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GREENING THE BUILT ENVIRONMENT

A review of Danish and German energy efficiency policy to reduce energy consumption and CO_2 emissions in the services sector

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TNO student report

Greening the built environment: A review of Danish and German energy efficiency policy to reduce energy consumption and CO_2 emissions in the services sector

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Summary

The aim of this paper is to serve as an additional report for the larger study "GREENING THE BUILT ENVIRONMENT. A review of Dutch, German, Danish and British energy savings policies to reduce the energy consumption and CO_2 emissions in the residential sector". This study focuses on the building stock of the Danish and German services sector in the residential sector. Another student report focuses on the services sector of Germany, which has a short description of the Dutch services sector as well.

The trends analysed in this paper indicate that the energy consumption in the services sector of both Denmark and Germany has remained somewhat steady, whilst Germany and especially Denmark are making use of more environmentally friendly fuels. The results are even more positive when the energy consumption is analysed with reference to the floor area occupied by the services sector in both countries. According to the Odyssee-Mure database, the Danish policy agenda includes only three measures. On the other hand, the German services sector is targeted by twenty-six policies measures and six of them are categorised as high-impact. The German central bank, with its direct links to the German government, has promoted the improvement of energy efficiency in the service sector mainly through financial policies.

Research Highlights

- Both the floor area and the number of employees in the Danish services sector has increased in the past few years by approximately 20%.
- In Germany, the floor area has increased by only 5%, while the number of employees increased by 20%.
- In both countries total energy consumption in the services sector has remained somewhat steady but note that only in Germany has the energy used for space heating decreased in recent years.
- In both countries more environmentally friendly fuels have dominated the fuel market the last three decades.
- Denmark has implemented only three policies targeting the services sector exclusively. All three policies refer only to publicly owned buildings in the services sector. However, there are many Danish energy policies target the building stock as a whole.
- Germany has implemented twenty-five policies targeting the services sector. The majority of the successful measures contain economic or financial incentives.
- Both Denmark and Germany have managed to realise energy efficiency in buildings in the services sector, because both countries have reduced energy consumption per square meter.

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Preface

In the 2013 report “Energy Agreement for Sustainable Growth”, the Dutch government set several targets in order to move towards a zero-emissions energy system by 2050. The two main national targets of the agreement were to realise energy-savings of 1.5% annually and to increase the share of renewable sources (14% by 2020 and 16% by 2030). Amongst others, vast energy-saving potential has been identified in the building stock of the country. The objective of this, and the other two related, studies is to review the energy-saving policies across (four) EU countries and to facilitate a cross-boundary discussion.

This internship report was written as partial fulfilment of the curriculum of MSc. Urban Environmental Management at Wageningen University. The internship was coordinated and supervised by Dr Mattjis Smitt of the Environmental Policy chair group and Jeffrey Sipma from the ECN-TNO organisation over four months. The entire project took place between October 2018 and February 2019.

Lastly, as the author of this paper, I would like to thank my supervisor Jeffrey Sipma and my colleague Rhianne Holdsworth-Morris, who supported and provided me with valuable feedback while I was conducting this research. Furthermore, I would like to thank the TNO-ECN office team for the warm welcome.

1 Introduction

Over the past decades, the energy demand for buildings has continued to rise globally as a result of improved access to energy, the increase of the total floor area per dwelling and the growth of energy-consuming devices (IEA, 2019). To date, the built environment accounts for 30% of the total final energy used globally, and for one-quarter of the energy-related CO_2 emissions. Without political action, the energy demand of buildings is projected to increase by at least 30% by 2060 (IEA, 2019). Thus, several countries use a variety of policies or measures to improve in the energy efficiency of the building stock and to substitute conventional non-renewable fuels within the built environment (Tettey, 2017). The objective of this research is to identify and analyse the effect of these policies[1] in the Danish and German services sector.

1.1 Scope and Design of this Study

After the completion of the paper "GREENING THE BUILT ENVIRONMENT. A review of Dutch, German, Danish and British energy savings policies to reduce the energy consumption and CO_2 emissions in the residential sector." (Sipma et al., 2019), the authors of the paper acknowledged that an analysis of the Service sector[2] of the four compared countries would form an interesting case study too. Even though the services sector accounts for a large amount of energy consumption and more than half of the GDP in most of the developed countries, not much attention has been paid to its energy performance (Odyssee Mure, 2014 & IEA, 2008).

Hence, this report serves as an additional chapter in the above-mentioned document, aiming to encompass an even wider range of energy-saving measures which have contributed to the realisation of energy efficiency in the built environment in Denmark and Germany. This study includes policies which on one hand aim to decrease the energy demand at the building level, and on the other to transform the overall energy system and lower the CO_2 emissions of the services sector. Thus, policies which aim to improve both the energy demand and the energy supply are analysed.

Since this study is written as a sequel to an existing paper, the same structure, methods, theories, and data have been used in order to provide coherent and consistent results. Thereby, the majority of the quantitative and qualitative data used in this research has been retrieved from the European platform Odyssee-Mure too.

Appendix A consists of a list of definitions and terms that have been used in this paper.

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1 In this paper the terms Policy and Measure have been used interchangeably.

2 The Service or Tertiary sector, according to the Danish Statistic organisation, comprises all the various enterprises offering knowledge and information instead of goods (Statistik Demark, 2018). Appendix A analyses further the Service sector definition.

2 Methodology

2.1 Energy Efficiency Indicators. Description and Evaluation of Policies

The main objective of this paper is to identify and analyse policies which promote energy efficiency in the Danish and German service sectors. The first stage this paper analyses the Danish and German energy consumption and CO_2 emission trends by using energy efficiency indicators. The International Energy Agency (IEA) has identified these indicators as an important tool for analysing interactions among economic and human activities, energy consumption and carbon dioxide (CO_2) emissions (OECD/IEA, 2014). In other words, energy efficiency indicators describe the energy consumed or the CO_2 emitted for a specific activity, and they can be helpful for policy-makers because they can be used for;

- **Monitoring** the achievements in the field of energy efficiency and CO_2 targets and trends, at national and international levels.
- **Evaluating** energy efficiency programs and policies.
- **Planning** forthcoming actions.
- Inputs into **forecasting** models.
- And conducting cross-country **comparisons** (Odyssee-Mure, 2014)**.**

After analysing the energy consumption and CO_2 emission trends, the measures that influence these trends will be described and evaluated.

2.2 Odyssee Mure

The Odyssee-Mure project is an online database maintained by Enerdata and supported by the H2020 program of the European Commission. In fact, Odyssee and Mure are two complementary internet databases which collect and provide quantitative and qualitative energy data respectively. More often, the data is provided by national institutions, organisations, universities or private companies. In the case of Denmark, the Odyssee-Mure partner is the Danish Energy Agency (DEA) organisation. For Germany, the national Odyssee-Mure partner is the Fraunhofer ISI organisation.

Odyssee contains energy efficiency and CO_2 emissions indicators and their drivers. The three energy efficiency indicators that are used in this paper are the:

- **Energy consumption per employee (GJ/employee).**
- **Energy consumption per floor area (MJ/m^2).**
- **CO_2 emissions per economic added value (with climatic corrections) (MJ/euro_2010)**.

➢ **Mure** contains a description and evaluation of all energy efficiency measures implemented at a national or European level.

The Mure part of the database contains descriptions and evaluations for all the measures that aim to promote energy efficiency in the IEA countries, implemented at a national or European level. All these measures have been categorised according to their type/s (Table 1. Type of Measure (source: Odyssee Mure 2014).) and evaluated according to their impact.

Table 1. Type of Measure (source: Odyssee Mure 2014)

Type of Measure-Policy	Examples
Legislative/Normative	Mandatory Standards for Buildings
	Regulation for Heating Systems
	Other Regulation in the Field of Buildings
	Mandatory Standards for Appliances
Legislative/Informative	Mandatory labelling
	Mandatory energy efficiency certificates/ audits
Financial	Grants/Subsidies for investments
	Grants/Subsidies for audits
	Loans/ Others
Fiscal/Tariffs	Vat Reduction
	Income Tax Reduction/Linear Electricity bills
International/Education	Voluntary labelling/Information Campaigns
	Detailed energy/electrical bills
	Regional and local information centres
Cross-cutting measures	Eco-tax on electricity/energy
	Eco-tax on CO_2- emissions

To this table can be added to the 'Market-based measures' (EPATEE, 2018):

- energy efficiency obligations (EEO).
- energy efficiency auctions/tender systems.
- emission trading systems, Clean Development Mechanism (CDM) and Joint Implementation programmes (JI).

The impact of the measures is estimated by the partner teams of Mure which are comprised of national policy-experts with knowledge of their county's policy agenda. A measure can be categorised as *low-impact, medium-impact or high-impact* depending on the percentage of energy savings that have been achieved due to this specific measure. Particularly, if a measure results in energy-saving less than 0.1% in its sector, it is considered as low-impact. Accordingly, measures that cause energy-savings between 0.1% and 0.5% are considered as medium-impact and measures which save more than 0.5% as high-impact (Odyssee-Mure, 2014).

In this paper, **national and EU-related currently implemented measures** are analysed.

2.3 Odyssee-Mure and barriers to overcome during a cross-country policy comparison

A cross-boundary policy comparison is a challenging process which entails overcoming several barriers. Two common barriers are the lack of common established methodology and terminology, and the effect of non-policy factors on energy consumption patterns. These two barriers in this research are overcome by using the Odyssee-Mure database.

The first barrier can mislead policy researchers to incorrect conclusions. In Odyssee-Mure, the data for each country is provided by "decentralised" national teams and partners (collected with commonly established methods), and they are edited in a centralised database by the Enerdata experts. This centralised-decentralised structure enables Enerdata to effectively carry out the control of data definition and disaggregation (Odyssee-Mure, 2014). Thereby, Odyssee-Mure database ensures that the data does not require further harmonisation (corrections) in terms of methodology and terminology.

The second barrier during a cross-country comparison of energy is that the energy consumption needs to be adjusted in order to correct structural variations of the compared countries such as economic, geographic or climatic differences. For instance, in a comparison of the energy demand for the services sectors of Germany and Denmark, the numbers will indicate larger energy demand for Germany since the country is considerably larger with larger economic activities. In that case, usually, the final energy consumption is divided by the total floor area of the services sector and provides a new adjusted indicator which gives a more accurate comparison.

3 Danish Services Sector Results

3.1 Country Overview

The ultimate Danish energy target is for the country to become fossil fuel free by 2050. In doing so, the government aims to decrease the energy demand, and to simultaneously increase the share of renewable sources (DEA, 2017). Similar to all the EU member states, the built environment in Denmark consumes large amounts of energy too. More specifically, Danish buildings account for approximately 40% of the national energy consumption (Danish Government, 2014). The total existing building stock consumes a substantial amount of energy for space heating in comparison with new buildings (Danish Government, 2014).

One of the priorities of the energy strategy in Denmark was to replace the environmentally unfriendly methods of heating with more energy efficiency methods (Rose & Thomsen, 2015). Thus, by planning and implementing District Heating (DH) and Cogenerated Heat and Power (CHP) systems, the Danish authorities have managed to considerably reduce the energy consumption in the building sector over the past decades (Danish Energy Agency, 2017b). Additionally, particular attention has been paid to the development of Renewable Energy Systems (RES) and their integration into the electricity grid.

In Denmark, the services sector is dominating the national economy as it contributes to approximately 65% of the GDP and employs 80% of the employed population. Furthermore, the GDP in Denmark has also increased from 138 to 324 billion dollars since 1990 (Knoema, 2017). Both the floor area and the employment of the Danish services sector have steadily increased since 1990 (figure 1). While the number of employees and the floor area of the services sector grows, one would expect the energy consumption to increase as well. However, in figure 2 the energy consumption does not follow the same trends.

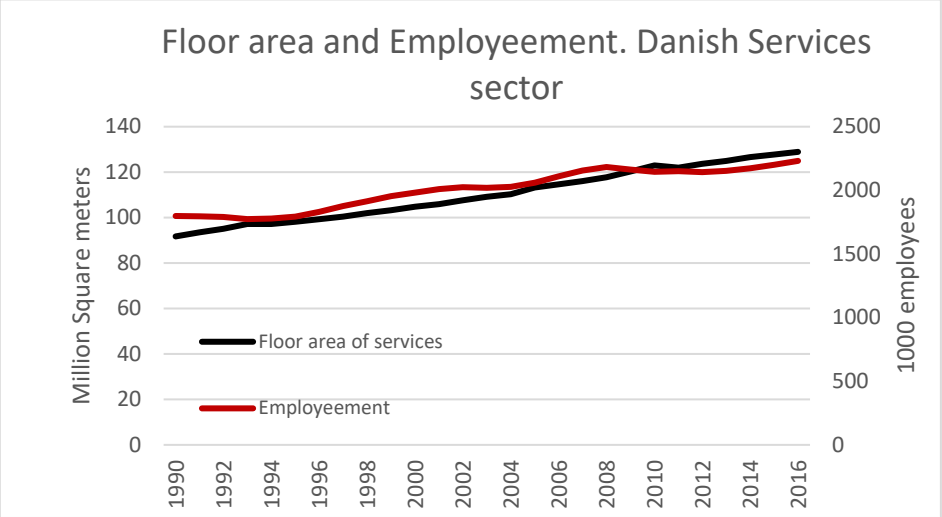

Figure 1. Floor area and employment of the Danish services sector (source: Odyssee-Mure).

3.2 Energy consumption in the Danish services sector

Figure 2 presents the total energy consumption in the Danish Service sector. According to the figure, the energy consumption fluctuates very little over the last 25 years and shows a slight increasing trend. In 2016, the total energy consumption of the services sector was approximately 83.5 PJ, which is only 5% higher than in 1990.

Following the trend of the total energy consumption, the energy used only for space heating in the Danish service sector has remained at the same level as back in 1990.

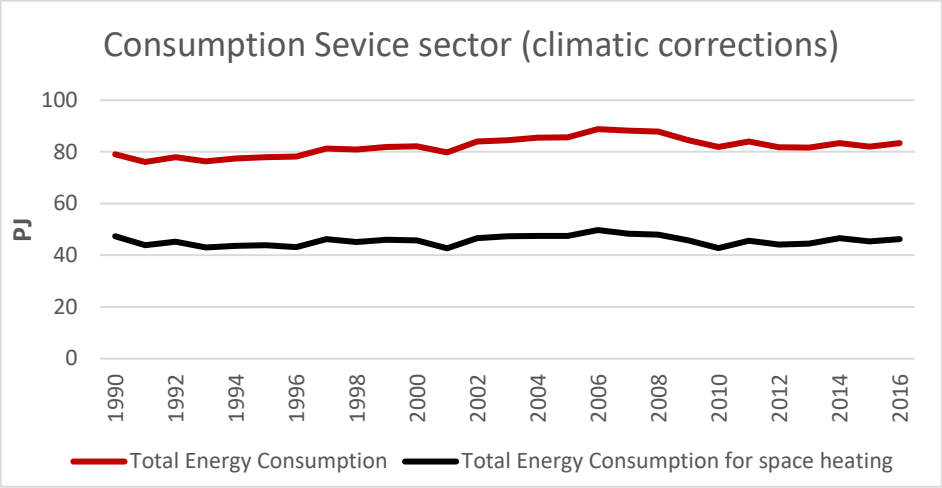

Figure 2. Consumption of Service sector. Denmark (source: Odyssee-Mure)

However, for a more accurate comparison, the energy consumption should be assessed with reference to the performance of the sector. Thus, it is shown in a different analysis figure that in the last fifteen years Denmark has managed to reduce the energy intensity per added value (euro_2010) and the energy consumption per

total floor area in the service sector (figure 3). These two energy efficiency indicators are suitable for describing the energy consumption with reference to the economic and building energy performance of the sector. To conclude, it is assumed that in Denmark the energy efficiency of buildings in the service sector has somewhat improved, as it does not follow the increasing trends of the sector.

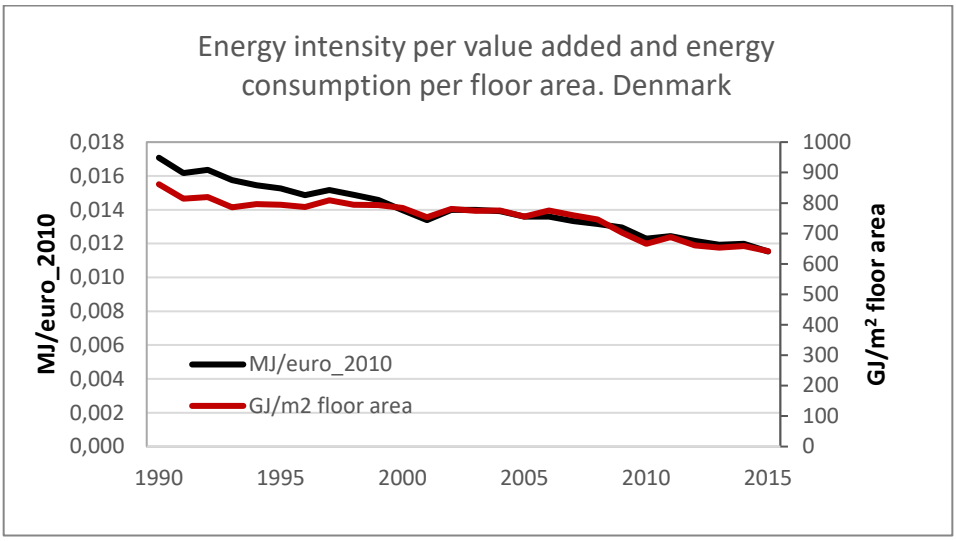

Figure 3. Energy intensity per unit of value added and floor area. Denmark (source: own presentation & Odyssee).

3.3 Consumption by fuel. Danish Service sector

There has been a transition in the mixture and share of fuels used by the services sector in Denmark from 1990 (figure 4). Particularly, similar to the energy trends in the Household sector, the consumption of oil fuels is decreasing considerably, while the percentage of heat is increasing. In 2016, the share of electricity has increased from 1990, while the share of gas remains the same as twenty-six years ago.

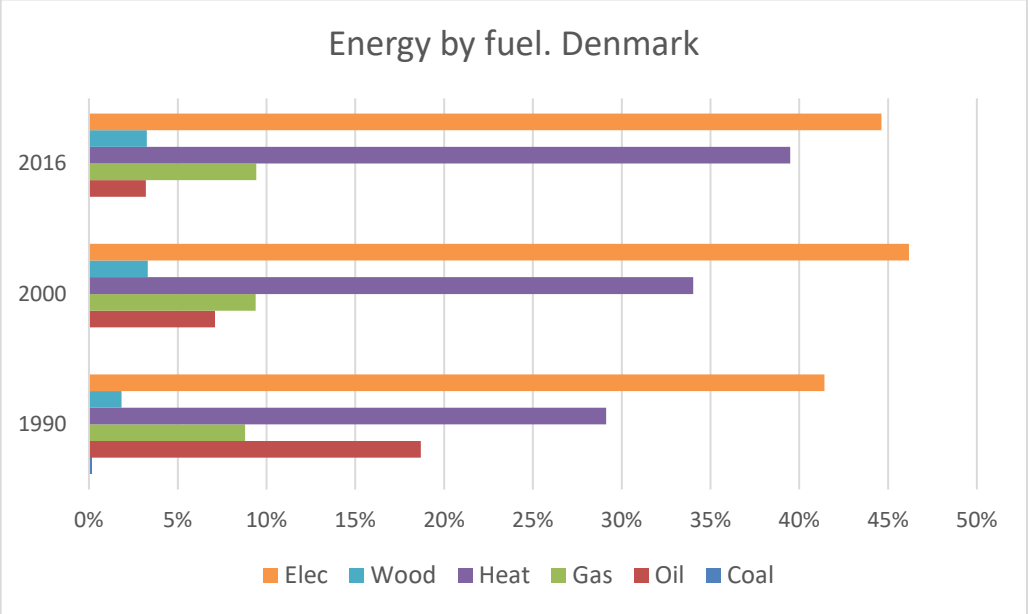

Figure 4. Consumption by fuel. Danish Service Sector. (source: own presentation & data: Odyssee-Mure).

3.4 Current Policies in Denmark; Services Sector

According to the Mure database, Denmark currently implements only three measures that exclusively target the services sector. One of them is EU-related, while the other two measures have been designed and implemented nationally. The last two measures do not consist of a semi-quantitative impact analysis, while the impact of the first one is low. Therefore, in the next paragraphs, the three measures of table 2 will be described. The first and second measures specifically target public buildings in order to give a good example from the governmental perspective.

Table 2. Service sector policy measures. Denmark (source: Odyssee-Mure)

Title	Type	Semi-quantitative impact	Starting Year
Promoting energy conservation in the public sector	Legislative / Informative	Low	2005
Energy saving efforts in public buildings	Unknown	Unknown	2007
Eu-related Energy Performance of buildings EPBD recast (Directive 2010/31/EU)- Inspection of air-conditioning systems	Legislative / Normative	Unknown	2008

The first undergoing measure ***Promoting energy conservation in the public sector*** has contributed to the reduction of energy demand in state-owned institutions. More specifically, the final aim is to reduce the energy consumption in state

institutions by 14% in 2020 in comparison with 2014 (Database Mure, 2016). The measure covers all energy uses and water consumption, except the energy used for transportation. Each state institution is required to update the national database and to publish an annual report which will refer to the energy-saving as a result of this specific measure.

Denmark has chosen to require with Article 5 (Exemplary role of public bodies' buildings) of the Energy Efficiency Directive (EED) with the policy ***Promoting energy conservation in the public sector***; which targets exclusively buildings in the public sector.

Particularly, a significant proportion of Danish services sector policies refer to public buildings. For the improvement of the energy efficiency of public buildings, the European Union includes Article 5 within the EED. More specifically, Article 5 of the EED requires from the member states to (source);

- The default option: renovate each year, 3% of the total heated and/or cooled buildings owned by the central government, or,
- Use alternative measures that achieve results that are better or at least equivalent to the savings results the default policy would have delivered.

According to the requirements of the article, initially only central government buildings with a floor area over 500 m^2 were included within the calculations to reach the total 3% rate of energy renovations, but in 2015 the requirement for floor area of buildings was reduced to 250 m^2. By widening the requirements, the European Union was able to include more government buildings in the article.

Denmark has, along with many other EU states, opted for the alternative approach instead of following the default policy option in Article 5 to renovate every year 3% of the floor area of central government buildings (figure 5). Therefore, each year the country must report the energy saving targets (Coalition for Energy Savings, 2015). However, it is hard to calculate whether the results of the 'Promoting energy conservation in the public sector' alternative policy are equivalent to the results of the default policy. Denmark has reported that they follow the next six alternative incentives;

1. Raising awareness
2. Switching to energy saving devices
3. Moving over to energy efficient construction
4. Optimising land use
5. Renovation of buildings
6. Operation optimisation.

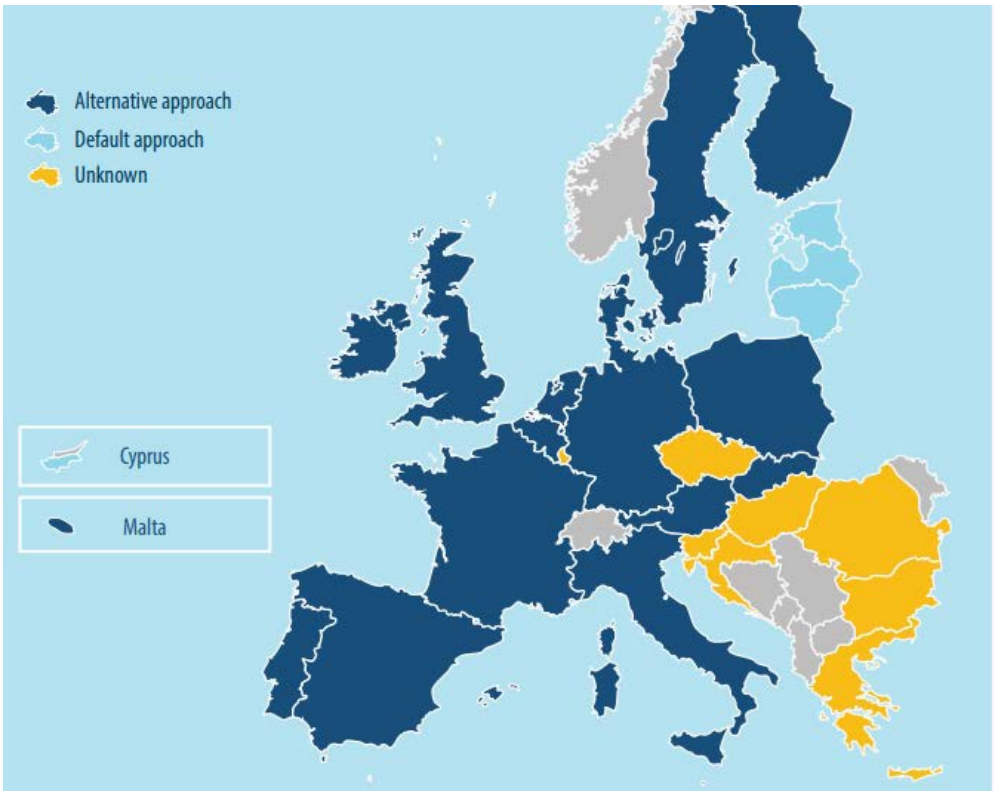

Figure 5. Implementation of Article 5 in the EU

The second measure, ***Energy saving efforts in public buildings*** is a national policy which aims to enhance energy efficiency in all publicly owned buildings. Since 2006, all Danish municipalities and regions have voluntarily agreed to reduce energy consumption in their own administrated buildings. Thus, a variety of government bodies and energy agencies have been involved in that measure. All buildings administrated by regional councils and municipalities are subject to the general 2012 Energy Efficiency Directive.

A policy evaluation conducted in 2016 demonstrated that all municipalities are on track towards meeting the final aim and reduce the energy consumption. In total, the municipalities have reduced their energy consumption by 10% between 2006 and 2015 despite a significant growth in the number of employees (IEA, 2017).

The ***Inspection of air-conditioning systems*** measure comes under the umbrella of the overall EPBD policy, which serves both the household sector and the services sector. The measure describes the obligation to conduct energy inspections of large air-conditioning systems once every five years. The aim is to increase energy efficiency and decrease the operating cost of both ventilation and air-conditioning systems. The inspection process consists of;

- Registration of the energy efficiency details of the systems.
- Inspection of the system's operation state.
- Measurement program.

The Mure database lacks a semi-quantitative evaluation of this measure.

Note that the EU-related Recast Ecodesign Directive for Energy-related Products (Directive 2009/125/EC) is not included in the Mure table for the services sector, although it will be present in all countries where it will target all sectors as a cross-cutting, legislative / normative measure. In Table 3 (the case of Germany) the Eco-design measure is present, which could serve as information for other countries as well.

3.5 Other policies in Denmark. Horizontal policies

In the database Odyssee-Mure, energy policies are not always accurately categorised according to the sector that they serve. More specifically, some energy policies serve simultaneously more than one sector (industry-service-household), but often in Odyssee-Mure they are categorised under only one sector. In Denmark, this different categorisation of policies is more obvious than in other countries, as several policies have been implemented to target buildings in all sectors.

In addition, the policies that have been designed to achieve energy efficiency do not always make the same distinction in terms of sectors. Some policies, according to the Danish NEEAP (2017) are designed to realise energy savings only in the publicly owned buildings of the service sector (these are present in table 2). Some other policies are designed to target only enterprises with a certain size. The term “size” could relate to the number of employees working at the organisation, and/or to the yearly turnover it makes. These enterprises could be part of the service sector or the industrial sector. One enterprise could own several individual buildings (Sipma et al. 2019).

With respect to this different categorisation of policies and targeted groups, the following chapter presents policies that are not included in table 2 but still to some extent influence the Danish services sector.

3.5.1 Strategy for Energy Renovation. (all sectors).

The *Strategy for Energy Renovation* policy has been previously described for the household sector (Sipma et al. 2019). The aim of this national measure is to compose a strategy for the energy renovation of the existing building stock, by involving a wide range of stakeholders from tenants and owners, to building professions and housing associations. In practice, the Strategy for Energy Renovation measure was designed to fill the gaps in the existing energy requirement measures and stimulate renovation in both residential and non-residential buildings.

The Danish government projected that the Strategy for Energy Renovation measure would bring a reduction of 35% in net energy consumption for space heating in all buildings by 2050. Some initiatives that the Strategy for Energy Renovation measure has introduced are;

- the revision of building regulations and energy requirements that apply to the retrofitting and renovation of existing buildings,
- the revision of the energy certification systems,

- the establishment of measures to improve professional training to craftsmen or engineers in the building sector,
- information to building owners, construction companies, financial institutions on how to improve energy efficiency,
- and the development and demonstration of new technologies.

3.5.2 Mandatory Energy Audits in Large Enterprises EED Article 8. (Both service and industry sectors but only large enterprises)

The policy Mandatory Energy Audits in Large Enterprises is an EU-EED related policy and is therefore also present in all EU-countries. Even though this policy serves both the industrial and service sector in Denmark, in the Mure database is categorised only as a measure for the industrial sector.

According to this policy, all large Danish enterprises are required by law to have a mandatory energy audit every four years, carried out by independent qualified experts. The audits comprise a detailed review of the energy consumption of buildings, or group of buildings, and the industrial operations or installations, including transportation (Odyssee Mure, 2014).

3.5.3 Centre for energy savings in small and medium size enterprises (both industry and service sector).

Larger companies are covered by the previously mentioned audits, whereas small and medium sized companies can receive support from the Centre for Energy Savings in Enterprises. This measure has also been mentioned under the industrial sector in Mure. The aim of the centre is to identify and exploit the energy efficiency potential already existing within companies (Odyssee Mure, 2014). The policy has been classed as ‘Information, Education, Training’ and supports ‘voluntary audits’. Top-level management and energy managers are involved, along with information campaigns given by energy agencies and energy suppliers.

3.5.4 Knowledge centre for energy savings in buildings. (all buildings)

Similar to the previous policy, the policy **knowledge centre for energy savings in buildings** has been designed for collecting and disseminating knowledge for methods which can reduce the energy consumption in all types of buildings. The ultimate aim of the measure is to upgrade the skills and the tools that are used by partners within the building sector (Odyssee Mure, 2014).

According to Mure, the knowledge centre’s main tasks are;

- Knowledge; collection, recapitulation and working up of existing knowledge about energy savings.
- Solution and implementation; Recapitulation of existing knowledge and working up of the collected knowledge to tools, standardised energy solutions and package deals.

- Communication; systematic communication of knowledge about specific solutions to reduction of the energy consumption primarily via networking and systematic information and education activities to the target group.

The target group is contractors, architects, workmen, engineers and building constructors within the building industry. Tools, solutions and examples of energy saving efforts are communicated through brochures, guides, newsletters and energy saving calculators all available on an official website.

3.5.5 Energy Efficiency Obligation scheme EED article 7 (All sectors)

Another policy which refers to multiple energy sectors, and still affects the buildings stock of the service sector is the EU-related scheme **Energy Efficiency Obligation (EEO)**. The Energy Efficiency Obligation scheme has been characterised as the main policy of Denmark for realising the targets of Article 7 (NEAAP, 2015). The importance of this policy has been highlighted in a larger study by Sipma et al. (2019).

The scheme is based on a voluntary agreement within a legislative framework with distributors of natural gas, district heating, and electricity. The main characteristic of the EEO scheme is the freedom to choose the methods and the sectors for realising energy savings (figure 6). Energy companies participate in the voluntary agreement and get involved in energy-saving efforts such as providing consumer information, energy audits, and subsidies. (Morten, A. & Petersen, L., 2018). Certainly, the efforts of the utility companies influence the energy demand of end-users and have a large impact on the energy performance of the national building stock.

The information for this policy has been retrieved from the large paper “Comparing energy efficiency policies in the built environment: Learning from each other” (Sipma et al., 2019). Further explanation is provided in this paper.

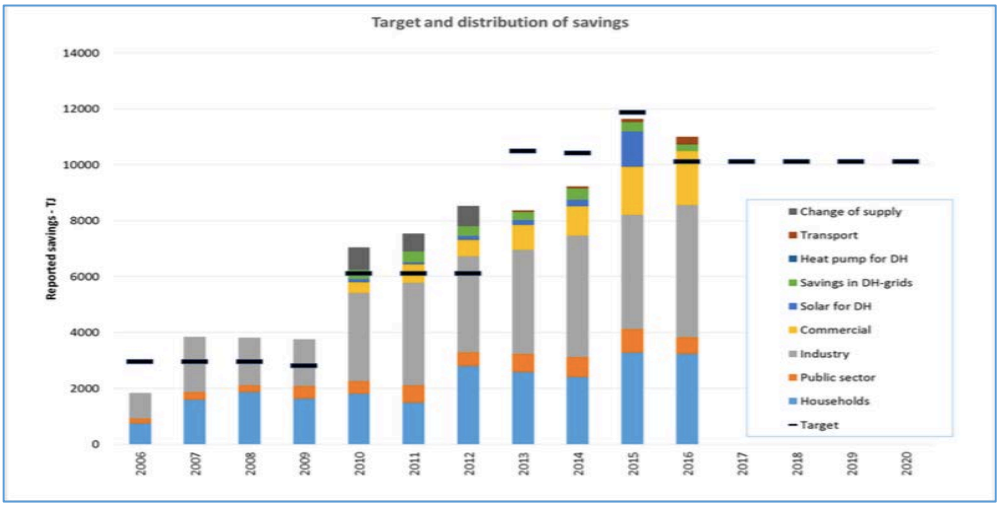

Figure 6 EEOs Targets and Distribution of Savings. (Bundgaard, S.S., Dyhr-mikkelsen, K. & Sommer, T., 2013)

3.6 Evaluation of the Danish Policies

In most of the national reports (NEAAP & DEA reports), there are three different groups of policies. The first group targets private buildings, the second targets public buildings, and the third group targets both public and private buildings and contains “horizontal” measures. In the Mure database the categorisation of policies varies, thus it is difficult to be compared with other papers. More specifically, while the horizontal policies target more than one sector (e.g. both household and services), the Odyssee Mure database evaluates them according to their performance in only one of them.

An exception is the EEO scheme, where scholars have distinguished the evaluation of the policy for each sector. In contrast with the household sector, the evaluation of the EEOs in the service sector is more reliable due to the different methodology that is used. The methodology that is followed for evaluating savings in the household sector is based on estimations, while the methodology for the service sector (commercial and public) is based on calculations (Sipma et al., 2019).

3.7 Chapter Conclusion

Similar to the Danish household sector, only a few energy-efficiency measures target the Danish services sector exclusively. Two out of three measures lack a semi-quantitative evaluation while the third one is qualified as low. The two nationally designed energy policies presented above, aim to promote energy efficiency only in public buildings.

Despite the low number of energy efficiency policies, the Danish authorities have implemented several policies which, among others, improve the energy efficiency in the services sector as well. Thus, it is clear that the Danish government implements general measures and do not focus on policies which target specific sectors. Additionally, in Denmark, there is a higher proportion of environmentally-friendly fuels in use compared to twenty years ago.

This general energy efficiency strategy seems to be successful for the services sector, as energy consumption has remained almost steady over the last twenty years, despite the fact the total floor area of the building stock is increasing.

4 German Service Sector Results

4.1 Country Overview

Germany has implemented a comprehensive energy strategy named Energiewende, which has helped the country to become one of the most energy efficient economies in the world. The national target is to reduce the energy consumption by 20% by 2020 and 50% by 2050 (NEAAP, 2017).

The built environment in Germany accounts for one-third of the total national energy consumption. Approximately 40% of this energy is used in non-residential buildings (Fraunhofer, 2015). Germany has been characterised as having one of the world's largest economies, as the country has the fourth largest economy by nominal GDP in the world (Statistic Times, 2019). The services sector is of fundamental importance to the German economy, employing over two-thirds of the German workforce and accounting for approximately 70% of national GDP (Business Development Germany, 2019).

Although the Danish GDP is increasing (Appendix C), the total floor area of the services sector has remained at similar levels since 2001. The trend line shows a slight increase of 5% in the last fifteen years (Odyssee-Mure). The number of employees in the service sector has increased by 18% in the last years (figure 7).

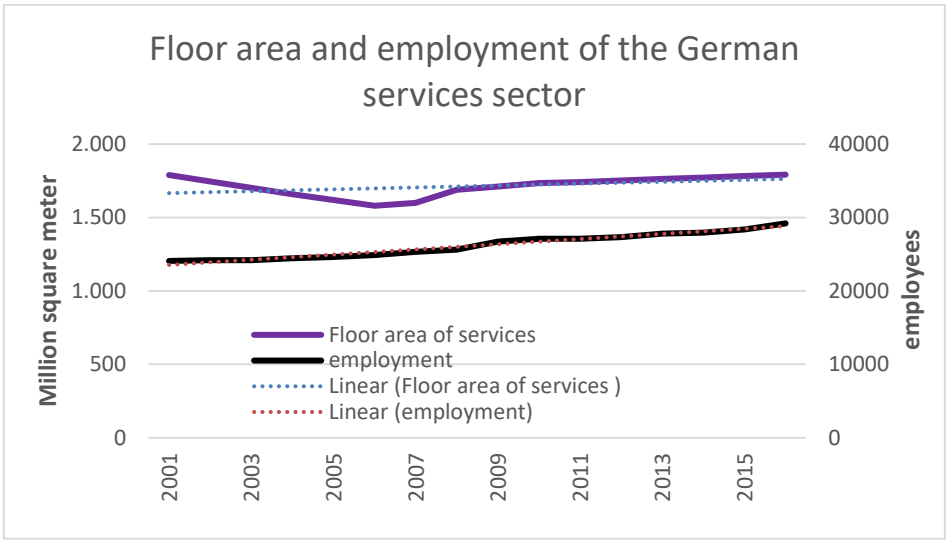

Figure 7. Floor area and employment of the services sector. Germany (source: Odyssee-Mure)

4.2 Energy Consumption in the German Service sector.

Germany had a comprehensive energy-saving strategy in place even before the Energy Efficient Directive was adopted, which has helped to decouple energy

consumption from economic development (NEAAP, 2017). The energy consumption in the services sector remains at the same level as in 1990. Notably, the energy used exclusively for space-heating in buildings associated with the services sector has been reduced by 21% since 2001. From 2001 to 2016, the annual energy consumption for space heating has fluctuated between the values of 600 and 800 PJ.

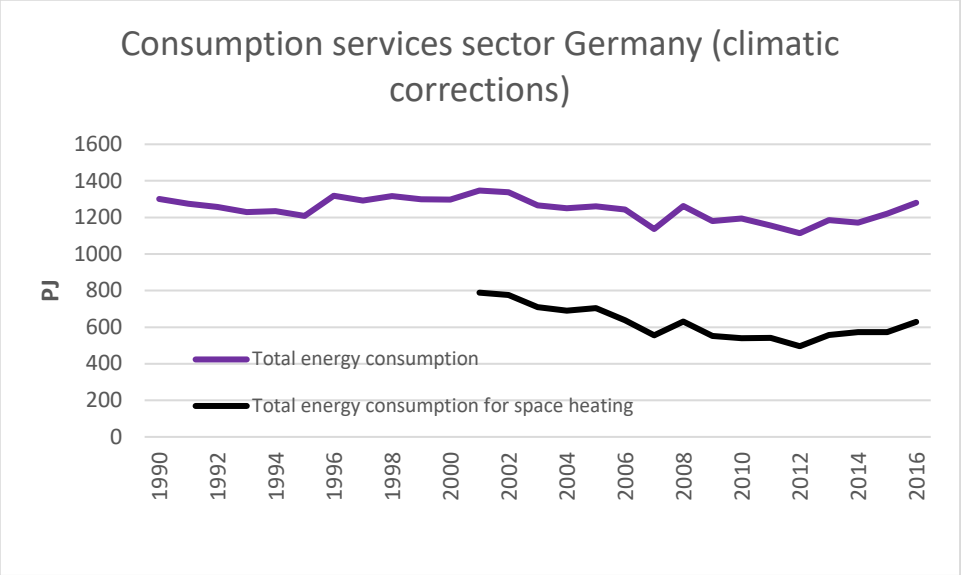

Figure 8. Consumption of services sector. Germany (source; Odyssee-Mure)

In figure 9, both the energy indicators energy consumption per value added and energy consumption per square meter show a reduction in the energy use of the past years. Both intensity lines follow the same pattern, but the reduction in the value added indicator (MJ/euro2010) is larger than in the indicator energy consumption per floor area (figure 9).

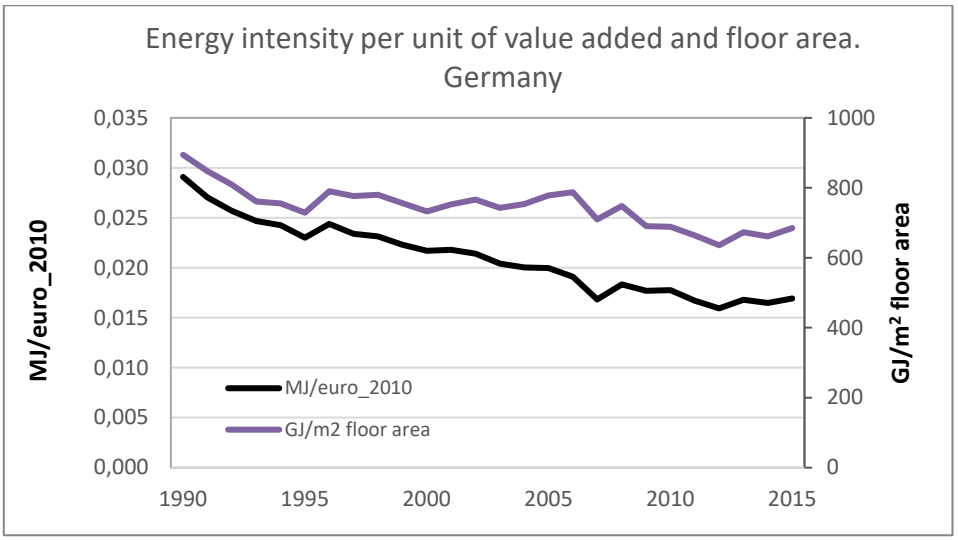

Figure 9. Energy intensity per unit value added and per floor area. Germany (source: own presentation & Odyssee-Mure)

4.3 Consumption by fuel. German Service sector

Back in 1990, Germany used a mixture of fuels, however, in subsequent years the most environmentally friendly fuels have dominated as a result of the implementation of environmental policies. In particular, coal has almost been eliminated and the consumption of oil has decreased. In contrast, the proportion of gas consumption has risen from 20% to 34% since 1990. Additionally, the use of electricity has also grown since 1990. The share of wood disappeared is slightly higher than in the 1990s, probably because of the introduction of new wood-based fuels (e.g. wood pellets).

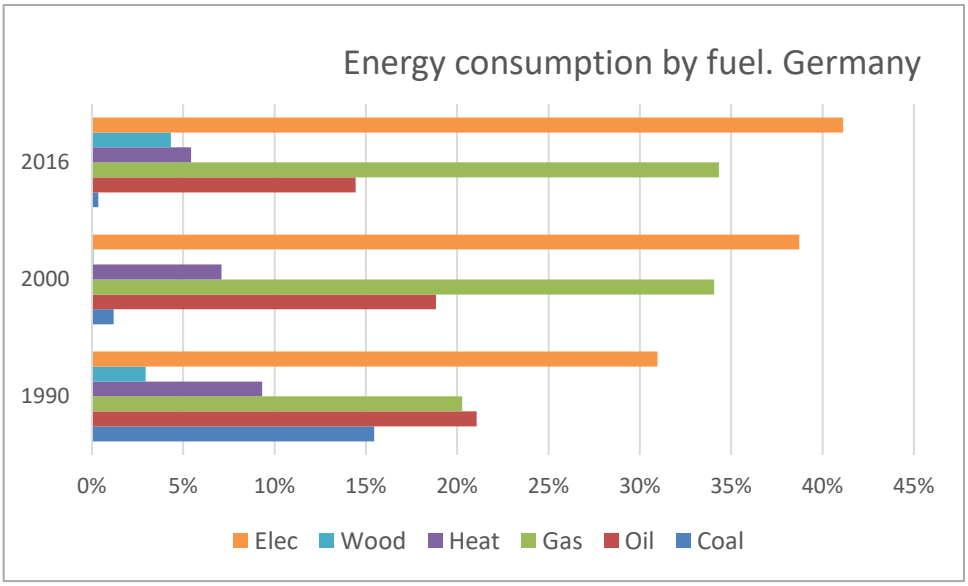

Figure 10. Consumption by fuel; Service Sector (source; own production)

4.4 Current Policies in Germany. Services Sector

Table 3 contains all the 23 ongoing measures targeting the services sector in Germany, according to Mure database. The table has been ordered by impact, followed by type and starting year. The first two measures are EU related and apply to all EU-countries; to both the residential and services sector.

At first glance, it is noticed that Germany implements more policy measures than Denmark, the UK and the Netherlands. However, when we compare this table with what we have found in the residential sector (Sipma et al 2019), it appears that Germany has 7 out of 21 ‘national measures’ (one third) that apply to both the services and residential sectors (indicated with a ‘YES’ in table 3).

Some of these measures were introduced decades ago, and they continue to be used. The most dominant category of measures is the *financial* and *legislative,* but there are also different categories of measures present such as *cross-cutting* and *information*.

Table 3. Service sector Measures. Germany (source: Odyssee-Mure)

	Title	Type	Impact	Present in residential sector?	Starting Year
1	EU-related: Recast Ecodesign Directive for Energy-related Products (Directive 2009/125/EC) - Eco-Design of Energy-using products (Energiebetriebene-Produkte-Gesetz - EBPG)	Legislative / Normative	High	YES	2011
2	EU-related: Energy Performance of Buildings EPBD Recast (Directive 2010/31/EU) - Energy Savings Ordinance (Energieeinsparverordnung - EnEV) 2012	Legislative / Normative	High	YES	2012
3	ERP Environmental Protection and Energy Efficiency Programme (ERP-Umwelt- und energieeffizienzprogramm)	Financial	High		1995
4	Special fund for energy efficiency in SME's (Sonderfonds Energieeffizienz in KMU)	Financial	High		2008
5	Ecological Tax Reform (Energy and Electricity Tax) (Ökologische Steuerreform – Energie und Stromsteuer)	Cross-cutting / Taxes	High	YES	1999
6	KfW Environmental Protection Programme (KfW-Umweltprogramm)	Financial	Medium		1984
7	Market Incentive Programme for Renewable Energies in Heat Market (Marktanreizprogramm für erneuerbare Energien im Wärmemarkt– MAP)	Financial	Medium	YES	1999
8	Heat Power Cogeneration Act (Kraft-Wärme-Kopplungsgesetz)	Financial	Medium		2002
9	Upgrading the CO_2 Building Renovation Programme	Financial	Medium		2015
10	Act on the Promotion of Renewable Energies in the Heat Sector - Heat Act (Erneuerbare-Energien-Wärmegesetz - EEWärmeG)	Legislative / Normative	Medium		2009
11	Smart Metering	Legislative / Informative	Medium	YES	2010
12	Top Runner Strategy	Legislative / Informative	Medium	YES	2016
13	Stimulus programme for the promotion of climate protection measures in commercial cooling installations (Impulsprogramm Kälteanlagen)	Financial	Low		2009

	Title	Type	Impact	Present in residential sector?	Starting Year
14	KfW investment programmes in municipalities and social facilities - IKK Energy-Efficient Renovation (IKK Energetische Stadtsanierung Energieeffizient Sanieren)	Financial	Low		2009
15	KfW investment programmes in municipalities and social facilities - IKU — Energy-Related Urban Renewal — Energy-Efficient Renovation (IKU Energetische Stadtsanierung Energieeffizient Sanieren)	Financial	Low		2009
16	KfW-IKK-Programme for Energy Efficient Urban Lighting (KfW-IKK-Programm zur energieeffizienten Stadtbeleuchtung)	Financial	Low		2009
17	Small-Scale Combustion Plant Ordinance (Kleinfeuerungsanlagenverordnung)	Legislative / Normative	Low		1988
18	Environmental Label "Blue Angel" (Umweltzeichen "Blauer Engel")	Information / Education / Training	Low	YES	1977
19	ECO Management and Audit Scheme (EMAS)	Information / Education / Training	Low		1996
20	Energy Efficiency Campaign (Initiative EnergieEffizienz)	Information / Education / Training	Low	YES	2005
21	Mission E	Information / Education / Training	Low		2012
22	Voluntary Agreement on CHP (Selbstverpflichtung der Wirtschaft zur Förderung der KWK)	Co-operative Measures	Low		2001
23	Energy Efficiency Strategy for Buildings	Legislative / Normative	Unknown	YES	2015

The majority of high-impact measures are categorised as *financial* and *legislative*, just as with the residential sector. Moreover, many low-impact measures (mainly under the categories of information/education/training) have been implemented for an extended period, as for instance the *Environmental Label "Blue Angel"* and the *Small-Scale Combustion Plant Ordinance* which were initially introduced in 1977 and 1988 respectively. It is interesting from a policy-making perspective to see that although informing and educating measure #18 has a low impact, it still is used.

One-third of the policies targeting the service sector have been used also for improving the energy efficiency of buildings in the household sector. The Odyssee-Mure database place some of the measures in both sectors.

Further analysis will be provided only for measures qualified as high-impact by the Mure database. Therefore, in the next paragraphs, the five high-impact measures that are currently implemented in Germany will be described[3]. The first three of them are nationally implemented, and the last three are EU-related measures.

4.4.1 High Impact Measures, Services Sector

1. The **Ecodesign Directive for Energy-related Products** aims to establish a framework which sets specific requirements for energy-related products. The Energy-related product measure replaced an already existing national measure known as "Energy using Products' in 2011. The new directive specifies three main issues. Firstly, the harmonisation of laws and distinctive measures related to eco-design among EU member states in order to promote fair competition within the European Union. Secondly, the identification of major sources of negative environmental impacts caused by products used within Europe. Thirdly, the directive applied for products which may use, transfer or measure energy.

2. The **Energy Performance of Buildings EPBD** (in German abbreviated as EnEV) is an EU policy categorised in the MURE database as legislative. This EU directive provides minimum requirements for the energy quality in new buildings and major renovations for existing buildings (e.g. envelope, systems engineering). The Energy Savings Ordinance is not targeting the services sector exclusively, as it provides energy requirements both to residential and non-residential buildings. This measure has been initially implemented in 2009 and revised in 2014. The impact of the Energy Savings Ordinance measure has been calculated in the German NEEAP reports. In all three NEAAP evaluations, the measure had a high-impact on the energy efficiency of the built environment.

3. The "**ERP Environmental Protection and Energy Efficiency Programme**" measure provides financial support for the promotion of energy efficiency measures since 1995. The financial support covers investments in the areas of buildings and technology (envelope, machinery, process cooling and heating) implemented by SMEs.

   More specifically, the measure is divided into two sub-programs. Program A supports investments that target the protection of the earth, water and air, energy conservation and the use of renewable energy, irrespective of the company size. According to Odyssee Mure database (2014), Program B supports investments which aim to significantly influence the energy efficiency of small and medium-sized enterprises (by 20% for replacement investments and 15% for new investments).

   The financial support of this measure is provided by means of long-term, very low-interest loans. The loans cover from 50% of the investment costs up to 100%. The maximum amount is two million.

4. The **Special Fund for energy efficiency in SME's** was introduced in 2008 and was designed to promote energy efficiency in small and medium-sized

[3] The fourth and sixth high-impact measures are referred to the same EU directive of 2008 revised and updated in 2012.

companies. This financial measure covers two different energy efficiency transition stages. In the first stage, financial support (up to 50%) can be provided for supporting energy-efficient consultancy by independent actors. In a second phase, the fund supports the resulting investments for exploiting the energy potential of SME's. The fund is provided in forms of low-interest loans within the Energy Saving Program[4] (ESP).

5. The **Ecological Tax Reform (Energy and Electricity Tax)** is implemented in 1999 and categorised as a cross-cutting measure. The ecological tax reform measure is in practice a raise in the taxes for non-renewable energy sources. By using this measure the German government aims on the one hand to eliminate the use of fossil fuel energy, and on the other hand to create jobs and decrease the unemployment (Odyssee Mure, 2014).

   Since the Ecological Tax Reform measure is relatively old, it is reformed and reshaped several times over the last 15 years. More specifically, many fundamental changes have been applied to the measure in order to adapt to the recent energy trends. For the explanation of this measure, it is should be mentioned that the tax reductions are starting to apply from specific energy consumption amounts per carrier (base amount). The above-mentioned changes have influenced the base amount and consequently the revenue as well.

   The revenues from the Ecological Tax Reform return in full to the taxpayers. In that way, the German government will achieve the second aim of the measure which is to increase employment opportunities. Thereby, the revenue is used for reducing the statutory pension contribution and decrease the labour cost (Beuermann et al., 2006).

   The measure has partially achieved its aim and has considerably changed the mixture of fuels over the last decades. Gas and electricity, which are considered more environmentally friendly have dominated in the fuel pie of 2016. However, it is not clear if the change in the fuel share has been achieved only as a result of the Ecological Tax Reform measure.

   Several evaluation studies (see on Mure description) have indicated that the Ecological Tax Reform measure has contributed to the reduction of CO_2 emissions by 2-3% in comparison with a scenario lacking an eco-tax policy.

4.5 Other policies in Germany

Some of the measure's titles in table 3 include the abbreviations KfW (Kreditanstalt für Wiederaufbau) which is related to one of the three biggest banks in Germany owned by the Federal Department of Germany. The KfW Group has committed substantial amounts of money (47 billion in 2014), for the promotion of housing and environmental protection. KfW offers financial supports and promotes investments by SMEs serving to protect water, air and the soil and the use of energy efficiently. Under this area the following programmes are available.

[4] The Energy Saving Program, and its importance is briefly described in the "Other Aspects of Policy" chapter.

- ERP Environmental Protection and Energy Saving Programme
- KfW Environmental Protection Programme
- BMU Programme for the Financing of Demonstration Projects
- Programme to Promote Renewable Energies.

The KfW group offers large building retrofit programs and supports building owners (in the household commercial or industrial buildings) who aim to undertake measures more ambitious than what just the EPBD-related code requires (Young et al., 2014).

4.6 Evaluation of the German policies

The policy data that has been presented in the above section has been extracted from the Odyssee-Mure database. The German partner responsible for inputting data into Mure is Frauhonfer Institute.

After research into the evaluation of the energy policies included in the Mure database, the impact evaluation of the German services sector measures can be characterised as inconsistent, because there is no specific method or approach that has been followed. For instance, the impact of the Ecological Tax Reform measure has been estimated by plural ex-post evaluation studies based on economic indicators, while the impact of the EU-related measure Energy Saving Ordinance has been estimated by some ex-ante evaluations based on assumptions (Odyssee-Mure, 2014)

4.7 Chapter Conclusion

According to GDP figures, Germany is one of the world's largest economies. The services sector plays a significant role in the economic development of the country. The total energy consumption in the German services sector has remained steady, whilst the energy used for space heating has decreased in past years. Despite the fact that the number of employees in German services sector has increased, the floor area has remained constant.

In total, the German government has implemented and adopted more energy-efficiency measures related to the services sector, than all the other three compared countries. The German agenda consists of six high-impact measures targeting the services sector, mainly categorised as financial and legislative. Moreover, several measures classified as educational and informational have been used the last years, although they have been qualified as low-impact.

All the national high-impact measures in the services sector consist of financial incentives. In particular, the EPR Environmental Protection and Energy Efficiency Programme and the Special Fund for SMEs seem to be two of the most important measures which have helped Germany to realise energy efficiency in the building stock of the services sector. The KfW Group, and therefore the German government, has shown strong support for the realisation of energy-savings by providing low-interest loans for energy renovation and the retrofit of commercial, residential, and

industrial buildings. In addition, the Ecological Tax reform has contributed to the transformation of the fuel mixture and the overall development of_energy-efficient fuels.

To conclude, Germany had already decoupled economic development from the energy consumption decades ago. Several measures which mainly consist of financial incentives have contributed to the realisation of energy efficiency without restricting the development of the services sector.

5 Discussion

5.1 Energy consumption and CO_2 emissions comparison

The comparison of the energy strategies proved to be challenging, as the size, the population and the economy of the two countries differ substantially. The total floor area of the services sector in Germany is approximately ten times larger than the total floor area of the Danish services sector. Furthermore, the German GDP is eleven times higher than the Danish GDP.

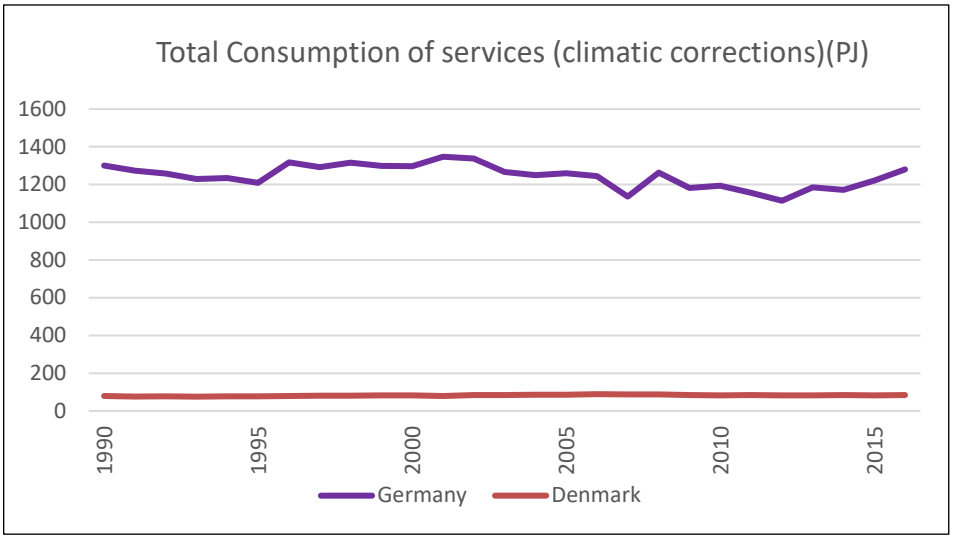

Figure 11. Total energy consumption of services. Comparison (source: Odyssee-Mure)

The energy consumption in the services sector for both countries has remained steady since 1990. The amount of energy that is consumed in the Danish services sector is by far less than the energy that is used in the German Service sector due to the difference in the size of the two countries (figure 11). Since this research investigates the energy consumed in a building level, it would be more accurate to compare the energy consumption in the services sector per unit of floor area.

Figure 12 aims to harmonize the substantial differences in the size of the two countries and provide a more accurate calculation of energy consumption patterns. Both countries have managed to decrease the energy consumption per square meter since 1990.

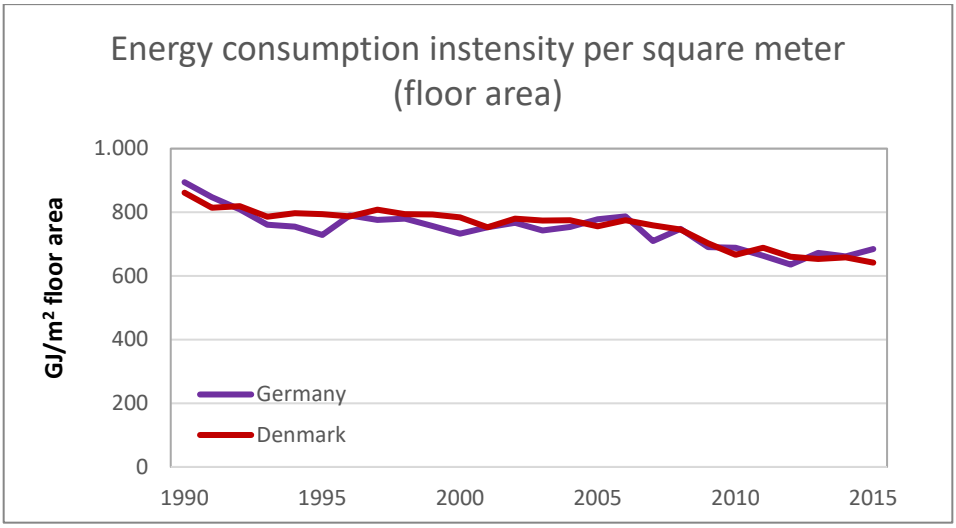

Figure 12 Energy consumption per square meter. Comparison (source: Odyssee-Mure)

The services sectors of both Denmark and Germany have switched to less polluting fuels (figure 4 & figure 10). More specifically, in Demark, the coal and oil-based fuels have been replaced by heat, gas and electricity, while in Germany the percentage of oil-based fuels is subsequently lower in comparison with the previous years (although still higher than in Denmark). The replacement of conventional fuels has stimulated the reduction of CO_2 emissions in the services sector of both countries.

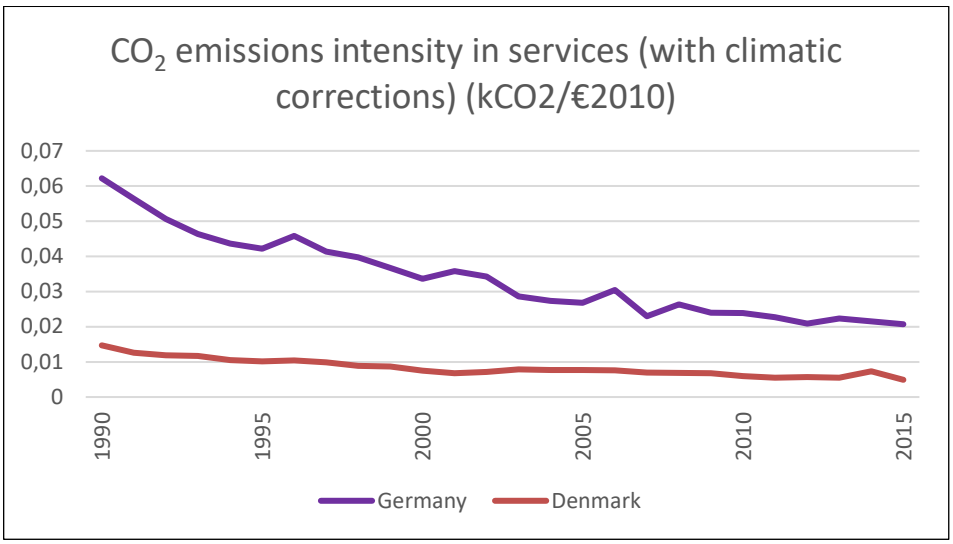

Figure 13. CO_2 emissions intensity in the services sector. Comparison (source: Odyssee-Mure)

Figure 13 presents the reduction in the CO_2 emissions per unit of added value. The line of Germany (purple) represents a rapid reduction of CO_2 emissions. However, the CO_2 intensity in Denmark is still lower than in Germany, following the very low CO_2 emissions trends of the household sector. It should be mentioned that the CO_2

emissions of a country reflects on the overall energy system and not on a specific sector.

5.2 Policies and methods in the compared countries and their impact

The two case study countries vary greatly when it comes to the number of energy policies implemented for their services sector. On the one side, Denmark implements only three measures and all of them lack either a semi-quantitative evaluation or categorisation. On the other side, Germany implements twenty-seven energy measures which aim to improve the energy efficiency in the services sector, and six of these are semi-qualified as high-impact.

The German government has financially supported the improvement of the energy efficiency of the service sector by offering a variety of financial schemes through the central bank KfW. In Denmark, the energy efficiency improvements have been focused only on the publicly-owned buildings. The privately-owned buildings of the Danish service sector have been targeted by general (cross-cutting) measures.

It is important to mention that it is hard to evaluate whether the decrease of energy consumption or CO_2 emission in the services sector has been achieved due to the policies that have been implemented in each case study. The services sector consists of a variety of economic activities that include different energy consumption patterns. For instance, tourism services, food and beverage services, schools, universities and logistics services, all entail different energy consumption patterns. Thus, the policies that have been analysed in chapters three and four have a different impact on these services.

6 Conclusion

The Danish services sector consists of only three policies, which target only the publicly owned buildings according to the Odyssee-Mure database. However, it is assumed that several other measures in Odysssee-Mure database are categorised under different sectors, for example the Energy Efficiency Obligation Scheme (EEO) has improved the energy efficiency of privately-owned buildings in the services sector. Furthermore, similar to the household sector, the overall energy transformation towards a greener energy system has enabled the country to decrease the CO_2 emissions across all the sectors. On the other hand, Germany has implemented several financial policies which have supported small and medium enterprises in improving their energy footprint. At the same time, the country has implemented EU-related policies that aim to improve the energy efficiency in the public building stock too.

Both the Danish and the German energy policy agendas for the services sector can be considered as successful. Both in Denmark and Germany, the national economy is growing whilst the energy consumption in the services sector has somewhat decreased or remained steady over the last years. In a comparison between the two countries, Denmark has lower energy consumption and CO_2 intensity than Germany. However, it not clear whether the energy efficiency that has been realised in Denmark is a result of the energy policy agenda targeting the services sector exclusively, or it is the result of a larger effect from the Danish energy system.

Recommendations

The paper aims to shed light on the best energy efficiency policies targeting the building of the Danish and the German service sector. During the research several times the author of this paper faced difficulties in the data collection, as in some cases the compared countries categorise the country's building stock differently. Therefore, it is highly recommended for future research projects to distinguish the national building stock differently.

Nonetheless, even though the Odyssee-Mure database proved to be a useful tool which provides the majority of data in this research, the authors of this paper identified several errors and uncertainties within the retrieved data. Therefore, it is highly recommended the improvement in Odyssee-Mure database.

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APPENDICES

Appendix A Glossary

Cogenerated Heat and Power: is an approach for applied technologies where heat that is normally wasted in conventional power generation is recovered as useful energy, which avoids the losses that would otherwise be incurred from the separate production of heat and power.

District Heating is defined as a system which distributes heat in forms of water or steam amongst multiple buildings.

Free riders: A person who benefits from something without expending effort/paying. People who are willing to increase energy efficiency because of the return on investment offered financial incentives to do so.

Horizontal measures according to the National Energy Efficiency Action Plan of Denmark (2017) are policies which targeting both the publicly owned and the private buildings.

ODYSSEE-MURE: The ODYSSEE-MURE contains two internet databases relating to energy efficiency indicators and policies. ODYSSEE comprises quantitative data on efficiency indicators such as energy consumption and CO_2 emissions. The MURE database includes a description and evaluation of the impact of all energy efficiency policy measures at a national and EU level.

Pre-bound effect: suggests that politicians and policy-makers who want to see more such initiatives in a wider range of homes may be over-estimating the benefits, and the rate of pay-back, because their judgements about how much energy those homes consume are already exaggerated.

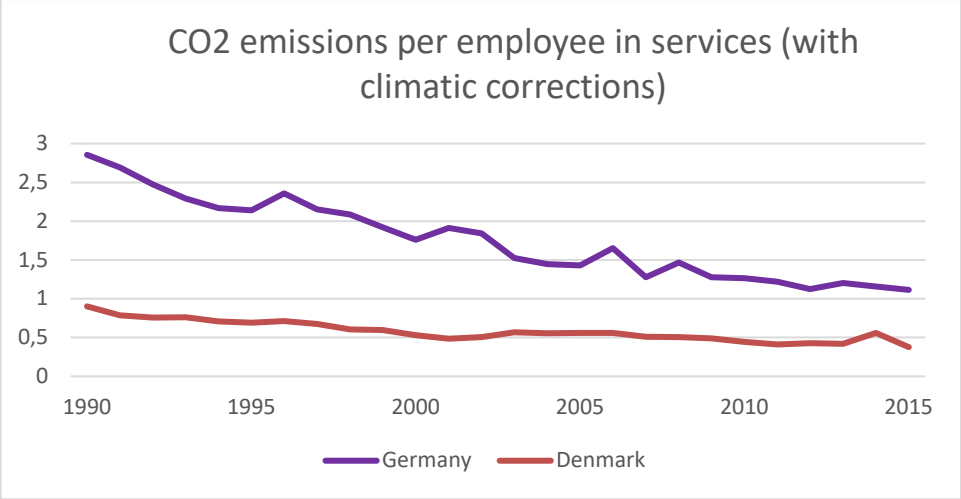
Public Service Obligation Service (PSO): is an energy tariff paid by the consumers via its electricity bill.

Service or Tertiary sector according to the Danish Statistic organisation, comprises all the various enterprises offering knowledge and information instead of goods (Statistik Demark, 2018). According to Odyssee-Mure database, the service sector is comprised of the eight categories of buildings. (1) Wholesale and retail trade, (2) Hotel and restaurant (3) Private offices (4) Public offices (5) Education (6) Health and social work (7) Other (8) Public lighting.

Specific calculations are used in areas where there is no standard value. These are typically large, integrated projects in commercial enterprises or public institutions.

Value Added: usual mode of measurement of the net output of a branch or sector in monetary units; the value added equals the difference between the gross output and the value of inputs; the value added can be measured at **factor cost** or at **market prices.**

Appendix B


CO2 emissions per employee in services (with climatic corrections)
3
2,5
2
1,5
1
0,5
0
1990
1995
2000
2005
2010
2015
Germany
Denmark

Appendix C

National GDP figures for both countries.

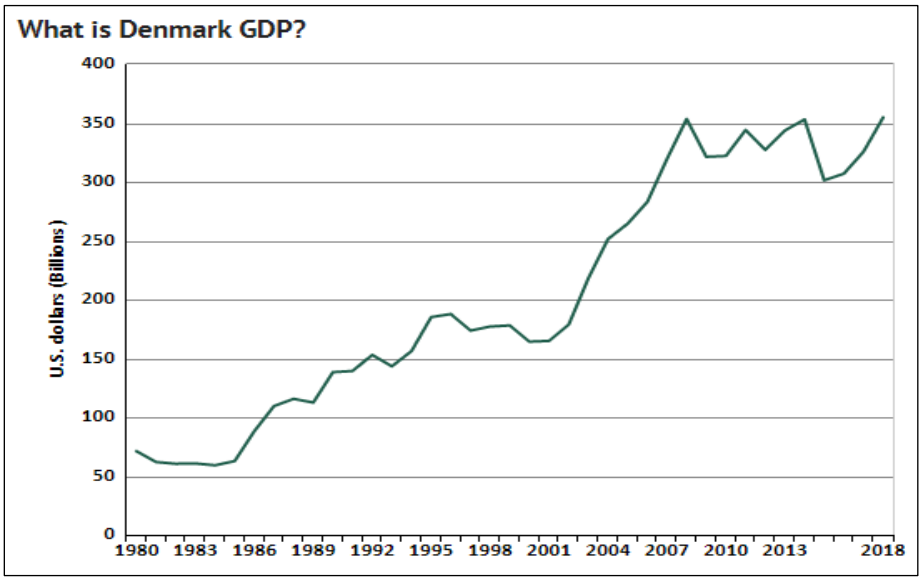


Figure 14 National GDP Denmark.
(source: Knoema, 2018. online at https://knoema.com/atlas/Denmark/GDP)

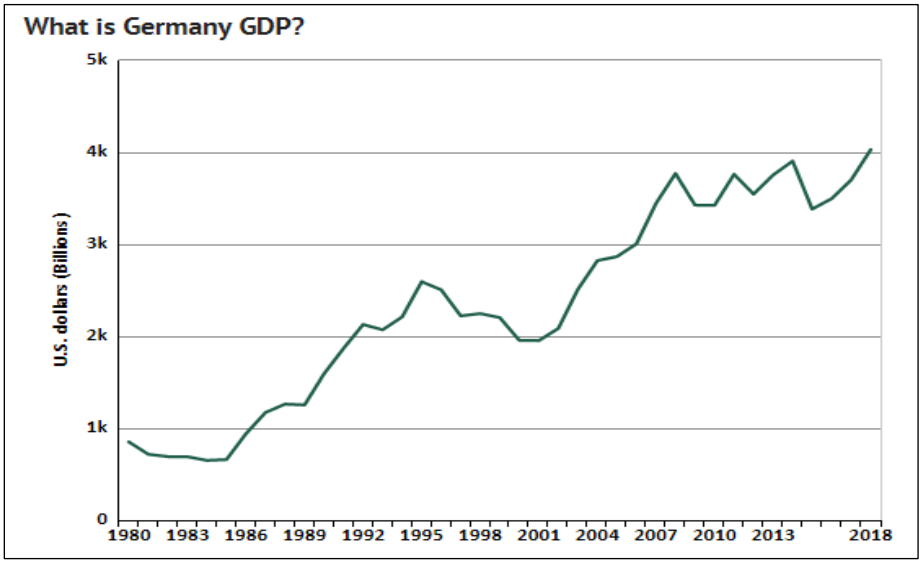


Figure 15 National GDP Germany.
(source: Knoema, 2018. online at https://knoema.com/atlas/Germany/GDP)