarks on a competitive basis, while in Germany, this tool is not employed as effectively. Nevertheless, a study commissioned by the Federal Environment Agency found that appliances are similarly efficient as in Japan, indicating that the effects of both systems are similar.

The following table provides a qualitative comparison of national-level instruments in the buildings sectors in Germany and Japan. A more detailed analysis of e.g. energy performance levels required by building regulation or supported by financial incentives was not possible in this study.

Table 36: Overview of energy efficiency-related policy instruments in buildings sector in Germany and Japan

	Regulation	Planning	Information & Advice	Incentives & Financing	Capacity Building & Networking	Research and Development & BAT promotion
DEU	• Energy Conservation Act (EnEG) / Energy Conservation Ordinance (EnEV) • Renewable Energies Heat Act (EEWärmeG) • Heating Cost Ordinance • Tenancy law (rent increases allowed following modernisation) • Energy Consumption-Relevant Products Act (EPPG), Energy efficiency Labelling Act	• Renovation Roadmaps	• Energy Performance Certificates • National heating label • "energy-saving meters" pilot programme • Information campaigns: e.g. "Deutschland macht's effizient" (Germany makes it efficient) • Top-Runner Initiative • Subsidies for Informational measures: On-site consulting, energy check	• Energy efficient buildings: CO_2-Building Renovation and New Build Programme – KfW support programmes and "Renewable energy" Market Incentive Programme • "Energy Efficiency" Market Incentive Programme • Tax deductibility of craftsmen's bills • Heating circulator replacement scheme	• ZEB guidelines and harmonized database for good practices by REHVA (Federation of European Heating, Ventilation and Air Conditioning Associations)	• The "Energy in buildings and neighbourhoods" research network • The Energy-Optimised Building (EnOB) research initiative • The EnEff:Stadt/Wärme (energy-efficient city/heat) research initiative
JPN	• Building Energy Conservation Act • Energy Conservation Act		• Energy efficiency labelling system for buildings • Information on the rational use of energy (best efforts) • Appliance labelling	• Subsidy system for ZEH (net zero energy houses) demonstration or ZEB (net zero energy buildings) construction • Subsidies for home energy management systems • Subsidies for high performance building related products during renovation • Tax reduction or credit for retrofitting residential buildings	• ZEH builder registration program. • ZEB/ZEH guidelines	• Demonstration program in operation for energy efficient new and retrofitted buildings (ZEB/ZEH)

3 Industry

Similar developments can be observed in both countries: Some of the most energy intensive industries in both, Germany and Japan, include chemicals, iron and steel, and pulp and paper. The savings potentials are highest for the iron, steel and chemical industries. The improvements for energy intensity are stagnating and energy intensity improvements are currently not sufficient in both countries.

Regulation

The policy approaches follow very different paradigms with a focus on regulatory instruments in Japan and financial support measures and voluntary commitments in Germany. In Germany, it is mandatory for non-SMEs to carry out energy audits for monitoring their energy management systems, however, energy efficiency measures recommended by the audits do not have to be implemented. Companies that have an energy management system in place can claim very substantial energy tax exemptions. The tax exemption was introduced after a voluntary agreement between the association of the manufacturing industry and the German government indicating that the manufacturing industry must increase its energy efficiency by 1.3% in the years 2013 to 2015 and by 1.35% in 2016 compared with the yearly average energy intensity of the 2007 to 2012 base years. For SMEs, there are energy tax exemptions in place as well, but they can implement different energy management systems that are not certified under the same standards as those for large industrial actors. In addition, the energy intensive industry is subject to the European Emission trading system (ETS).

In Japan, the Energy Conservation Act includes mandatory targets and benchmarks for industry. In addition to an absolute target of an annual 1% reduction in energy intensity per company for all large businesses, a relative benchmark exists: In each of the covered subsectors, the top 10-20% best performing companies set the benchmark. This applies to iron and steel, cement, thermal power plants, pulp-papers, petroleum refinery, petrochemicals and soda chemicals. About 90% of industry is covered by the relative benchmark. Small and medium-sized enterprises are not covered by the regulation. Site inspections by authority do not occur often, but are executed for enterprises with bad performance. It has been mandatory to report energy consumption annually since the oil shocks in the 1970s. Fines for missing or false information in the energy consumption and medium-term planning reports exist as well as for the failure to appoint an energy manager. Further, fines for non-compliance with energy intensity improvements or rational energy use reductions exist.

It can be noted, that Japan uses more regulatory measures in the industry sector, compared to Germany where historically (especially since the 1990s) policies were built as voluntary agreements.[38]

Barriers

A common **barrier** in both countries are long investment payback periods. In Japan, barriers to energy efficiency in the industry sector include stagnation as a result of past improvements, lack of proactive engagement of multiple enterprise businesses, and a lack of funds, human resources and know-how for small and medium enterprises. In Germany on the other hand, some of the barriers with particularly high relevance include the low price for carbon certificates, payback times on investments in energy efficiency exceeding industry's expectations of usually around two to three years payback times, competition between energy efficiency investments and more strategic investments with higher rates of return, low energy tariffs for industrial companies, and high transactional costs for the application of subsidy programs. In larger enterprises, organisational aspects are inhibitive while in SMEs, information deficits are more relevant.

The following table provides a qualitative comparison of national-level instruments in the industry sectors in Germany and Japan.

[38] For an overview of existing and previous voluntary agreements with the industry see: http://www.bmub.bund.de/themen/wirtschaft-produkte-ressourcen-tourismus/wirtschaft-und-umwelt/selbstverpflichtungen/

Table 37: Overview of energy efficiency-related policies in the industry sectors of Germany and Japan

	Regulation	Planning	Information & Advice	Incentives & Financing	Capacity Building & Networking	Research and Development & BAT promotion
DEU	• **Greenhouse Gas Emissions Trading Law:** mandatory emission trading for energy-intensive industry • **Tax law:** Special compensation regulation for electricity intensive companies & railways (according to §§ 63 ff. EEG 2014, electricity and energy tax law) • **Energy Services Law:** Mandatory energy audits and energy management systems for non-SMEs, implementation of Art. 8 of the EED (EDL-G)		• **Energy advice** for SMEs: free of charge • **Consulting** for performance contracting • **Top-Runner Initiative** • Campaign **Germany makes it efficient** (Deutschland macht's effizient)	• **KfW Energy Efficiency Program:** Production facilities/processes; construction and renovation and heat recovery • **KfW financing** for energy efficient and climate-friendly production processes • **BAFA funding** for highly efficient cross sectorial technologies • **Funding** for energy management systems for SMEs • **Tendering model** ("STEP-UP")	• **Energy Efficiency Networks (LEEN):** voluntary approach	• **6th Energy research framework program** • **Research for an Energy Efficient Industry** • **BMUB's Environmental Innovation Programme**
JPN	• **Energy Conservation Act:** (1) annual energy intensity and benchmark targets, mandatory reporting, mandatory appointment of energy managers, (2) top-runner program for domestic sales	• Medium term energy saving planning	• **Free energy diagnosis** assistance by Energy Conservation Center Japan (for small and medium enterprises) • Performance labelling with energy and cost saving estimates for products	• **Subsidies** for equipment or systems • **Interests** replenishment system for equipment purchase • **Loans** for equipment	• **Keidanren** (Japan Business Federation) represents 1340 companies, 109 industrial associations, 47 regional economic organisations own declaration for annual energy performance, reports (monitored by industrial association)	• **New Energy and Industrial Technology Development Organisation (NEDO):** R&D subsidy for industrial processes etc.

4 Transport

In Germany and in Japan the transport sector accounts for around one fourth of total energy consumption. While in Germany absolute traffic volumes continue to increase, efficiency gains via technical improvements are offset and overall energy consumption has increased by 16% since 1990. Since 2000 in Japan absolute final energy consumption of the transport sector is decreasing which is due to the large share of hybrid cars and decreasing size of cars. Absolute energy demand for passenger transport is stagnant and freight demand is decreasing. Costly maintenance requirements especially for older cars result in shorter exchange rates of cars and, hence, in a more modern fleet in Japan. The share of hybrid cars in sales is around 35% according to recent statistics (IEEJ 2017). This development is not mirrored in Germany, where cars tend to become heavier and larger (VCD 2015).

In both countries, fossil fuels are dominant. In Germany, as 90% of all transport fuels used are fossil fuels, biofuels and electricity play a minor role. In Japan, 97% of all transport fuels used are oil-based and other fuels play only minor roles: The most important fuels are gasoline (54.9%) and diesel (32.4%), while electricity makes up for only 2.4% (IEEJ 2017).

Both countries have regulations for fuel efficiency of cars. While for Germany, this is implemented directly by the EU's CO_2 fleet limit values and Energy Labelling, it is included in the Top-Runner Scheme in Japan. Both countries also have tax exemptions for electric vehicles. While in Germany tax breaks for electric vehicles are available for ten years and taxes are staggered by CO_2-content, in Japan tax exemptions or tax breaks are available for electric vehicles, fuel cell vehicles and very fuel-efficient cars. For initial registration, eligible vehicles are exempted from taxes completely. For the annual payment, there are staggered tax breaks that are in effect for the first year only.

In terms of barriers, both Germany and Japan having difficulties to achieve an energy efficient modal composition as motorised individual transport plays a prominent role in both countries. Major efficiency gains have not been made in the transport sectors. In Japan, slow diffusion of next-generation vehicles and traffic flow control are cited as the main barriers to increased energy efficiency in the transport sector but such issues are not notable barriers in the German transport sector. In Germany, barriers with 'very high' relevance include incentives for manufacturers to produce large and heavy cars, high investment requirements for a high-quality public transport system, cars as status symbols, and lack of holistic concept for an integrated (energy efficiency) transport policy, to name a few. Culturally, automobiles are an important status symbol in Germany. This is complemented by scepticism towards electromobility.

For a qualitative comparison of national-level instruments in the transport sectors in Germany and Japan, see the table below:

Table 38: Overview of energy efficiency-related policy instruments in the transport sectors of Germany and Japan

	Regulation	Planning	Information & Advice	Incentives & Financing	Capacity Building & Networking	Research and Development & BAT promotion
DEU	• European CO_2 fleet limit values for passenger cars and light commercial vehicles • Adaptation of European Renewable Energy Sources Act (EAG EE) • Biofuel Sustainability Regulation • Ordinance on Energy Consumption Labelling • Energy labelling of car tyres	• Federal road planning • National bicycle traffic plan • Government program electromobility • Commitment to build up a tanker and charging infrastructure for alternative fuels	• Initiatives and pilot projects in the field of company / municipal mobility management	Vehicle-related taxes: • CO_2-based vehicle tax • Ten-year car tax exemption for cars with only electric motors • Energy tax • Reduced taxation of natural gas and liquefied natural gas beyond 2018 Other: • Funding program for electric vehicles and charging infrastructure • Mode-independent distance (tax) refund • Air traffic tax • Truck toll (and further development)	• National platform electromobility	• Innovation programme for hydrogen and fuel cell technology • Field trials of electric motors in heavy commercial vehicles
JPN	• Top runner program includes passenger and freight vehicles • Fuel efficiency standards are gradually being strengthened; current fuel efficiency standard base year is 2015, but 2020 efficiency level has been determined to prepare automobile industry • Intensity targets and its reporting for transport operators • Shippers: intensity target setting and annual reporting	• Efficiency improvement of logistics • Road planning for urban area	• Next generation Electric Toll Collection (ETC 2.0) provides more intelligent driving with car navigation system for avoiding road congestion (operating)	• Tax exemptions available for tonnage, acquisition and ownership taxes which apply to hybrids, plug-in hybrid electric, electric, fuel cell, clean diesel, and natural gas vehicles. In addition, there are 5-40% tax reductions for gasoline (including hybrid) and LPG fuelled vehicles, depending on the energy efficiency achievements • Subsidies for EVs and FCVs • NEV (next-generation vehicle promotion center): subsidies for EV charging stations and FCV refuelling stations	• Eco-driving campaign (e.g. idling stop)	• Demonstration projects with trucks, taxis and ships testing modal shift (rail, ship) and logistic efficiency improvement • New Energy and Industrial Technology Development Organisation (NEDO): R&D for automobiles • Hydrogen energy related R&D

5 Cross-sector

5.1 Information and communication technologies, smart cities and smart communities

Japan (rank 10) is ranked slightly better than Germany (rank 15) on the network readiness index of the World Economic forum, which indicates the degree to which digital infrastructures are ready to support the digital transformation (World Economic Forum 2016). Clearly, both countries will have to invest into the digital infrastructure in order to keep up with the pace of digitisation. Technologies such as system learning, demand forecasting and virtual aggregation of storage devices are currently in development and could contribute significantly to energy efficiency gains. However, the realistic impact of these technologies for energy savings will have to be determined.

In the present phase, both countries have **demonstration projects** underway. In Germany, the SINTEG project ("Smart Energy Showcases - Digital Agenda for the Energy Transition") is a prominent example while Japan has implemented demand response projects and demonstration projects for smart communities and cities as well as energy management systems in buildings, factories and homes. Both countries envisage the development of business models especially for big data, visualisation of energy use, etc.

In the case of **smart meters**, Germany's law on the digitalisation of the energy transition prescribes smart meter roll-out in several stages. In contrast, in Japan no legal obligation is in place. Instead, the smart-meter program is operated by power retailers. According to the Electricity and Gas Market Surveillance Commission (EGC, 2017), about 30% of low voltage meters are smart meters as of November 2016 in Japan. It is expected that all residences will have smart meters by 2025, as the official lifetime of power meters is 10 years. Germany obliges large consumers with over 10,000 kWh/year and producers between 7-100 kW installed capacity to install smart meters until 2024 while for smaller consumers and producers, the smart meter roll-out period commences in 2020 and will last until 2027. In conclusion, roll-out in Japan seems to have progressed slightly further. Yet, in neither of the countries is roll-out matched with energy efficiency targets.

For the purpose of promoting the dialogue on **smart cities and communities**, both countries are engaged in international evaluation groups such as IEC SEG1. Four large scale demonstration projects were selected and conducted in Yokohama, Toyota, Kansai Science city and Kitakyushu from 2010-2014. In Germany, the responsibility for the promotion of smart elements in cities and communities lies with the local authorities. On the federal level, a national strategy group on smart cities is working on smart city guidelines and strategies.

5.2 Demand Response

For the widespread application of demand response (DR) measures, Japan and Germany will both have to take into consideration open questions concerning price sensitivity, announcement effects and weakening effects due to habituation.

In Japan, demonstration projects for tariff based DR and negawatt trading, time of use pricing (TOU) and critical peak pricing (CPP) were tested for price sensitivity. Demand reduction for CPP was found to be at 10-15% and for TOU at around 10%. Currently, virtual power plant demonstration projects are underway with the aim to use aggregation for flexible energy management in order to meet variable renewable energy production. Germany is testing different aspects of demand response in the different SINTEG projects, e.g. "NEW 4.0", "WindNODE" and "Designnetz". The outcomes of these projects are yet to be expected.

Flexible electricity tariffs are legal in Germany, but are not yet on the market, except for traditional time-of-day tariffs. Large consumers, however, can buy directly at the electricity exchange. There is no wide-spread application of DR mechanisms although some large industrial consumers are already capable of employing them such as the aluminium producer Trimet. In Japan, flexible electricity tariffs require permission from the government, but tariffs will be deregulated after 2020. Currently, consumers can choose for example TOU tariffs (time intervals are pre-defined) but uptake has not been significant so far.

For a comparison of national-level instruments in the ICT, demand response, and smart cities and communities in Germany and Japan, see the table below:

Table 39: Overview of energy efficiency-related policy instruments in the ICT, Demand Response, and smart cities and communities

	Regulation	Planning	Information & Advice	Incentives & Financing	Capacity Building & Networking	Research and Development & BAT promotion
DEU	• **Law on the digitalisation of the energy transition**: regulation of smart meter rollout	• **Digital Agenda** 2014-2017 • **High-tech Strategy** "Innovation for Germany" • **Digital Strategy 2025**	• **Platform Industry 4.0** • **Energy transition platform**: research and innovation	• **Pilot programme Savings Meter** ("Einsparzähler")	• **Digital networking** in the framework of the digital agenda • **Green IT Initiative**	• **Large-scale demonstrators ('Showcases'):** Digital agenda for the energy transition (SINTEG) • **6th energy research framework:** Support initiatives "Energy storage" and "Future-proof Power Grids" • **Technology programmes:** "Smart data", "Smart service world", "ICT for electric mobility II", "E-energy – ICT based energy systems of the future", „material science research for the energy transition "
JPN		• ICT as a core energy technology in **National Energy and Environment Strategy** for Technological Innovation towards 2050 (NESTI 2050)	• **Traffic information provision** to avoid congestion • **Study group on energy digitalisation** in Agency of Natural Resource and Energy	• Favourable treatment of smart meter examination commission fee	• **Communication protocol** between smart meter and Home Energy Management System (HEMS)	• Ministry of Economy, Trade and Industry funds virtual power plant projects • Standards of Home Energy Management System (HEMS) • Demand management through negawatt trading demonstration

5.3 Rebound effects and the behavioural approach

The rebound effect is a widely-recognized phenomenon and negatively impacts energy savings targeted by policy measures. Rebound effects can be counteracted by behavioural approaches. This means that policy measures aim to induce pro-environmental behaviour.

In Germany, information campaigns such as "Germany makes it efficient" and subsidized energy advice aim to increase awareness and thereby lead to energy savings because of more sustainable consumer decisions or use patterns.

In Japan, a trend towards a decline in electricity demand, especially in the commercial and residential sectors is attributed to increased consciousness of energy saving and became known as the Setsuden initiative. In Japan, the Great East Japan Earthquake in 2011 lead to a temporary 10% reduction in electricity consumption. Currently, there is a government campaign of 'Cool Choice' during summer and winter. It aims at replacement to energy efficient and low carbon products and services, and lifestyle changes to reduce greenhouse gas emissions.

The Japanese "Eco-point system" incentivizes the purchase of energy-efficient products such as air-conditioners by allowing consumers to purchase LED light bulbs with points awarded. In the case of residential heating, consumption behaviour is different in Japan, as only those rooms that are used for the moment are heated up. In residential buildings, central heating or cooling is very rare while non-residential buildings frequently use central heating or cooling. The residential heating demand is quite low, even after Heating Degree Day (HDD) adjustment, compared to Germany (Juukankyo Research Institute 2013). However, the residential energy consumption portfolio is quite different in two countries. For example, Japanese hot water consumption is relatively large because of bathing habits. Also, electric appliances power consumption is relatively large in Japan, including more space cooling needed than in Germany. In total, German residential energy consumption per household may relatively be larger because of high heating demand and larger dwellings.

Energy service market

There is considerable growth of the energy service markets in both countries. Energy services can be divided into information, consulting, energy management and ESCO models.

The supply side of Germany's energy service market is characterized by high competition and well developed. It remains however a challenge to create corresponding demand. Japan's Energy Conservation Act requires companies to appoint energy managers, which preform various energy efficiency management services. Hence, what is offered by energy service markets tends to be rather performed with in-house personnel in Japan. While Table 40 aims to compare different energy services in both countries, it can be seen that a classification of energy service products (see table below) such as in Germany does not exist in Japan.

The Japanese market scale of energy service companies is estimated at 20-30 billion JPY (~EUR 230 million) per year (Japan Association of Energy Service Companies) and it is reported that there is a potential to save 174 PJ/yr in the commercial sector (Jyuukankyo Research Institute 2014). The German market had a total turnover of about EUR 135 billion to date, with a market size of 8 to 9 billion per year.

Table 40: Energy service markets in Germany and Japan

	Germany	Japan
Energy consulting	**Energy consulting** is the most offered and demanded energy service product. Around 14,000 companies are estimated to provide a variety of energy consulting services. The market has increased from a volume of EUR 270 to 460 million in 2012 to EUR 480 to 520 million in 2015. Energy consulting is often an entry point for further energy efficiency services and investments. A high potential on demand side is estimated, while currently only around 1% of objects have been subject to energy consulting. Positive expectations dominate the market as around 73% of energy service providers expect a market growth in terms of turnover in the coming three years.	See ESCO models
Energy Management	In the European Union, it is a prerequisite for non-SME companies to have a certified Energy Management System in place or carry out energy audits every four years. Since 2016, in Germany, all companies – which are not SMEs – need to have a certified Energy Management System in place or an energy audit. For SMEs, this can alternatively be an energy audit or alternative systems to improve energy efficiency. The market volume for energy management services is estimated around EUR 250-500 million per year with a growth tendency.	In Japan, large companies must appoint qualified in-house energy managers to comply with the Energy Conservation Act obligations such as energy consumption reporting, medium term planning, etc. For small and medium-size enterprises, energy conservation diagnosis is free of charge.

	Germany	Japan
ESCO Models	Energy Performance Contracting (EPC) and Energy Supply Contracting have the highest market volume of around EUR 7.2-8.4 billion with a steady annual increase (BfEE 2017). The market volume has increased from EUR 3.5-5 billion (2012) and EUR 1.7-2.4 billion (2010) (JRC, 2014). More than 60% of energy service suppliers expect growth or even strong growth of the ESCO market until 2020 (BfEE 2017). The market research conducted by BfEE finds around 500 specialised ESCOs and utilities providing ESCO models while only around 10-15 ESCOs provide EPC in their portfolio. And while utilities only generate 17%, ESCOs generate almost two thirds of their turnover from energy services (BfEE 2017). ESCOs mainly originate from utilities, energy companies and independent energy service companies (e.g. provider of building automation). Other market participants are energy consultants, engineering firms, crafts businesses and planners.	Companies that implement energy conservation measures and provide further services such as a comprehensive engagement of energy related business have business opportunities in Japan. A market survey by the Japan Association of Energy Service Companies (JAESCO) estimated that the annual market scale of the member companies on a new order basis has been in the range of 20 to 30 billion JPY per year (150 to 230 million EUR per year).

6 Conclusion on the mutual review

The mutual review of the individual country reports has revealed a number of parallel developments as well as clear differences in the regulation of energy efficiency in both countries.

While energy efficiency is regulated by two comprehensive Acts in Japan including the Energy Conservation Act and Buildings Energy Conservation Act, the regulatory landscape in Germany has more complexity, also due to the EU which has created an additional governance layer.

In contrast to Germany, which has a comprehensive energy transition strategy in place known under the term "Energiewende", a similar, but less comprehensive strategy called "Long-term Energy Outlook" exists in Japan. However, while Germany has formulated targets for 2050, there are no such long-term quantitative energy targets in Japan.

Especially for the regulation of buildings and in the industry as well as appliances covering both sectors, mandatory competitive benchmarks play an important role in Japan. This instrument is not commonly used in Germany, where standards for appliances are agreed for each individual appliance on a EU-level. In Germany, the building envelope performance regulation is advanced. The Japanese regulation however, was rather weak in the past, but the recent establishment of the Building Energy Conservation Act will accelerate energy efficiency especially in large buildings. In contrast to the German energy performance certificate, labelling for new and existing buildings is encouraged, but not mandatory in Japan.

Energy efficiency developments and regulation in the industry are difficult to compare in detail because the production style of each industry differs. However, the monitoring and compliance systems are different. While in Germany, mostly third party audits are contracted for energy consumption reports, Japan requires in-house reporting from each company. In some cases, energy diagnosis for small and medium enterprises are done by third parties as well in Japan.

Efficiency improvement of vehicle and next generation vehicle diffusion are a common agenda for Germany and Japan, as the automobile (i.e. passenger cars, buses, freight trucks) share is dominant in both countries' transportation energy demand.

With regard to information and communication technologies, demand management and response measures and smart cities and communities, both countries seem to be in a similar position. Research and development is being undertaken and supported by the government. Yet, there are no wide-scale applications employed for improved energy efficiency and the energy savings potential remains largely unclear.

Energy consulting services as well as energy providing services exist in both countries. Yet, the energy efficiency service market seems to be more defined in Germany compared to Japan. One explanation is that most energy services are done by in-house management as energy managers are required by Japanese law. Nevertheless, both countries expect a growth in energy services especially with regard to digitisation.

7 Recommendations

The following section outlines the policy recommendations and business opportunities for each country as well as mutual learning opportunities and identifies further research. The section draws on the results of the analysis for both countries including the previously discussed similarities and differences.

7.1 Policy recommendations and business opportunities

Germany

Germany has a large range of policy instruments to improve energy efficiency. Most policies are set up to act mutually reinforcing. This includes for example several subsidies such as the possibility to finance measures identified in the energy efficiency networks for industry, or via energy advice, through public funds. Other instruments, such as information measures, are complementary to other instruments. This includes for example energy audits or energy consultations which act as precursors to the implementation of energy efficiency measures. However, there are also instruments that are contradictory or cancel each other out. For instance, the exemption from the Renewable Energy Act levy ("EEG-Umlage") for large industrial energy consumers acts as disincentive to save electricity as these actors want to avoid falling below the minimum energy consumption threshold defined for the exemption. Generally, further or improved measures are needed to close the gap for reaching the 2020 targets in all sectors. In the following, recommendations are provided per sector to follow the same set-up of the report, starting with the **overall governance framework**. No priority is assigned to the instruments, all are considered important. It was not possible to quantify an expected impact in the scope of this study.

In addition to the further development of existing policies and new policies, it will be necessary to integrate elements regulating **energy prices and subsidies**. Energy prices are a strong driver for energy efficiency, e.g. through increased fuel prices. Additional revenues could be re-invested in energy efficiency measures. Another crucial point is to embed new policy instruments more strongly into the overarching energy transition. In an energy system with a high share of variable renewable energies, sector coupling and flexibilisation of demand have to be taken into account in the future policy package for energy efficiency. Therefore, Research and Development projects will play an important role in successfully realizing the *Energiewende* and will need to be adequately reflected in the further development of policies.

Additionally, Germany has committed to the **Energy Efficiency First Principle**, which will need to be reflected in the development of policies and needs to be incorporated in all policy and investment decisions. Within the policy mix, a focus is set on financial incentives rather than regulatory instruments. Therefore, more balanced and comprehensive policy packages that use regulatory, financial, informational and all other instrument types will need to be considered for the development of new policies.

For the **buildings sector**, ensuring a high-quality qualification of building experts is key. In order to overcome the barrier of lacking trust in energy efficiency auditors and energy consultants, stricter qualification requirements should be set. Additionally, stricter laws are necessary to assist with the verification of the correct presentation of energy certificates and, if necessary, implement sanctions consistently. Additionally, policies to incentivise the energy efficient refurbishment of the existing building stock are primarily of financial and informational nature, regulation to refurbish old and inefficient building stock should be considered. Further incentives for deep renovations is crucial, especially with respect to the long-term targets. Yet, barriers such as split incentive or lacking trust in energy efficiency auditors still exist. The KfW provides a considerable amount of funding for building renovations and has been very effective in doing so. Transaction costs for funding programs for non-residential buildings should be further reduced. KfW programmes will also need to be expanded to consider sector coupling opportunities when refurbishing buildings. Additionally, a revision of the building codes for new built with very energy efficient nearly zero energy building requirements is still pending.

In the **industry sector,** most policies have a voluntary nature. The implementation of article 8 EED to perform mandatory energy audits for non-SMEs has been a first step to increase the number of regulatory instruments, however the implementation of recommended measures by the audit is not mandatory. For the further development of policies, recommended efficiency measures will have to be implemented. To facilitate this, thresholds (e.g. of financial nature) can be set to determine the order of implementing measures. Moreover, the obligation to perform energy audits should also apply to SMEs. Also, the examination of useable waste heat potentials should be included as mandatory requirements in energy audits and energy management systems. Additionally, energy taxes are a strong instrument in the industry sector. The public consultation of the Green Book Energy Efficiency has highlighted the interest and support by the public to implement a CO_2-tax. Furthermore, for industrial processes the development of standards, norms and benchmarks for efficiency technologies is crucial. Financial instruments should be designed in a transparent and permanent manner with low transaction costs. For the further development of subsidies, the successive rising of minimum standards is necessary.

In the **transport sector**, obstacles to reaching the full efficiency potential exist on all levels (system efficiency, transport efficiency, vehicle efficiency). On the systemic level, the lack of a comprehensive strategy for an integrated transport regulation is the main issue. It also remains difficult to achieve a modal shift towards energy efficient and climate friendly modes of transport. In order to reach the targets of a 10% reduction until 2020 and a 40% reduction until 2050 (baseline 2005) in final energy consumption, further energy efficiency measures are necessary. Existing instruments focus on increased vehicle efficiency. Against the background of the current emission scandal in the German automobile industry, severe issues of implementation have become obvious. Furthermore, system and transport efficiency are hardly addressed at all in the current state, so that a mere strengthening of current standards will remain insufficient. Therefore, a fundamental *transport transition* is needed that entails a national strategy for an integrated, climate friendly transport policy mix. Financial incentives as well as investments in public transport to secure a higher quality of service in the public transport system are important. Existing policies on the EU level such as fleet targets for automobile manufacturers in combination with restrictive policies for individualised motorised transport, e.g. speed limits are necessary. Further goals should include the complete internalisation of external costs in the fuel tax (greenhouse gas and CO_2-content) as well as the kerosene tax for domestic flights. Taxes for individual motorised transport should be based on greenhouse gas emissions as an indicator. Setting off prices for purchase and operation of privately used vehicles from tax liability should only be allowed to a limited extent. Repayments from commuter allowances could be linked to sustainable transport, favouring public over private transport. Finally, information measures that target mobility behaviour and choice of transportation mode in favour of climate friendly alternatives are recommended as a complementary measure.

Appliances are primarily regulated by the Ecodesign and Energy Labelling Directives. National regulations are not allowed to have more ambitious standards than required by the EU Directives. Therefore, efficiency policies focus on information and financial measures. On EU level, it is recommended that efficiency requirements should be increased progressively and not linearly and where applicable should include limits. Market surveillance should be strengthened. According to MarketWatch (2015); every fifth product consumes more energy than indicated. Default values of appliances should mandatorily be set to energy-efficient modes by the producers.

Digitisation can provide an opportunity for new consulting tools to save energy in equipment by enabling cost-effective consulting services, which at the same time are more responsive to individual, real-world use. This also includes building automation. For the industry sector, business opportunities lie in demand response. Third-party aggregators and utilities could recruit customers for demand response programs to relieve the grid during periods of high energy demand, which will facilitate the development of demand response automation. In this context, utilities could also implement pilot programs for flexible electricity structures. For this, Germany could look at the virtual power plant demonstration projects which are currently underway in Japan.

Japan

Long term policy goal and deregulation of power market

Japanese energy efficiency policy has a broad coverage in industry, buildings (i.e. commercial and residential) and transport. After the initial establishment about 40 years ago, there have been frequent revisions in the Energy Conservation Act. The Building Energy Conservation Act was added in 2015 to cover the building envelope performance. Japan tries to avoid a complex legal structure which is burdensome for energy consumers.

However, social and political needs are always changing. For instance, Japan must submit mid-century long-term climate change strategy to UNFCCC by 2020. Discussions are in progress in the Ministry of Environment and Ministry of Economy Trade and Industry. Energy efficiency improvement is one of important energy policy package in the long-run. In addition, deregulation of the power market is underway. Power retailers can propose a new tariff design to small scale customers from 2020. New tariffs would eventually accelerate energy efficiency improvements. Under this competitive situation, universal service assurance and tariff design to accelerate energy savings are major public issues and should be discussed.

Energy conservation of small scale businesses

Small scale business energy users are exempt from annual energy consumption reporting and energy intensity compliance mandates in the current regulation institutions. We find that the increase in the coverage is due to the energy conservation act revision in 2008, which treats a franchise chain like convenience stores and restaurants also as single enterprises. Other incentive schemes such as energy consumption diagnosis and advice with monitoring systems which are using information databases would be an attractive policy package. It should be designed as a simple system to avoid policy transaction cost.

Buildings: energy monitoring during utilisation phase

The building energy performance requirements, under the Building Energy Conservation Act, are applied to new construction/extensions/renovations of buildings with a floor space area over certain thresholds. Additional supporting measures should be provided for buildings with small floor space and old vintage housing stocks. However, it is based on the design phase evaluation before the completion of the building. Policies on energy monitoring with advice during the utilisation phase are recommended because the building performance would be degraded compared to the initial condition in the long-run.

Transport: autonomous driving with assistance of traffic and geographic information

Vehicle efficiency improvement and traffic management are the major current policy tools as stated in the previous sections. In addition, autonomous driving may improve energy efficiency. We need guidelines for autonomous driving especially in terms of safety concern. The establishment of guidelines and other institutions is necessary to expect an energy conservation effect accompanying autonomous operation.

Business opportunities: Big data and market for energy saving values

Energy related data is being produced every day. Some data has been captured by monitoring equipment such as smart meters and energy management systems. Autonomous driving in the future would combine driving data and traffic data to assure driving function as a service. Future building appliances can be controlled automatically via the automatic demand response request. We need to establish the market system to exchange energy saving values. The system can be combined with an energy trading system to ensure flexibility such as ancillary services of power supply.

7.2 Mutual learning opportunities

After highlighting the similarities and differences in WP2, it became apparent that mutual learning opportunities exist. While Germany and Japan have a similar set-up of the industry sector with a large share of energy intensive industry, it is interesting to note that the policy approaches diverge. Germany has traditionally focused on voluntary approaches as well as tax exemptions and financial support for industry. Commonly it is perceived that the Emissions Trading Scheme is the largest energy and climate policy tool in the industry sector. The effects on energy efficiency are however only of secondary nature and due to the low CO_2 prices, the overall effect is limited. Japan on the other side focuses on regulatory approaches and 90% of industries are regulated by the Energy Conservation Act. The energy intensive industry even sets benchmark targets where the benchmark is used as the target standard of the best performing companies (top 10%-20%) in each subsector. Companies in these subsectors are subject to annual mandatory reporting on the status of their performance. It should be analysed, whether benchmarks for the rational and efficient use of energy in Germany could be for example integrated into the Bundesimissionsschutzgesetz (BImSchG). Furthermore, a nationwide energy data base, which provides industry-specific and process-specific data and information on energy consumption and mitigation techniques, should be established for monitoring.

Another learning opportunity for Germany is the Japanese Top-Runner approach. Japan’s Top Runner Programme, introduced in 1999, is a set of energy efficiency standards for energy intensive products, such as home appliances and motor vehicles. As of 2017, the programme involves 31 product categories. Products are included due to either their high energy or widespread use or their substantial scope for improving energy efficiency. Energy efficiency targets are set to be achieved within a given number of years on the basis of the most efficient model on the market (the ‘Top Runner’). Over the years, the number of products covered has been continuously increasing. *Additionally, non-compliance with the standard is penalised with a ‘name and shame’ approach* (peer pressure), putting the brand image of companies at risk as opposed to their profit. Germany‘s National Top Runner Initiative currently focuses more on sensitizing consumers and increasing awareness about energy efficient appliances. Additionally, the initiative provides a platform for manufacturers exchange ideas for continuous improvement of energy efficiency. It could be beneficial for Germany to implement energy efficiency targets that need to be achieved with the Top Runner Initiative and to penalise non-compliance. This however, can only be done for types of products not regulated by the EU's Ecodesign requirements.

One of the learning points for Japan is related to building energy policy, although the Japanese residential energy consumption per household may be smaller than that of Germany. Some sources say that heating demand is about one-fifth compared to German household (Jyuukankyo Research Institute 2013). On the other hand, Table 34 above seems to indicate that per capita energy demand for buildings is even higher in Japan than in Germany. Heating equipment are operated partial and intermitted operated for in Japan, while German system employs central heating system in most cases; Germany could save energy by adopting the intermittent heating practices as in Japan, which were also traditional in Germany in the past. Japan can learn from Germany in terms of long-history large scale building envelope insulation policy and its mandated characteristics and high energy performance levels. The same may be true for policies to stimulate energy-efficient refurbishment of existing buildings.

On the other hand, it seems that Germany could learn from Japan in the transport sector, where according to Table 34 per capita energy consumption is considerably lower in Japan.

Another learning point for Japan is the long-term view. The target year for the Japanese long-term energy outlook is 2030, just after 13 years from now. On the contrary, Germany has a 2050 target and intermediate targets of the 'Energiewende' and submitted 2050 national long-term strategies to the UNFCCC. A long-term energy efficiency national strategy with quantitative targets is essential because energy related infrastructure, such as urban planning with adequate building performance is essential to achieve long-term energy efficiency goal.

7.3 Further need for research

Given the limited scope of this study, the present section identifies further need for research that would help to deepen the mutual comparison.

The information on energy efficiency potentials varies between Germany and Japan and also within sectors. More detailed studies about energy efficiency potentials in Japan will be beneficial and would allow for a more detailed comparison between the two countries. Additionally, for Germany energy efficiency potential studies for the timeframe 2050 are needed. This also includes studies analysing the cost-effective saving potentials containing information on economic efficiency (e.g. Net benefit/Cost curves of negawatts). Such cost curve data was last revised in 2011 in Germany. It should be expanded to the multiple impacts of energy efficiency.

Further analysis is also needed to understand the differences in per capita energy consumption in buildings between the two countries (cf. Table 34 and chapter 7.2). How much of the consumption and the differences is due to climate, energy performance levels of insulation and equipment, operation and energy management, and to daily routines of building use? In order to be able to distinguish, e.g., between the German Nearly-Zero- or Plus-energy-Standard and the Japanese Zero-Energy house or building, more data is needed. The Japanese standards rely on a roof-mounted PV powered by solar radiation, yet they fell short of prescribing sufficient insulation of the envelope, because it was not a mandatory. The Japanese country report shows the high impact of the building envelope either in the commercial sector or in the residential (about 50%). It would be helpful to obtain more detailed information about the regional differences in climate and the specific data of energy saving potentials in different house types after the completion of buildings. This is especially true for the obligations that apply in Hokkaido, the northern island of Japan, which has similar climatic conditions to Germany. Houses in Hokkaido have high insulation including double glazing and other options. However, Japan is a very wide county from north to south. Building envelope efficiency is defined by 8 zones. It is difficult to achieve ZEH conditions in Hokkaido, but examples exist. Most climate zones require countermeasures for humidity, cold and heat simultaneously in the building design. In Germany, high insulation with radiative heating is the simple answer for buildings and it is relatively easy to achieve.

Similar in-depth analysis is needed to understand why Japan's per capita energy consumption is lower than Germany's in the transport sector: How much is due to differences in travel/transport distances, modal shares, and fuel efficiency of vehicles?

For a better understanding of the differences in energy service markets, a dedicated line-up by type of services would provide insights why and in what services the German market has a higher turnover. Current studies only look at the market size, while the total turnover of the Japanese energy efficiency technology service market would be of interest.

Additionally, a more detailed assessment on the impact of existing and potential new or improved energy policies is needed. This includes their impact on energy prices in both countries as well as the role of energy prices as drivers for energy efficiency. While Germany exempts their energy intensive industry from renewable energy levies, Japan does not have exemption for a feed-in tariff surcharge in its power tariff. However, electricity prices remain competitive.

Furthermore, the impact of exchange rates on energy productivity will need to be studied. Final energy consumption per capita in total and in industry similar in both countries. Energy productivity in industry in Germany is higher than in Japan, though, which might be partly explained due to the exchange rate.

In addition to an assessment of final energy efficiency, other potential future assessment methods are currently being debated. In order to shift the perspective to the overarching target of decarbonisation, valuation methods based on CO_2 (t/(m^{2}a)) based on energy consumption may be a promising option. The Japanese buildings target is based on the primary energy consumption in reference to a standard building. In the long-run, energy intensity will have to be reduced while the net building energy consumption and CO_2 emissions from buildings could be zero in both countries. In this respect, the German Federal Government is reviewing the creation of incentives for taking into account the emissions generated during the production, construction and disposal of building materials. This supports efforts to consider the entire lifecycle in assessing the effects of i.e. appliances on climate change, rather than just taking into account the final or primary energy consumption of the operation phase. In the German context, this is recognized in the assessment systems for sustainable construction, including the BNB (Sustainable Building Assessment System), the DGNB (Certificate of the German Sustainable Building Council), the BNK (Rating System for sustainable small residential buildings) and the NaWoh (Sustainable housing for multi-family houses). Life cycle assessments show that for very energy-efficient buildings, the energy used for the building construction during the lifecycle is the greater share of the total energy consumption, especially in the case of the "Nearly-Zero-Energy-Building" standard. The German Sustainable Building Council (DGNB) calls for the introduction of a new assessment strategy of the environmental impact. The introduction of a limitation on CO_2 emissions is planned for the approval of new buildings in the planned amendment of the EnEV / EEWärmeG. Such assessment methods should coexist with energy parameters in order to reduce heating and cooling energy demand.

8 Conclusion

This report has analysed the energy efficiency policies, potentials and barriers in Germany and Japan. It has furthermore compared similarities and differences and outlined policy developments as well as future research questions.

Energy efficiency is a strong pillar of the energy transition. In Germany, buildings (esp. heating) and transport are addressed by national sectoral targets, yet an efficiency target is not in place for the industrial sector. Energy efficiency measures in all sectors are derived from a whole array of regulation and supporting measures. Different ministries including the Federal Ministry of Economic Affairs and Energy, the Ministry for the Environment and the Ministry for Transport are involved in the compilation of the policy mix. The regulation on the EU level adds another layer to the governance framework and formulates efficiency targets as well as directives that have to be implemented into national law. Additionally, national law must not introduce higher standards, for example for the efficiency of appliances than EU law.

In Japan, there are two comprehensive main regulatory acts, namely the Energy Conservation Act and the Buildings Energy Conservation Act. Similar to the German context, multiple ministries such as the Ministry of Economy, Trade and Industry (METI), Ministry of Land, Infrastructure and Transport (MLIT) are involved in the energy efficiency regulation. The industrial sector is subject to mandatory efficiency requirements, which is not the case in Germany.

Germany still has considerable saving potentials in all end use sectors. Nevertheless, further policy developments are needed to lever these potentials, reduce barriers and achieve the energy efficiency targets.

Japan improved its energy efficiency in the past and further saving are expected, especially in building sector. Economic incentives, manufacturing and selling of end-use energy equipment, efficiency improvement of the building stock, the energy system infrastructure innovation and other policy measures are an important policy portfolio to realize short to long-term energy efficiency improvements in Japan.

This report has shown that Japan and Germany share similarities in energy efficiency potentials and barriers while using different approaches to lever the potentials. Due to this, opportunities for mutual learning were identified. However, these opportunities are somewhat limited by external circumstances that are difficult to alter. This includes especially the governance level of the European Union which steers German energy efficiency policy and cultural differences. Especially in the building and transportation sector, energy saving opportunities largely depend on the urban area design. Local governments also play important roles as well as the coordination between national government, businesses and public. Stakeholder involvement is therefore essential in both countries to accelerate an ‘energy-efficiency transformation’.

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