Decarbonisation and the Economy

An empirical analysis of the economic impact of energy and climate change policies in Denmark, Sweden, Germany, UK and The Netherlands

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pwc

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Our scope and access to information

Our scope

The European Climate Foundation has commissioned PwC (PricewaterhouseCoopers Advisory) to perform a study on the impact of energy and climate policies on carbon emissions and a wider economy in five countries – Sweden, Denmark, Germany, The Netherlands and The UK.

The study aims to qualitatively assess the impact of energy and climate policies on the economy, given a time period between 1970 and 2011-2012. At a high level, we analyse historical data on heat and power production, fuel mix and consumption patterns in households, the service sector and industry (includes construction). The transport sector is excluded from the analyses, so general conclusions have to be treated with caution as it may not represent all aspects of decarbonisation in countries.

We accept no liability (including for negligence) towards any party other than our client or for any other use of this report for which it is intended.

Access to information

We have performed desk research and carried out interviews with industry experts. The availability and accessibility of information varied per country. So case studies may differ in the level of detail it contains or the information may not always be perfectly comparable.

At a glance

When economies are decarbonising…

Despite general trends in the market (a concern for energy security, climate change, competitiveness and affordability), governments in the countries we studied (Denmark, Sweden, Germany, UK and the Netherlands) chose different policy paths to respond to these developments. Different domestic conditions and deep-rooted political visions determined these choices about energy efficiency and changes in the fuel mix. So clearly, if economic growth is decarbonising, this can take different shapes.

Historical analysis of energy and climate policy measures revealed that it took financial resources and political will to reduce carbon emissions.

Decarbonisation can bring economic benefits too. But as countries are different in many aspects, adequate policy measures should be adopted. There is no single energy policy design that fits all. On the right hand side, we outline the main takeaways, which we observed across the countries analysed.

01 Aggregate investments in low-carbon power and heat production increase if a country adopts a long-term policy vision and embeds a local ownership of renewables

Investments in low-carbon solutions, especially in renewable energy sources, require a continuous financial support in the early stages as initial investment costs are generally higher than those of conventional energy production. Investments in renewables may also be limited as some countries are facing a so-called path dependence, when infrastructure choices once made determine country's energy and carbon intensity for years to come. Besides financial support, local ownership of small-scale renewables can play a very important role. It has been a key success factor to expand renewables in Denmark and Germany.

02 Renewables require subsidies, which are often financed by higher taxation on energy. But industry's competitiveness can be protected

Renewable energy expansion was largely stimulated by feed-in subsidies or by creating green certificate markets. Fossil fuels and/or carbon emissions were taxed to stimulate this shift even further. In the countries studied, energy-intensive industry was exempted from this additional tax burden, often combined with incentives to increase energy efficiency. This approach shields an investing country from adverse effects on its competitiveness during the transition to a low-carbon energy system. But these tax exemptions lead to a shift of the burden to domestic consumers, who face an increasing energy bill.

03 Targeted industrial policy that is aligned with energy policy's goals can foster economic growth

A significant expansion of renewables requires substantial funds and R&D efforts. But in this case, initial investment costs can create long-term benefits. New industries could emerge if the technology is largely created locally. And first movers can also become market leaders.

Energy efficiency improvements can contribute to economic growth too. Not only can the resulting energy savings partially offset higher energy costs, but also domestic demand for energy efficiency measures can contribute to local employment creation.

Executive summary

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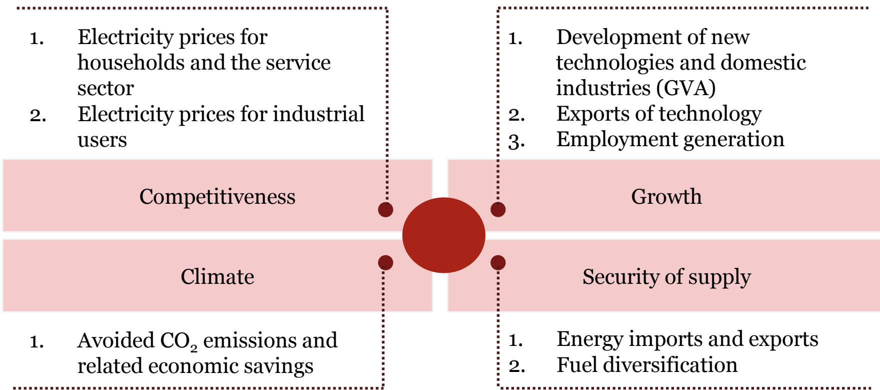
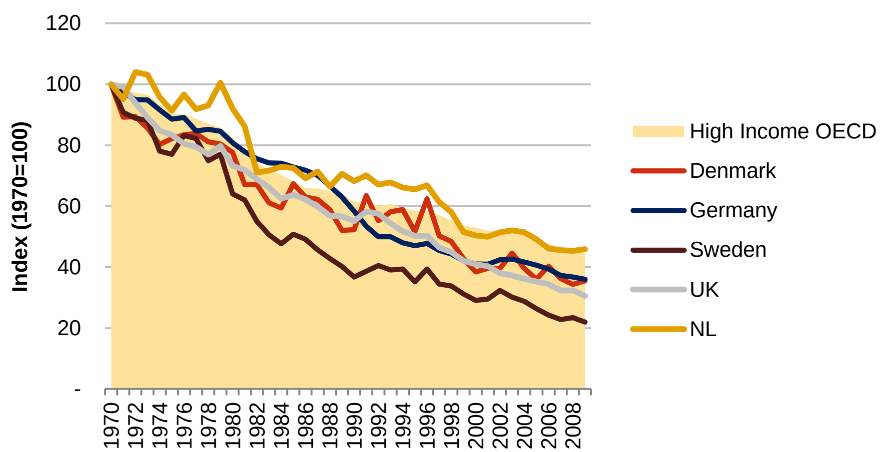
This study assesses the impact of decarbonisation on the wider economy using empirical evidence. We chose five countries (Denmark, Sweden, Germany , UK and the Netherlands) to demonstrate this impact. They have diverse domestic conditions and made different policy choices, from which we can learn.

Parameters of the economic impact of decarbonisation



Source: PwC

CO2 emissions per GDP (indexed), 1970-2009



Source: The World Bank

What are the economic effects of decarbonisation?

There is a near unanimous agreement amongst the global community that carbon dioxide (CO_2) emissions must be reduced to avoid dangerous climate change*. Resulting climate and energy policies not only impact CO_2 emissions but also influence the economy through energy prices, security of energy supply and even economic growth.

Whether decarbonisation reduces or enhances welfare is a question often raised in discussions about climate policies. Such discussions often draw on modelling studies of the economic impact of these policies. Empirical evidence of the economic impact in countries already decarbonising their economies could also serve as valuable input in these discussions. This study aims to provide such analysis.

Countries with relevant energy and climate policies

We assess energy and climate policies and resulting economic impacts (*please refer to the above-left figure for the framework*) for five countries – Denmark, Sweden, Germany, The Netherlands and the UK. With an exception of the Netherlands, all countries outperformed the average high-income OECD country in decarbonisation rates (*please refer to the adjacent figure*) **. All countries have a long history of relevant energy and climate policies, so the analysis can provide valuable lessons for countries themselves or other countries that need to catch up with decarbonisation progress. The Netherlands and the UK case studies can also serve as a good learning basis for countries that are resource-rich and owning large fossil fuel resource reserves imposes a challenge for developing decarbonisation-oriented energy policies.

Fuel use for producing heat and electricity is one of the main sources of carbon emissions. In this study we focus on policy developments in electricity and heat production and end-user efficiency related to electricity and heat use.

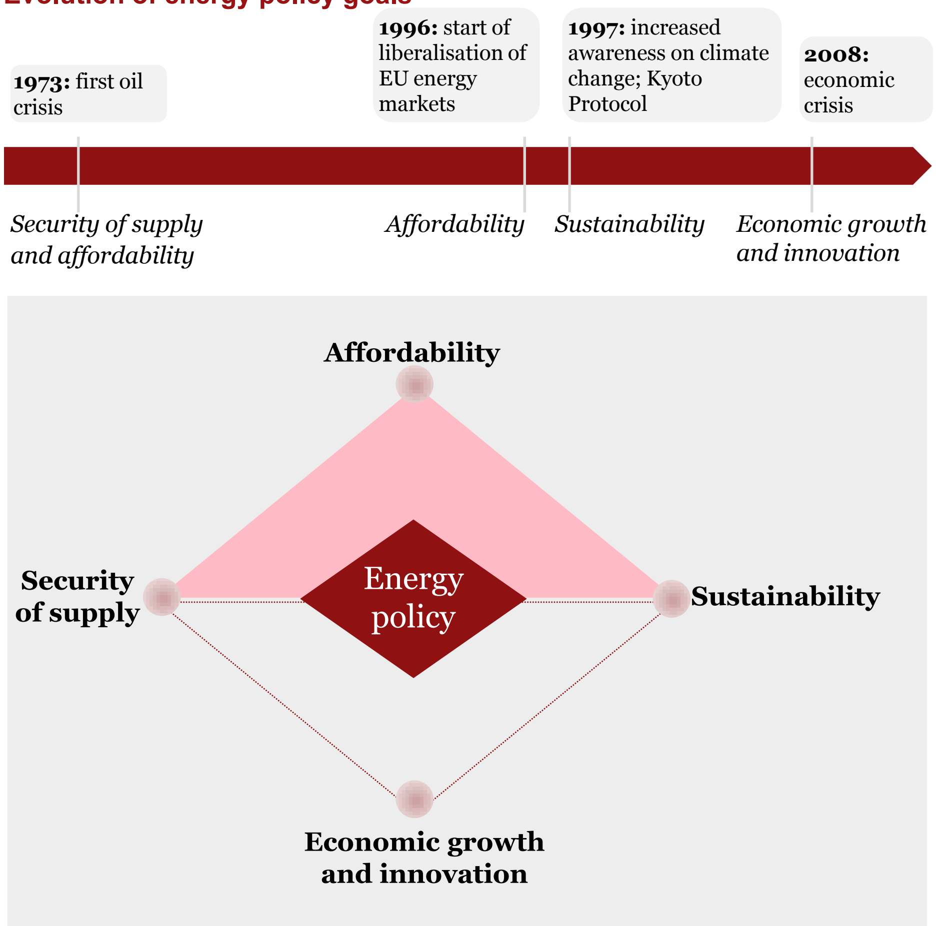
* To have a 50% chance of keeping the global mean temperature rise below 2°C relative to pre-industrial levels, atmospheric GHG concentrations must stabilise below 450ppm (EU Climate Change expert Group 'EG Science, 2008, *The 2°C target).*

** We look into production-based emissions as they are directly affected by country's policy choices. The ranking of countries could differ if consumption-based emissions were analysed.

The aims of energy policies have varied over time. New goals have emerged in response to national economic circumstances, and global challenges and events. This has made energy policy development an increasingly complex undertaking.

PwC view *– Decarbonisation can be a specific goal as well as a side effect of other policy goals as these goals interact. Economic growth is influenced by these goals as energy is necessary to fuel economic activities and a transition to a low carbon energy system stimulates innovation and the rise of new industries.*

Evolution of energy policy goals



Source: PwC analysis

The power of crisis

Different crises and events have led to new energy policy goals being developed *(please refer to the figure for the evolution of energy policies).*

Oil crises in the 1970s affected many countries and resulted in policies to reduce dependence on oil by proactively searching for new energy sources, scaling up domestic energy production and increasingly focusing on energy efficiency. Energy security and affordability became the main focus of energy policies at that time. Stabilising or, in some countries, decreasing carbon emissions were a side effect of the resulting policy choices.

Similarly, the economic climate in the 1990s raised a need for affordable energy without harming the competitiveness of increasingly open economies. Many European power and gas markets were liberalised and opened to competition in order to increase cost effectiveness and lower prices for consumers.

At the same time, growing concerns about climate change and pollution led the countries in our study to reconsider their energy strategies. These were reflected in targets to reduce carbon emissions.

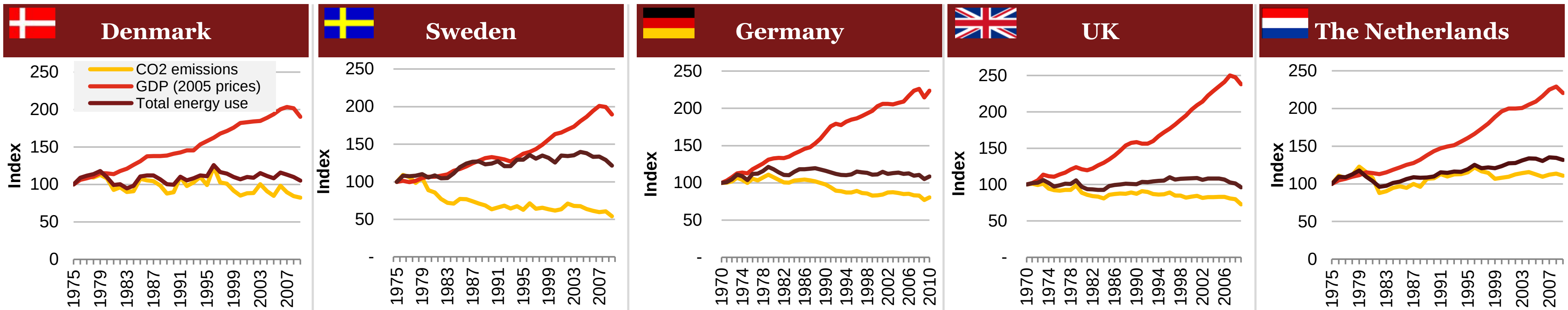
The recent economic downturn and financial crisis call for new ways to generate growth. Coupled with sound industrial policies, energy and environmental policies can give rise to new domestic industries that produce new energy technologies, as demonstrated later in this summary.

Complexity due to higher number of interacting goals

As the above discussion shows, the number of goals of energy policy has increased over time. Moreover, the various goals influence each other. This gives energy policy-making an increasingly complex context. Our analysis shows that before specific decarbonisation policies were developed, emissions were decreasing, partially driven by other energy policy goals (increasing security of supply or affordability).

All five countries have experienced economic growth decoupled from CO_2 emissions and energy use. As in most countries, decarbonisation intensified in the 1990s. But the pace and the magnitude of decoupling differ by country due to different policy goals and local circumstances.

CO2 emissions, energy use and GDP in 1970-2010



Denmark	Sweden	Germany	UK	The Netherlands
CO_2: absolute decoupling **Energy use**: relative decoupling	**CO_2**: absolute decoupling **Energy use**: relative decoupling	**CO_2**: absolute decoupling **Energy use**: absolute decoupling	**CO_2**: absolute decoupling **Energy use**: relative decoupling	**CO_2**: relative decoupling **Energy use**: relative decoupling

Source: The World Bank; PwC analysis

Decoupling of CO_2 emissions in all five countries

CO_2 emissions were decoupled from GDP development all countries in our study. This resulted from changes in fuel mix and energy efficiency due to energy and climate policies, as well as structural changes in the economy and economic cycles.

There are two types of decoupling — relative and absolute. Absolute decoupling occurs when CO_2 emissions are stable or decreasing while the GDP is growing. Relative decoupling refers to the condition where the growth rate of CO_2 emissions is positive, but less than the growth rate of GDP.

Our high-level analysis of GDP growth, energy use and carbon emissions in Denmark, Sweden, Germany, UK and The Netherlands shows that in the period 1975-2009 all countries decoupled their growth from carbon emissions in absolute terms, except for the Netherlands which achieved relative decoupling. On average, a 1% GDP increase has coincided with a 0.5-0.9% decrease in carbon emissions (*please refer to the table below*).

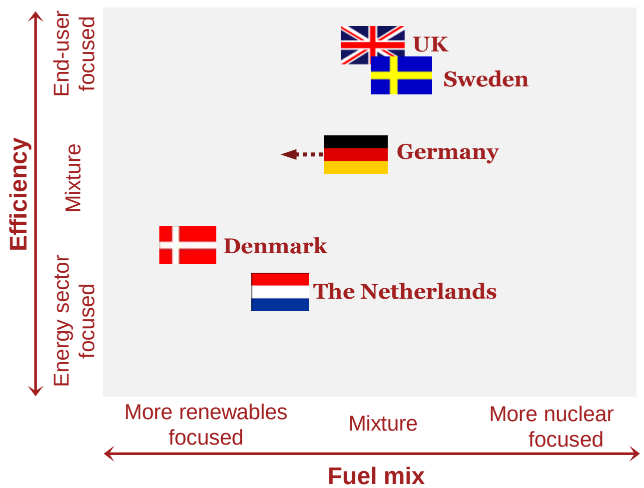
Decoupling became significantly stronger after 1990, when decarbonisation became one of the goals of energy policies. Decoupling of energy use from GDP, driven by structural economic change as well as energy policies was an important driver for carbon emissions being decoupled. Energy use relatively decoupled from economic growth in Sweden, UK, the Netherlands and Denmark, and absolutely decoupled in Germany.

Correlation	Denmark	Sweden	Germany	UK	NL
GDP and total energy use	0.3	0.7	(0.4)	0.6	0.9
GDP and CO_2 emissions	(0.5)	(0.7)	(0.9)	(0.7)	0.4

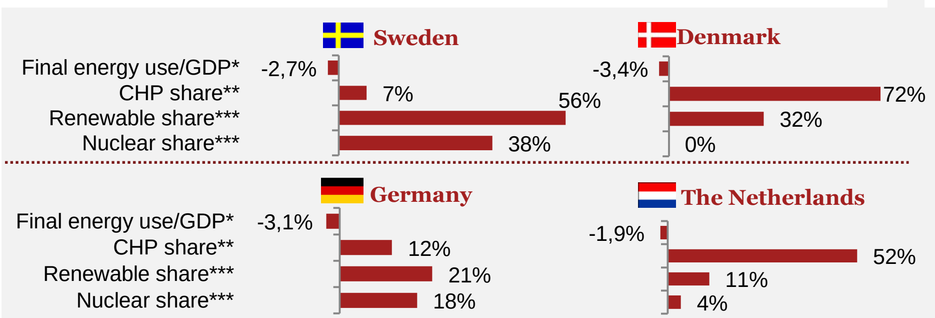
The difference in decarbonisation pace, magnitude and costs depends on countries' energy policies. The main variables for these policies were fuel mix choices (renewable vs nuclear energy) and efficiency measures (energy sector's vs end-user efficiency).

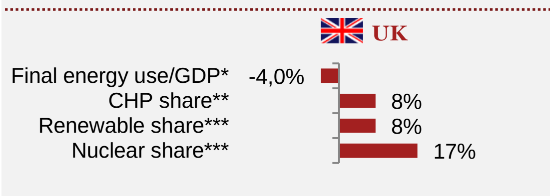
PwC view *– Although autonomous developments (structural changes in the economy or consumer demand) can drive decarbonisation, policies clearly influence the changes in the fuel mix and efficiency, stimulating decoupling of CO_2 emissions and economic growth.*

Decarbonisation profiles



Source: PwC analysis





*Annual change in energy intensity for end users, measured as final energy use (TWh) per €1,000 GDP, measured over the period 1990-2011;
**CHP share in total power production (2011);
*** Share in generated electricity (2011)

Ways to decarbonise the economy

Decarbonisation can be stimulated by the following:

1. *Shifting to a low carbon fuel mix*: from fossil fuel-based to an increased renewables-based fuel mix, an increased nuclear-based fuel mix, or a combination of both.
2. *Decreasing energy use*: focusing on the energy sector's efficiency, end-user efficiency, or a combination of both****. The latter effect might be reduced due to the rebound effect as savings free up resources for more consumption.

Opportunities to foster decarbonisation depend on political agreements and public support (e.g. possible public opposition to nuclear power). Limited domestic resources can be another constraint.

Each path determines energy production costs

Choices made in fuel mix and energy efficiency differ among countries.

Sweden's decarbonisation can be characterised by a fuel mix change towards nuclear (since 1970s), which complemented large hydro power generation. Sweden did not focus on efficiency in the energy sector as much as Denmark.

Denmark decarbonised its economy by using renewable energy and natural gas, instead of coal and oil, and increased energy efficiency through district heating and CHP. Nuclear was not an option as it was banned.

Germany decarbonised by increasing the use of both nuclear and renewable energy. As nuclear is phasing-out, renewable energy sources will become increasingly important. End-user energy efficiency have been central too.

The *Netherlands* mainly focused on increasing energy efficiency through CHPs. Nuclear energy has not been utilised much.

The *UK*, similarly to Sweden, relied more on end-user efficiency and less on CHPs, and used both nuclear and renewables in its fuel mix.

****Fuel use for producing heat and electricity is one of the main sources of carbon emissions. In this study we focus on policy developments in electricity and heat production and end-user efficiency related to electricity and heat use.

Each country used a number of policy instruments that stimulated demand for and/or supply of renewable energy, as well as efficient energy use. Energy and industrial policies were in some cases coordinated to stimulate the development of domestic industries.

PwC view *– Energy policy leading to decarbonisation can stimulate innovation and therefore economic activities. A mix of long-term supply and demand-stimulating measures, resulting in a domestic market for renewable technology, can create a favourable environment for new industrial activities to arise.*

The value chain of the energy sector and relevant policy measures to stimulate decarbonisation

Value chain	Technology development	Energy production	Energy consumption
Policy measures	Supply-stimulating (technology)	Supply-stimulating (production)	Demand-stimulating
Less carbon-intensive fuel mix	• Technology procurement programmes • R&D investments	• Feed-in tariff • Energy and carbon taxation • Investment subsidies • Energy and carbon taxation	• Obligations to buy renewable electricity • Local ownership obligations • Energy and carbon taxation
Increased energy efficiency	• R&D investments	• n.a.	• Energy and carbon taxation • Subsidies • Low interest loans • Obligations

Source: PwC

Stimulating supply as well as demand…

Decarbonisation resulted from energy policy measures that stimulated both supply and demand for renewable energy and efficiency investments. Supply-stimulating measures focused on stimulating technology development and creating the right incentives for investors to invest in renewable energy production. But demand-stimulating measures were targeted at energy consumers to create the right incentives to switch to renewable energy or invest in energy efficiency measures.

… while protecting the competitiveness of export industries

The combination of obligations to buy renewable energy with taxation to price externalities, or subsidies to improve return on investment, was essential to scaling up renewable energy production. The common practice is to exempt (energy-intensive) industries from increased carbon or energy taxation to protect their competitiveness, especially if a country relies heavily on exports. Often this was combined with incentives to increase energy efficiency.

… and maximising conditions for developing new economic activity

Germany and Denmark have combined industrial policies with decarbonisation goals to generate economic growth. R&D policies combined with the creation of a domestic market for renewable technology contributed to the rise of an innovative renewable technology industry in these countries. A long-term (technology) demand-stimulating policy approach was crucial to create a stable domestic market. This stimulated investment in wind and solar. These industries were able to gain experience in the domestic market and develop a technological competitive advantage, making export to other countries, and so further growth of the industry, possible.

Countries that have a limited domestic renewable technology industry, focus on stimulating the use of the least costly renewable energy technologies, while countries with higher stakes in the renewable technology industry stimulate domestic demand for the relevant technology despite its higher levelised cost.

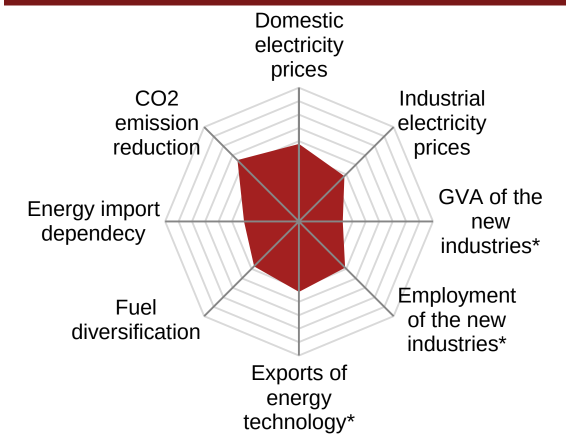
The UK and the Netherlands both discovered large natural gas reserves in the 1950-60s. The discovery clearly shaped their energy markets and policies. Both countries focused on stimulating energy efficiency. Only recently, there is an increased policy effort to stimulate renewable energy.

Other countries were by then well ahead on developing a clean technology industry. But a part of economic effects of renewable energy and energy efficiency are more local (such as construction, services and production of renewable energy). So, even if technologic activity is limited, the implementation and use of energy efficiency and renewable energy measures can still result in increased local economic activity.

Denmark, Sweden and Germany remained open and export-oriented economies, while at the same time showing above-average decarbonisation rates in their peer group. But the degree of economic impact varied with the selected energy policy approach.

Economic impact of decarbonisation in Denmark, Sweden, and Germany

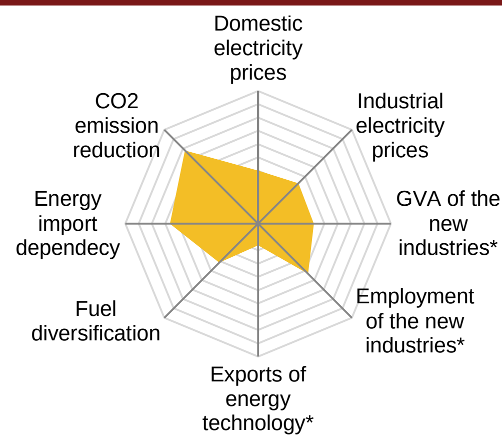
Denmark



Denmark stimulated the growth of renewable energy and energy efficiency industries by investing in R&D and creating a domestic market for technology. These industries are estimated to contribute 1.6% to GVA and 1.5% to employment in Denmark. The stimulation of a domestic market for renewable energy is reflected in the energy prices and, more specifically, in the energy tax burden for consumers: Danish energy prices are among the highest in Europe. But tax exemptions protect the competitiveness of Danish industry.

CO_2 emissions fell substantially and security of supply improved through diversification, with Denmark becoming a net exporter of energy.

Sweden

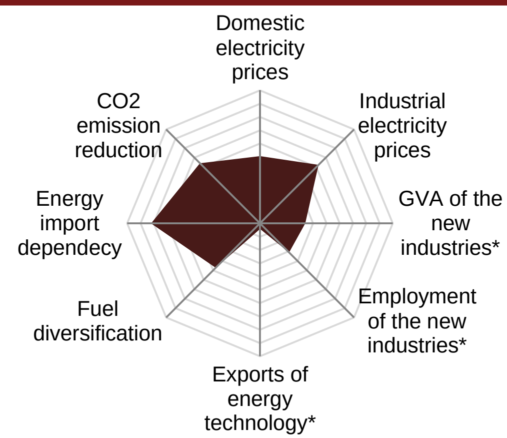


Electricity prices in Sweden are similar to the European average and even lower for industry. Energy tax exemptions and reduced CO_2 tax rates for energy-intensive industry have helped maintain its competitiveness.

The environmental industry is estimated to contribute 2.1% to gross value added (GVA) and 1.6% to total employment in Sweden (in 2010). Renewable energy production's GVA accounts for 0.8% of total GVA (in 2010).

The fall in CO_2 intensity in Sweden 1990-2011 is among the highest of the countries in our study. Fuel diversification and exploitation of domestic energy sources have increased the security of supply in Sweden.

Germany



Germany has actively stimulated new industrial activity through long-term demand-stimulating policy measures. The renewable energy industry is estimated to contribute 1.7% to total GVA and about 1% to employment. The contribution to exports is less than 1% since total exports are relatively high compared to other countries.

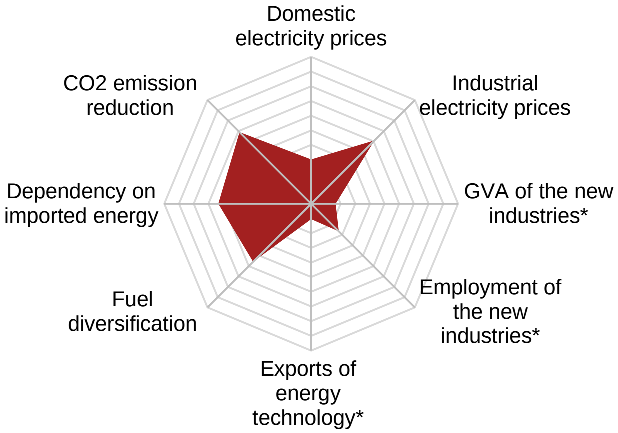
A higher tax burden has increased electricity prices. But tax exemptions (exempted from the mark-up for financing of the feed-in tariff) protect the competitiveness of the industry. The burden falls mainly on consumers. Decarbonisation has resulted in avoided costs of CO_2 emissions, estimated at €7.4-€7.8bn in 2009. Security of supply improved due to fuel mix diversification, but Germany still largely depends on foreign imports.

* Corresponds to the economic impact of the energy technology sector (Denmark) or the environmental sector (Sweden), includes a broader range of activities than for Germany, where only the economic effects of renewable energy is shown. The comparison between countries should therefore be interpreted with care.

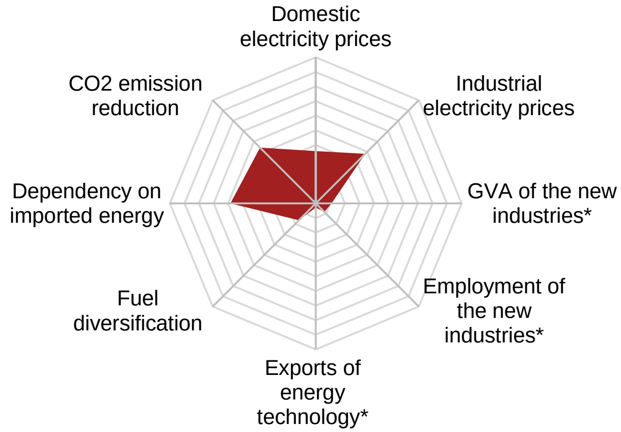
The Netherlands and UK decarbonised due to higher energy efficiency and structural changes in the economy. New industry creation was limited. Still, the economic impact of the renewable and energy efficiency sectors proved to be substantial and power prices remained relatively low.

Economic impact of decarbonisation in the UK and the Netherlands

UK	The Netherlands



The UK's economy has been decarbonised by mainly replacing coal and oil with natural gas and increasing energy efficiency. UK energy policy on renewables was lacking due to large domestic fossil fuel reserves. Affordability was UK's important policy pillar, which resulted in relatively low power prices, particularly for domestic consumers. But despite of a limited number of interventions before the 2000s in the renewable sector, decarbonisation has led to additional economic activities. Renewable energy and energy efficiency sectors together generate about 0.8% of jobs in the UK. CO_2 intensity fell significantly (partly due to structural changes). Natural gas and increasing share of renewables resulted in improved security of supply. Among the five countries, the UK has one of the most diversified fuel mix.



Electricity prices remained at relatively low levels in the Netherlands but gas prices are above EU average, mainly driven by taxes. Similarly to the UK, large own natural gas reserves and focus on energy efficiency have led to a relatively low CO_2 intensity. But frequent policy changes have resulted in a limited domestic renewable or energy efficiency technology industry. Security of supply in the country has decreased as it started to import more and renewable energy growth was not sufficient to satisfy the growing demand for energy. Fuel mix is also largely dominated by natural gas, which imposes further risks for security of supply. Overall, the competitiveness and affordability were maintained in the Netherlands at the expense of renewable expansion and fuel diversification.

* Corresponds to the economic impact of renewable energy and energy efficiency sectors in the UK and the Netherlands. In the UK, the share of GVA of new industries is replaced with the share of turnover of the sector in market value of total production output in the economy.
The comparison between all five countries should therefore be interpreted with care.

From our analysis we conclude the following on the impact of decarbonisation (of the electricity and heat sectors) on the economy:

PwC view *–Although total costs for the energy system are rising, the competitiveness of the economy can be protected by exemptions from taxes and levies for industry. This implies that consumers should be willing to pay the extra costs for the benefits of reducing carbon emissions, creating new industries, and increasing security of supply.*

1 Energy prices rise but competitiveness can be maintained

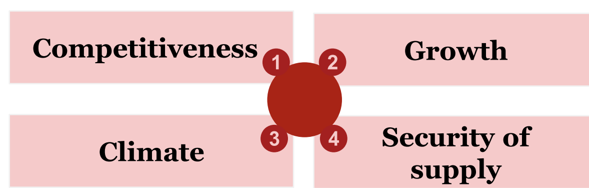
Decarbonisation requires renewable energy. As technology costs for renewable energy are high compared to conventional power and heat plants, the total costs of the energy system increase and so do prices, which may result in a welfare loss for consumers.

In the countries analysed, electricity prices have increased more than the average European price, mainly due to increased taxes (energy taxes, feed-in mark-ups) to cover the investments in the energy system. But concerns over the effects of the increased tax burden on competitiveness were taken into account in all countries. Energy-intensive industries are exempted from feed-in mark-ups and energy taxes or pay reduced rates. Exemptions are sometimes combined with incentives to increase energy efficiency. As industry is, to a large extent, exempted, the costs for decarbonisation through renewables are covered by the domestic consumer as they are paying higher energy prices.

2 New sources of economic growth can be generated

Increased energy costs due to renewable investments could be offset by increased economic activity as new industries, products or related economic activities. When energy policies are aligned with industrial policies, new industries can be created through an interactive process of policies, public and/or political support and innovation.

A competitive advantage can, however, dissolve quickly. Countries must therefore continuously invest in innovation to maintain their competitive advantage. The overall effect on economic growth can be limited as investments in other industries are decreased.



3 Costs are avoided due to decreased energy use and CO_2 emissions

Energy policies can lead to avoided costs of CO_2 emissions and energy savings. Besides avoided costs of CO_2 emissions, energy costs were avoided by increasing energy efficiency.

Although there is autonomous decarbonisation through changes in the economic structure, policies have clearly influenced the changes in the fuel mix and efficiency, intentionally or unintentionally. The levelised cost differences between renewable and conventional technologies are too large to generate spontaneous large-scale market development. If countries had not implemented their policies, fuel mix changes and energy efficiency changes would likely have occurred at a lower pace, resulting in higher emissions.

4 Increased security of supply decreases the vulnerability to price shocks and geopolitical risks

Energy policies aim to ensure security of supply. This can be achieved by diversifying the fuel mix and reducing dependence on foreign imports. Switching to renewable energy and investing in energy efficiency can reduce demand for imported conventional energy resources, which are often scarce domestically. Reduced dependence on imports positively impacts the balance of payments, which benefits the economy as a whole. A diverse fuel mix as well as reduced import dependence, spread over different countries, reduces the risks of price shocks and geopolitical conflicts.

On the other hand, a significant expansion of renewable energy sources makes the energy system less stable and more vulnerable to variable weather conditions. This provides an additional risk that is hard to mitigate unless countries are well connected to an international grid. This requires substantial investments in R&D and infrastructure development.

Case studies

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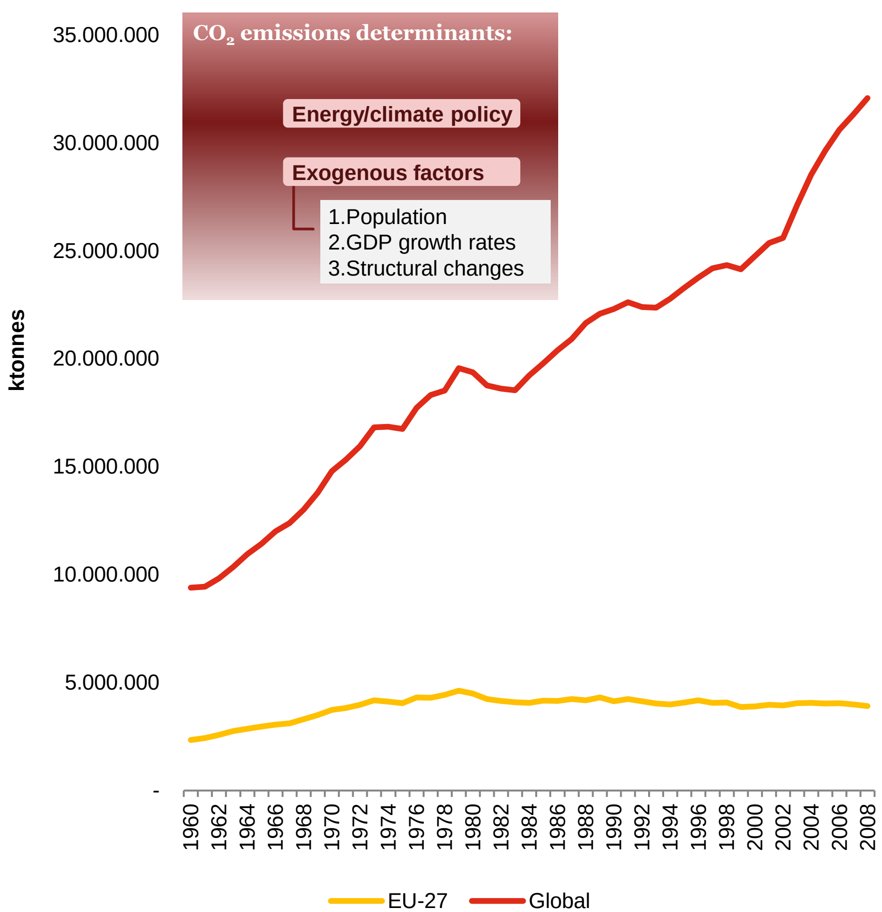
Global CO_2 emissions have been increasing, driven by economic development and population growth. In Europe, the decarbonisation process started in the late 1970s, caused by structural changes in the economy and targeted energy and climate change policies.

CO2 emissions EU-27 and global (1960-2008)



Source: The World Bank

Increasing carbon emissions

Global emissions have been growing at around 3% per year since 1960. Economic growth and an increasing world's population resulted in more demand for energy for household consumption, production of goods and services and transportation. This made CO_2 emissions rise.

Europe, in contrast, has managed to stabilise carbon emissions, which is a result of not only de-industrialisation and economic cycles, but also energy and climate change policies. Decarbonisation ambitions have added another dimension to energy policy-making, which was historically focused on assuring affordability of energy and securing energy supply.

Decarbonisation means decoupling

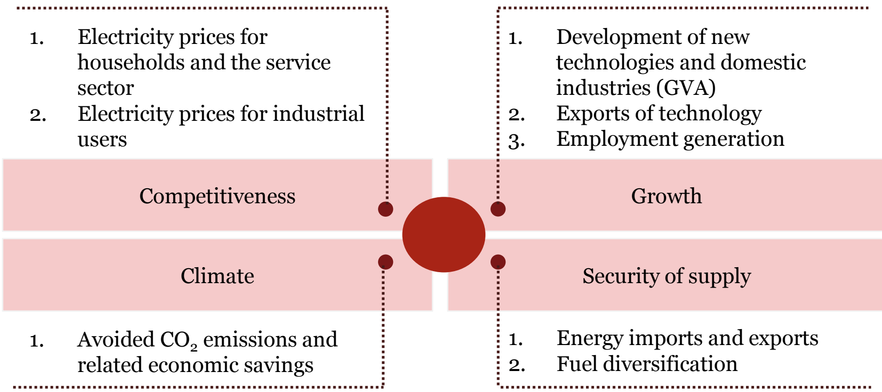
Climate change awareness calls for measures to reduce energy use and, consequently, CO_2 emissions. Economic growth that is decoupled from carbon emissions and/or energy use is a solution to climate change without compromising welfare growth. Decoupling can be realised by energy efficiency improvements (less energy to produce the same output), energy conservation in homes or changes in the fuel mix towards low- or zero-emission fuels. Two types of decoupling can be distinguished:

1. ***Relative decoupling*** – When GDP grows at a faster pace than carbon emissions or energy use do
2. ***Absolute decoupling*** – When GDP grows, whereas carbon emission or energy use decreases or stay stable.

The degree of decoupling depends on multiple factors. Generally, each country's energy system and its carbon intensity are influenced by the availability of domestic resources, the culture, the structure of the economy (industry versus service based), economic and environmental events. All the same, energy policies are crucial for achieving a low-emission economic growth, as they can stimulate improvements in energy efficiency and changes in the fuel mix.

Energy and climate change policies affect the economy. Main effects include changes in energy prices and competitiveness, impact on economic growth, security of supply and CO_2 savings.

Parameters of the economic impact of decarbonisation



Source: PwC

The energy system is at the centre of economic development in a country and therefore can facilitate economic growth if conditions are right: i) Energy prices impact the competitiveness of the country, ii) the energy sector and related technology and construction sectors generate economic activities, iii) energy provision must be secure enough to fuel economic activity in a reliable way. Carbon emissions from the energy sector also have social costs which are forwarded to future generations. So the fourth (iv) economic impact of this study is avoided costs of carbon emissions.

i) Energy prices and competitiveness

Governments want to guarantee the affordability of energy to remain competitive as a country and to keep energy affordable for its citizens. For decarbonisation (or emissions reduction) to happen, the energy sector has to undergo a transformation from fossil fuels to renewables, nuclear or other less carbon-intensive fuels (natural gas, if it is replacing coal or oil). This transformation will impact the costs of the energy system and as a result could impact the competitive position of the country.

ii) New opportunities for economic growth

The transformation of the energy system to a lower-emission system requires innovation and investments. These investments result in additional economic activity in a country. New economic activities could raise the level of economy's output.

Whether this effect materialises depends on the extent to which the investments can be realised with local inputs (technology or labour). This may be stimulated by country specific conditions (existing skills or industry) and industrial policy. If effective, industrial policy can stimulate various economic opportunities, for example, the emergence of new industries in clean technology.

iii) Changes in security of supply

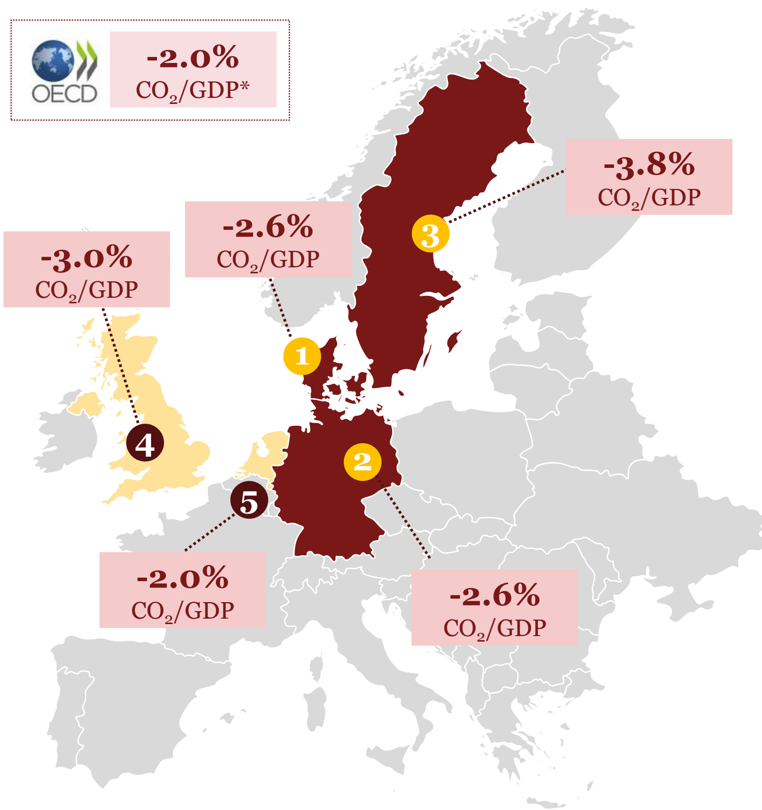
Security of supply affects economic performance of countries, which was confirmed by the oil crises in the 1970s. To decrease the vulnerability of a country to price shocks or supply issues, countries started to secure their energy supply by increasing domestic production, diversifying the fuel mix and increasing energy efficiency. But a fuel mix shift to renewables in the energy system makes power production more volatile due to weather conditions. This can again cause security of supply issues, if no safeguards are in place.

iv) Avoiding costs of energy use and carbon emissions

One more economic impact of energy and climate policies is the avoided costs of CO2 emissions and energy use. Full social costs of carbon emissions are not reflected in energy prices, but result in costs for society which are forwarded to future generations. Policy measures such as emission trading schemes that put a price on carbon try to include these costs in the energy price. Avoiding carbon emissions can therefore result in avoided future costs.

We will look into five countries – Denmark, Sweden, Germany, UK and the Netherlands – to illustrate how energy and climate policies impacted carbon emissions and to determine the economic impact of decarbonisation.

Compound annual decarbonisation (CO_2 per GDP) rates in Sweden, Denmark and Germany, 1970-2009



Source: The World Bank

*High-income OECD countries. We compare the performance of these countries mainly against high income OECD countries to be able to compare their performance against countries with a comparable level of development and welfare.
We use domestically created carbon emissions per GDP. This does not include emissions of imported goods (consumption based emissions).

Investigating decarbonisation in five countries through case studies

In this report we analyse the economic impact of decarbonisation illustrating it with country case studies.

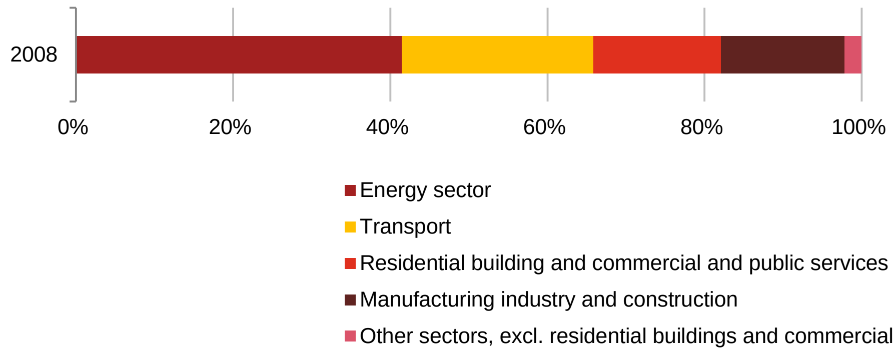
Among countries, which managed to decouple their economic growth from carbon emissions either in relative or absolute terms, Denmark, Sweden and Germany stand out as being among the most advanced countries. This achievement was influenced by a long history of various policy measures to stimulate a low carbon fuel mix or energy efficiency improvements. The cases of the UK and the Netherlands are rather different due to the availability of large natural gas resources. Carbon emissions decreased simply as a side effect of replacing coal or oil with -cleaner- natural gas. But now, to be able to achieve future decarbonisation targets, they too have to undergo a transition to the use of low carbon fuels.

As local conditions vary, each country chose its own unique way to design its energy, climate and industrial policies:

- ***Denmark*** is known for its high share of wind energy and the industry that developed around this and low energy intensity.
- ***Germany*** focused on increasing energy efficiency and the share of renewables. The country invested largely in solar power technology. Germany also uses nuclear power, but the plants are planned to be closed.
- ***Sweden*** has radically changed its fuel mix by rapidly developing nuclear power, which reduced the country's oil dependence significantly. Sweden is one the few countries largely powered with renewables (hydro energy).
- ***The UK*** has undergone a gas revolution, which largely improved its carbon footprint, together with structural changes in the economy. Renewables started increasing just recently.
- ***The Netherlands***, similarly to the UK, relied heavily on gas, which indirectly contributed to less focus on renewables. Energy efficiency was the means to decarbonise further.

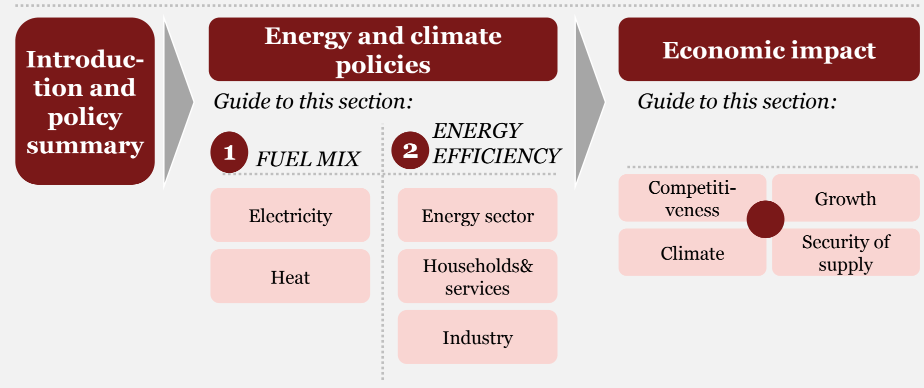
Within each case study, we will focus on power and heat production and consumption as these are responsible for the largest part of CO_2 emissions and significant policies have been developed in this area.

EU-27 CO_2 emissions by source. 2008



Source: The World Bank

Set up per case study:



Scope of the case studies: emissions from electricity and heat

The energy sector has always played an important role in the economy. It enables economic growth. At the same time, the sector is responsible for a large part of CO_2 emissions (c.40% of total emissions in the EU-27). Naturally, first attempts to stimulate the development towards a low carbon economy were focussed on this sector. Substantial policies have been developed in many countries to decrease carbon emissions from production of electricity and heat. On top of that, the energy sector can play an important role in decarbonisation because of fuel switching, for example the electrification of transport.

In this study, we will therefore focus on production and consumption of heat and electricity. This covers the energy sector as well as end users of heat and power because total emissions depend on both fuel mix used in the energy sector and for decentral production of heat and power, as well as energy use by end consumers.

The decarbonisation of transportation has in most countries taken a smaller role in policies to decrease carbon emissions and less progress has been shown in this sector. Transport sector is therefore out of scope of the study but should be a subject of future analysis.

The structure of the report

We present the case studies in the remainder of the report according to the structure as described in the adjacent figure. We start each case study showing the development of carbon emissions and a summary of the policies that contributed to that. Per case study we then present in more depth the evolution of energy and climate policies, placed in the political context, and the development of main fuel mix and energy intensity indicators. Finally, we look at the country's economic development (using the framework described on the previous page) and draw conclusions on the implications of energy and climate policies for the economy.

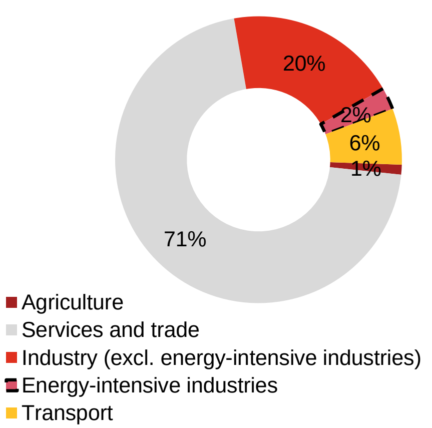
*only fuel combustion related emissions are taken into account in this study. Emissions from land use change are not taken into account.

Case Study Denmark

Decarbonisation in Denmark: *Denmark has decarbonised its economy through the use of renewable energy and natural gas as well as through increased energy efficiency, combining district heating and CHP use. Feed-in tariffs and eco taxes important policy instruments to stimulate this transformation.*

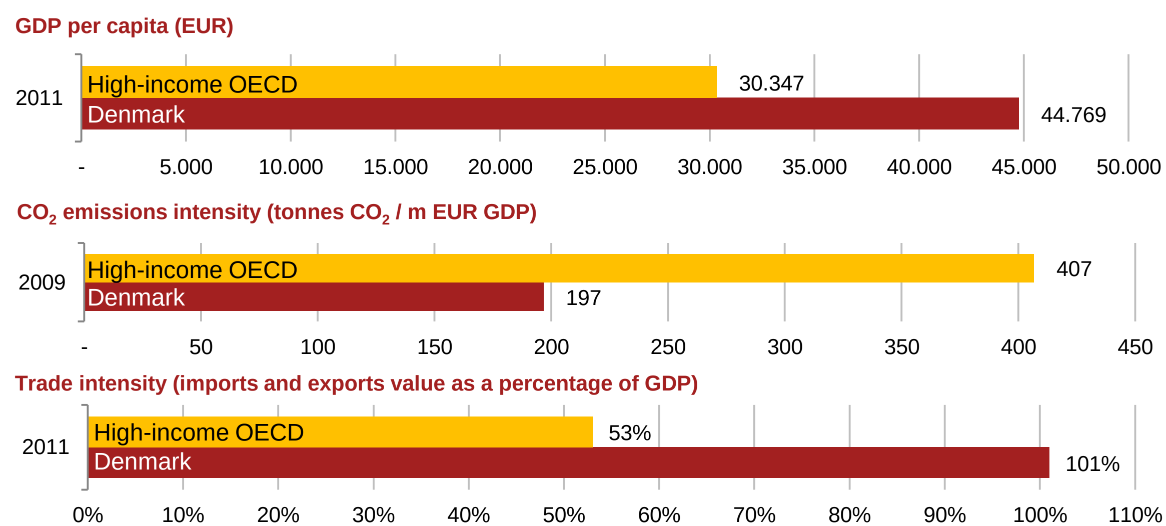
The economic impact of decarbonisation: *Denmark stimulated the growth of new renewable energy and energy efficiency industries by creating a domestic market and investing in R&D. These industries are estimated to contribute 1.6% to GDP and 1.5% of employment in Denmark. The stimulation of a domestic market for renewable energy is reflected in energy prices, and more specifically in the energy tax burden for consumers: Danish energy prices are among the highest in Europe. The competitiveness of the Danish energy industry has been protected by tax exemptions. The total tax burden in the country has remained stable in the past 10 years. The increase in energy taxes was balanced by a reform of the tax system (decreasing labour tax) to improve incentives coming from taxes.*

Gross value added by sector in Denmark (2010)



Source: Eurostat, Statistics Denmark
Energy-intensive industries include manufacturing of paper, products, chemicals, (basic) metals and coke/refined petroleum products

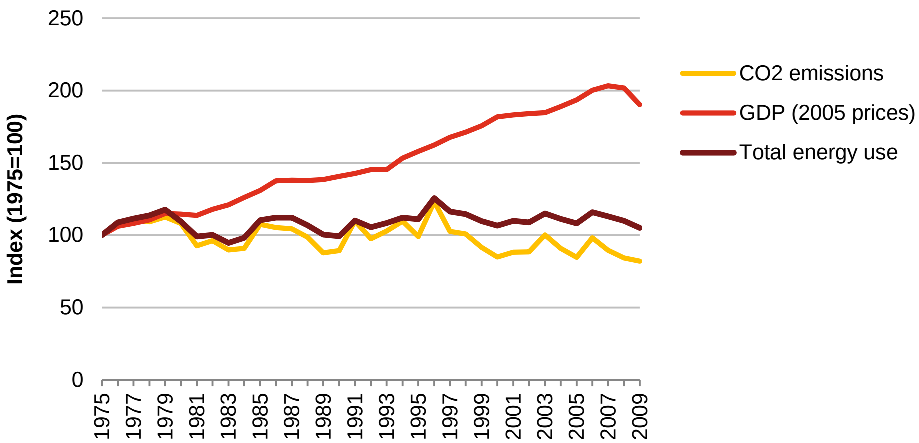
GDP 2011: €260 billion | Population: 5,57 million



Source: The World Bank

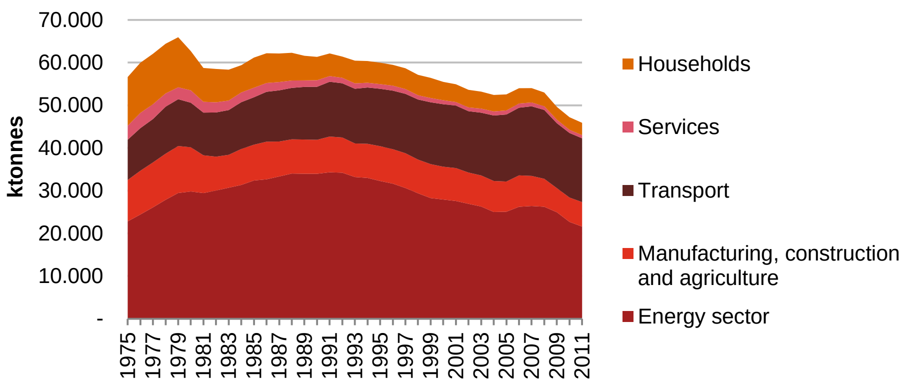
Denmark has managed to reduce energy use and carbon emissions while achieving economic growth. The energy sector is responsible for about 40% of total carbon emissions.

GDP, energy use and CO_2 emissions in Denmark, 1957-2009



Sources: The World Bank

CO_2 emission per sector (1975-2011)



Sources: The Danish Energy Agency (2011)

Decoupled carbon emissions from economic growth

The Danish economy is now twice as large as it was in 1975, yet CO_2 emissions are lower. According to our econometric analysis, during 1975-2009 Denmark achieved absolute decoupling of GDP from CO_2 emissions and relative decoupling from energy use. During this period, 1.0% growth in GDP coincided with a 0.4% decrease of CO_2 emissions and a 0.3% increase in energy use.

Improvement in energy efficiency is one of the main instruments leading to relative decoupling. The focus on a cleaner fuel mix in the beginning of the 1990s led emissions to decrease relative to economic growth in Denmark.

Lastly, structural changes in the economy, for instance a gradual development towards less energy intense industries (driven a by global trend) and increasing value added of services, might have contributed to the absolute decoupling trend as well.

The energy sector responsible for 40% of carbon emissions

Households and the services sector now contribute a lower proportion of total carbon emissions in Denmark than they did in the 1970s. These are the sectors which have reduced their energy intensities the most.

The energy sector accounts for 40% of total emissions. After an increase in emissions from the 1970s, major improvements have been made following significant changes in the fuel mix after 1990, moving from coal and oil to gas and renewables.

In the rest of this country case study, we focus on electricity and heat production and end-user efficiency connected to electricity and heat demand, as drivers of carbon emission reduction.

We will start by describing the energy policies that have lead to decarbonisation (section 2), after which we analyse the impact on the economy (section 3).

Energy and Climate Policies

Guide to next section:

1 *FUEL MIX*	2 *ENERGY EFFICIENCY*
Electricity	Energy sector
Heat	Households, services
	Industry

Political vision –Danish energy policy after the oil crises focused on increasing domestic production and efficiency to prevent future price shocks. After 1990, attention turned towards decarbonisation to meet ambitious CO_2 reduction targets.

Evolution of the focus of energy policies in Denmark

International events

- 1973 – First oil crisis
- 1979 – Second oil crisis, Nuclear accident in U.S.
- 1986 – Chernobyl nuclear disaster
- 1990
- 1996 – First EU electricity and gas liberalisation directive
- 1997 – Kyoto Protocol; adopted in 1997, enforced in 2005
- 2002
- 2005 – Introduction of the EU ETS
- 2007 – EU Council adopts 20-20-20 goals
- 2008 – Global financial crisis
- 2012

Phase

1. *A call for increasing security of supply*
2. *Broad support for decarbonisation*
3. *Decreased government support*
4. *Renewed political agreement*

Policy focus

Security of supply

1973-1990

At the time of the first oil crisis, Denmark was highly dependent on imported oil (about 90% of energy use). Due to this dependency, Denmark's economy was hit harder than other countries by the first and second oil crisis. Increasing security of supply became the focus of energy policies in this period. Denmark started its own oil and gas production in 1984 (first licences). It successfully reduced dependency on imports of energy and became a net exporter in 1998. Energy efficiency polices were developed to decrease energy use (for example, through district heating) and the first support for renewable energy was created (subsidies, ownership rules to support local and regional ownership).

Decarbonisation

1990-now

Previous policies to improve security of supply resulted in coal powered electricity generation and rising greenhouse emissions. From the 1990s, globally growing environmental concerns emerged. Denmark has reacted by becoming one of the biggest supporters for stringent climate policies.

The two main contributors to decarbonisation in this period have been capacity expansion in combined heat and power (CHP) plants to reduce energy losses and a strong boost in renewable energy. The government implemented various measures to achieve this: CO2 taxes and quotas, expansion of feed-in tariff schemes, R&D support, infrastructure development, and, except in 2002-2006, proactively supported the wind industry. Energy savings in buildings and stringent efficiency requirements and standards are another pillar of the Danish energy strategy.

Denmark now plans to rely 100% on renewable energy by 2050.

Political context

Political consensus as a driver of energy policies

Denmark's political system is based on a multiparty system, which frequently requires coalitions of several parties to form a Cabinet. From the 1970s, three periods can be distinguished, which were dominated by the Social Democrats (1975-1982), the Conservatives in coalition with the Liberals (1982-1993) and the Social Democrats in coalition with mainly the Centre Democrats and the Danish Social Liberal Party (1993-2001). At the beginning of the period, politicians focused on securing the domestic supply of energy, which was formalised in the Energy Plan of 1976. As this goal was reached, the focus turned to decreasing Denmark's environmental footprint. Denmark's long history of consensus-based policymaking and political stability has resulted in comprehensive energy policies which often focused on decarbonisation. Investments in renewables were also designed to boost employment in the 1980s. During the rule of the social democrats in various governments (from 1993 to 2001), wind energy started to grow significantly.

Liberalisation of the electricity and gas market (started in 1996 at the EU level) has turned the focus towards fostering competition between energy suppliers.

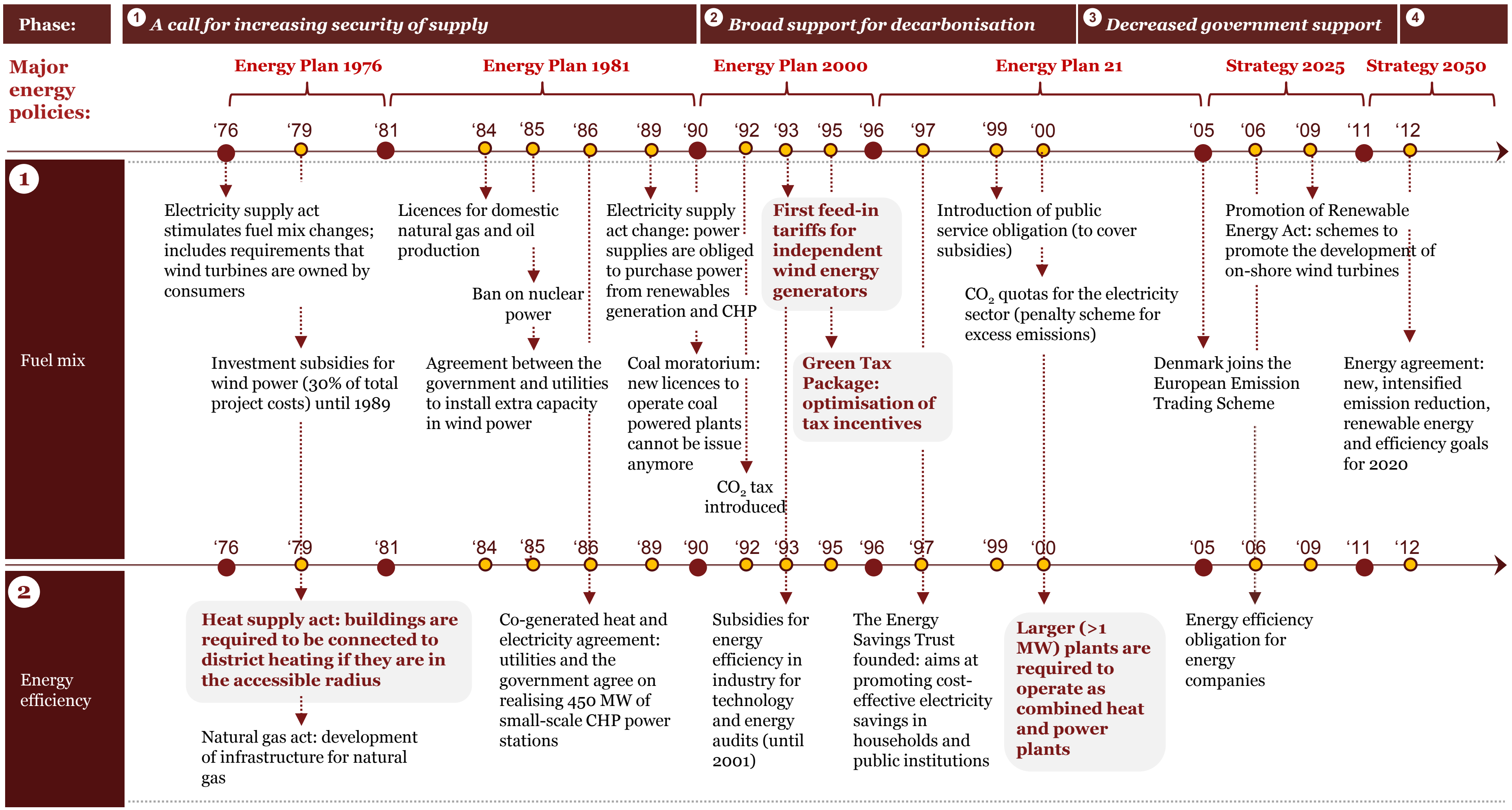
A changed political context

In 2002-2008, a right coalition altered the energy policy. Denmark considered implementing a green certificates scheme for electricity. Renewable feed-in tariffs were downscaled. In 2006 the Cabinet changed its strategy. Security of supply (dependency on Russia), economic development and climate change all played a role in the decision to step up the policy efforts to stimulate renewables.

Increased support for renewables

Renewables returned to the political agenda in force after the election in 2011. In March 2012, a broad political agreement was reached to pursue the goals of 50% wind energy by 2020 and 100% renewable energy by 2050.

Implemented policy instruments - The Danish government has used a large array of policy instruments to increase security of supply and reduce carbon emissions. The most distinctive measures include fiscal measures, expansion of district heating, combined heat and power production and financial incentives for the renewable energy producers.



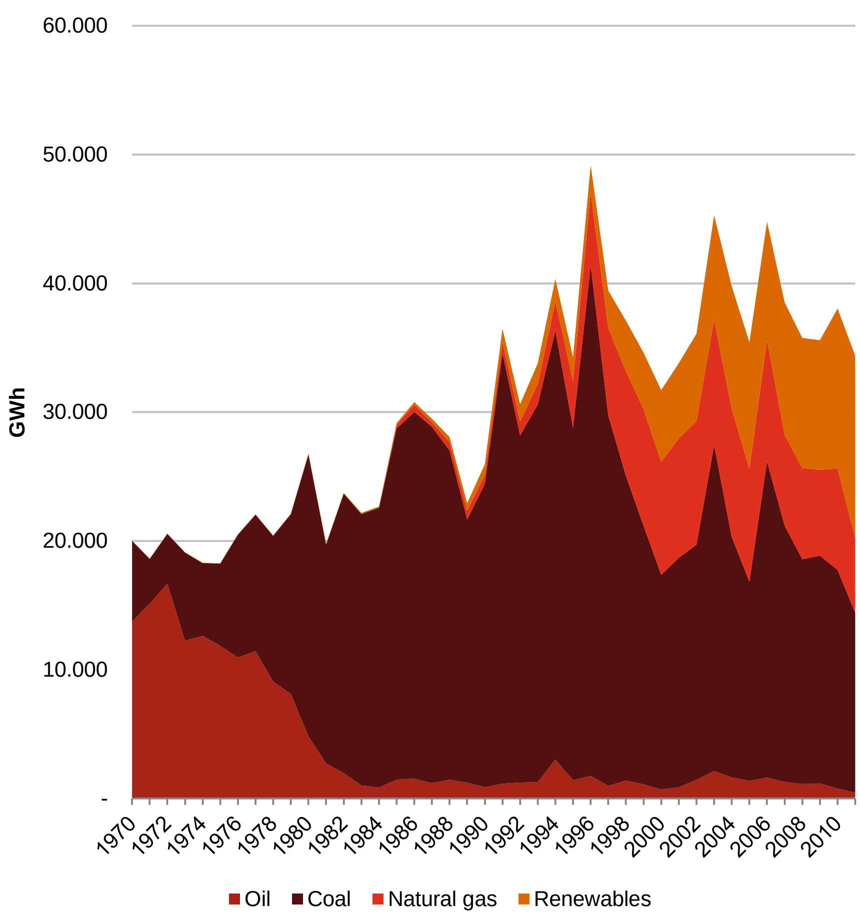
Source: The Danish Energy Agency, European Commission, Bolinger 2001, Mendonca (2009), IEA Policy Overview, Jamet (2012)

FUEL MIX

1 Danish energy policy started to focus on renewables due to an increased awareness on climate change and soaring carbon emissions from the energy sector. After nuclear was banned in the 1980s, options for decarbonisation became limited. The government has focused on reducing coal use and stimulating renewable energy.

Electricity | Heat

Electricity production by fuel, 1970-2011



Source: The World Bank

From security of supply to decarbonisation

The focus on security of supply after the oil crises decreased the use of oil, which was largely replaced by coal, one of the largest sources of CO_2 emissions.

In the late 1980s, the focus of Denmark's energy policy shifted from assuring security of supply to mitigating carbon emissions (from Energy Plan 2000 in 1990) due to rising emissions in the energy sector and increased awareness of climate change. Denmark was one of the key supporters of the Kyoto Protocol. The country implemented various measures prior to the agreement actually being enforced in 2005, such as a tax on CO_2 for end-users and CO_2 quotas.

Increased awareness of climate change led to a coal moratorium

In 1990, a moratorium on new coal-fired power plants was discussed. In the national plans from 1990, no development plans for new coal plants were included. No licences were issued for new coal-fired power plants. However, coal is still used in existing power plants.

The use of natural gas in energy production contributed to the decrease in coal use and subsequently CO_2 emissions, as gas is a less CO_2 intensive fuel than coal. Domestic production of oil and gas increased after new licences were made available from 1995.

Nuclear was not an option

One of the options for Denmark to diversify energy supply after the oil crisis was to increase the use of nuclear power. After the Three Mile Island nuclear accident in 1979 in the US, the debate on nuclear power plants intensified in Denmark. The unsolved nuclear waste problem negatively influenced this debate. A ban on nuclear power was subsequently established in 1985, limiting the options for Denmark to decarbonise as no nuclear plants could be built on Danish territory. But, the ban on nuclear did stimulate an increasing focus on renewable energy as an alternative for realising a cleaner fuel mix.

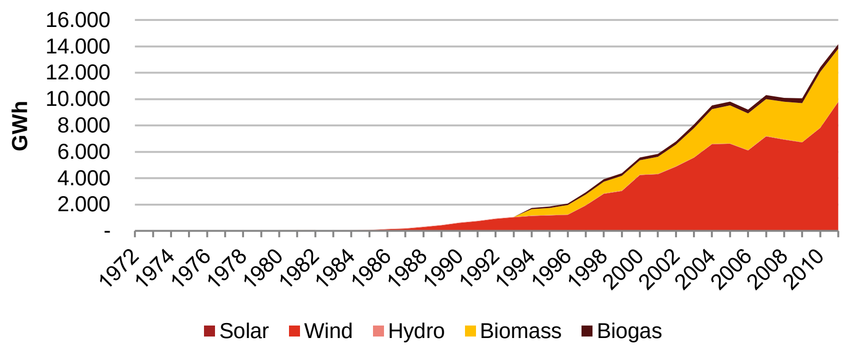
Sources: The Danish Energy Agency (Energy Plan 2000), Maegaard (2008, Petersen (1996), IEA Policy Overview

FUEL MIX

1 Denmark stimulated domestic renewable energy production (wind and biomass) by combining purchase obligations with financial incentives.

Electricity | Heat

Renewable electricity production by type, 1972-2011



Source: Danish Energy Agency (2011)

The Danish government stimulated domestic demand

Obligation to purchase renewable power to assure a customer base

From 1989, an obligation for electricity suppliers to purchase electricity from renewables and CHP generation was implemented (an amendment of the Electricity Supply Act). This priority access provided certainty to investors that energy produced would have access to the grid.

Financial incentives to provide long-term stability to investors

The Danish government used subsidies to provide long-term certainty to investors. The investment subsidies given in the 1970s and 1980s were first converted to feed-in tariffs (85% of consumer price) combined with CO_2 and energy tax refunds, and finally to fixed subsidies per kWh (including a compensation for CO_2 tax). When the electricity market was liberalised (in the Electricity Reform Agreement 1999), the subsidies were converted to a public service obligation (paid by consumers through their energy bill).

Taxes on energy were increased over time to improve incentives to decrease energy use and decrease carbon emissions *(please refer to page 31).*

Private ownership to raise local acceptance

The private ownership model was an integral part of the Danish wind industry's success and was regulated by law. During the 1980s and early 1990s most new turbines were installed by local co-operatives, which were stimulated by ownership restrictions. In 1998, due to liberalisation in the sector, the ownership model changed. The restrictions in ownership were abolished, with no limit on the number of windmills a person could own, provided they could get the relevant permissions, anywhere in the country. There were a series of takeover bids, resulting in a decrease in public involvement. But, today, 20% of a new windmill project must still be owned by private individuals.

Market-based incentives to move away from subsidies, but implementation delayed

The 1996 EU directive on the liberalisation of the electricity market lead to an increased focus on providing market incentives. In the Electricity Reform of 1999, a renewables portfolio standard for suppliers was agreed upon combined with a green certificates scheme, with the aim of replacing renewables subsidies. But, before implementing the portfolio standard, it was put on hold by the Parliament, awaiting the establishment of a common system in Europe.

CO_2 quotas were agreed upon in the Electricity Reform of 1999 and implemented through an Act on CO_2 quotas for the electricity industry in 2000. A penalty tax (of about €5) was used per tonne of CO_2 that was emitted above the quota. By increasing the price of CO_2, renewable alternatives became more attractive. The system was replaced in 2005 by the EU ETS, which is considered to be less effective due to the current functioning of the scheme.

Voluntary agreements

Several agreements were reached between utilities and the government to install additional windmill capacity.

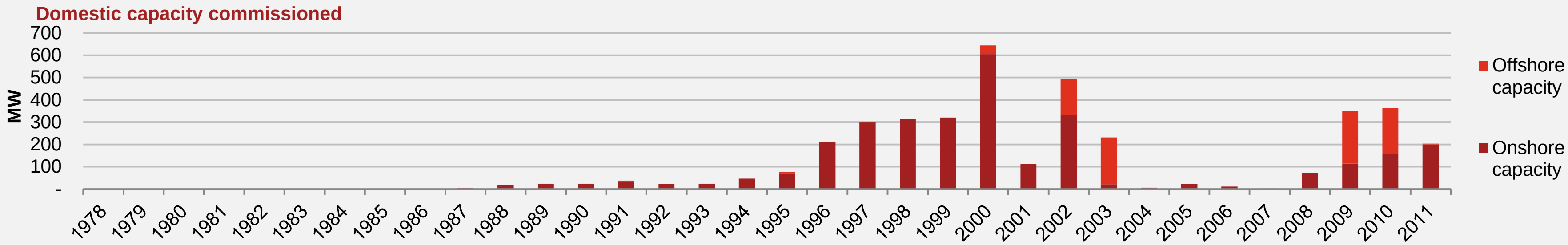
Source: Danish Wind Energy Association, Bolinger (2001), IEA Policy Overview, Mendoca (2009), Act NO.376 of June 2nd, 1999

FUEL MIX

1 *Case study wind* – The government has provided several incentives to the market to stimulate the domestic demand for wind energy. The development of the Danish wind turbine industry was stimulated by domestic demand combined with local technological knowledge and ownership.

Electricity | Heat

Domestic capacity commissioned has been strongly affected by subsidy schemes



Industrial development: early steps to export driven growth

Initial development of the market: emergence and development

After the first oil crisis the political interest for windmills was increased. A range of technically astute people pioneered new designs. The government developed quality and safety regulations. Subsidies and obligations for power companies further stimulated wind sector development. Local involvement and ownership played an important role in the acceptance and development of wind energy in Denmark. During this period, the first exports to California took place (under the Californian subsidy scheme).

Market expansion

Increased efficiency of wind turbines, government planning and financial incentives led to an increase in domestic production. Exports rose due to increased demand caused by subsidies in neighbouring countries.

Standstill and market revival

The focus of the new Cabinet shifted away from wind power in 2002. The subsidies ended, which brought domestic demand for wind turbines to a standstill. The Cabinet changed its approach in 2006, increasing the guaranteed tariff and bringing a revival of the domestic market.

Financial incentives have been substantial

Investment incentives

Subsidies covered about 40% of an investment. These subsidies were reduced and finally discontinued in 1989.

State production subsidies

Early off-grid windmills were not subjected to energy tax. Starting in1984, a direct state subsidy system was introduced for wind power as compensation for the electricity tax due to the connection with the grid of the larger windmills that were developed. After several changes in the electricity tax fees, in 1993, the guaranteed tariff was fixed at DKK 0.27/kWh, of which DKK 0.10/kWh is the tax compensation. Supply companies only received the DKK 0.10/kWh.

Public service obligation

The subsidy was transformed from a government subsidy into a public service obligation. The price that wind power generators will receive was set at 85% of the electricity retail price (for a consumption pattern of 20 MWh), with an additional surcharge of DKK 0.27/kWh. In 2001, the subsidy was reduced to DKK 0.10/kWh. Since 2008, the guaranteed tariff was increased to DKK 0.25/kWh. Tendered wind parks are exempted from the subsidy, as their subsidy is negotiated in the tender and could thus differ from the general subsidy.

Ownership has played a vital role

Ownership regulation resulted in support for windmills

Local commitment and the economic involvement of the community are likely to have contributed to the general acceptance of turbine installation in society. It started with windmills built by municipalities or citizen corporations. With the introduction of large wind farms the ownership of supply companies started to broaden. Concurrently, support for new windmills has decreased over time. However, it is currently legally mandated that 20% of shares in a windmill must be made available for purchase by people from the region where the windmill is built. An estimated 43% of wind power was owned by independent power producers, owned by municipalities or the community (Maengaard, 2009).

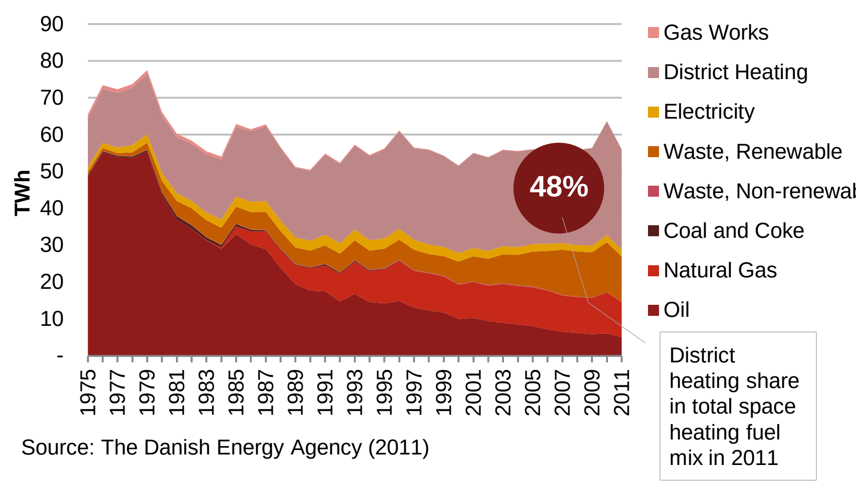
Sources: The Danish Energy Agency, Krohn (2002), IEA Policy Overview

FUEL MIX

1 Early investments in district heating have enabled fuel switching from oil towards renewables and natural gas. District heating also provided the infrastructure for switching to efficient heating through combined heat and power production (CHP).

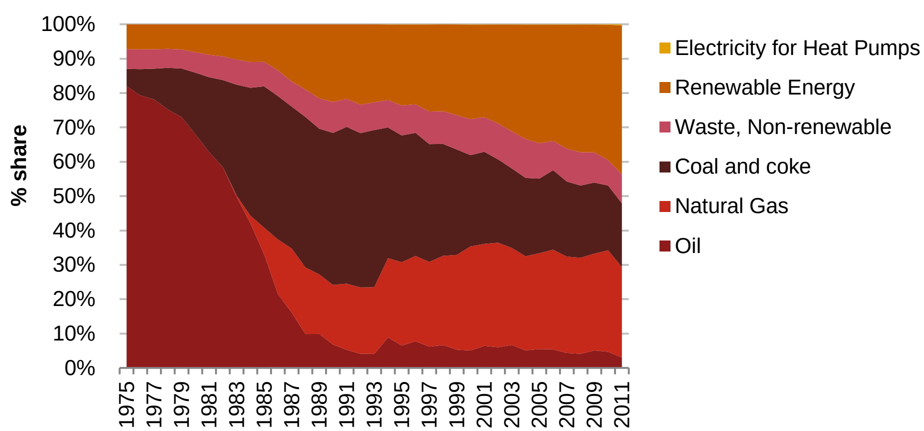
Electricity | Heat

Space heating use by source, 1975-2011



Source: The Danish Energy Agency (2011)

Primary fuel mix for district heat production, 1975-2011



Source: The Danish Energy Agency (2011)

Space heating fuel mix diversified

Since the early 1980s, oil was largely replaced as the main energy source for space heating by district heating, natural gas and waste. As with fuel for electricity production, Denmark has aimed to diversify the fuel mix for heating.

The growth of district heating was mainly achieved via the Heat Supply Act, from 1979 onwards, which contained an obligation for buildings within close proximity to connect to the district heating grid, or to connect to the natural gas network which was also built up in this period. In 1988, a ban on electric heating in new buildings was enacted. From 1994, the ban also applied to existing buildings, stimulating the use of district heating. When applying district heating, the heat is produced at a central spot and distributed to households and other buildings through pipelines. This provides cost advantages compared to historical fossil fuel burners for space heat and hot water. Currently, about 48% of heat demand is met through district heating.

District heating fuel mix

The fuel mix for district heating is similar to that for electricity.

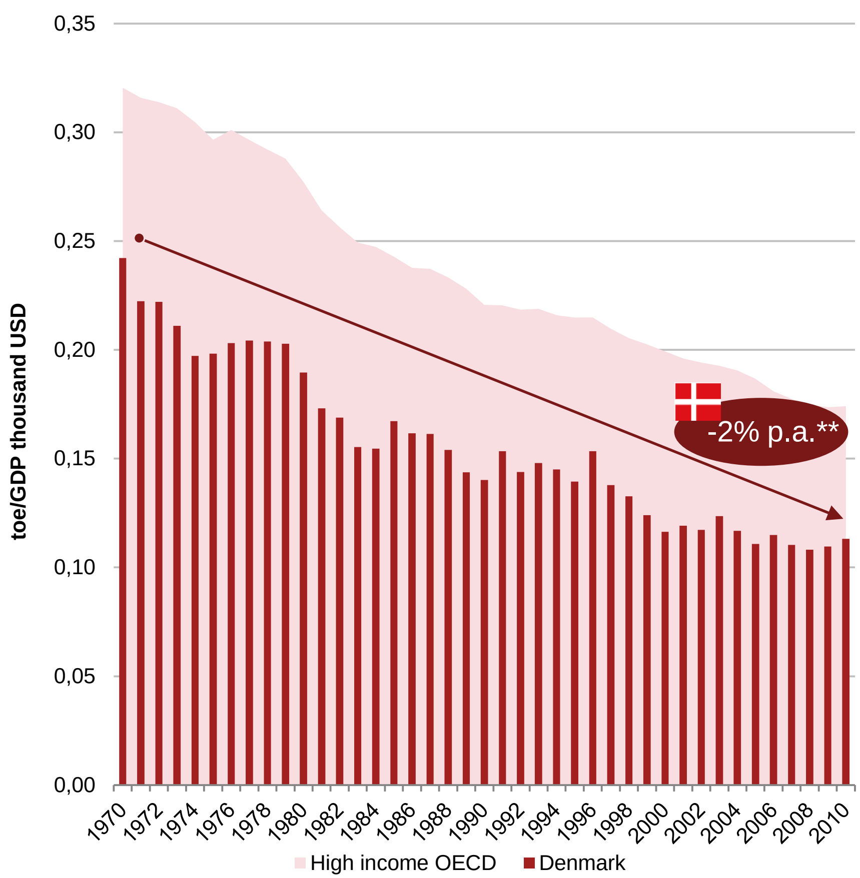
The majority of the heating network was installed between the 1960s and 1998. It was, in a large part, owned by the community. Initially, district heating production was fuelled with oil. After the oil crisis, coal, natural gas and renewables were used to reduce dependency on oil. The increased focus on decarbonisation, starting in the 1990s, and the resulting environmental taxes shifted the fuel mix towards renewables and natural gas, since CHP plants may use any kind of fuel or renewable energy source.

Source: IEA Policy Overview

ENERGY EFFICIENCY

2 Energy intensity in Denmark has historically been lower than in other high-income OECD countries. Still, the country has made progress in energy efficiency in all sectors, which has allowed Denmark to keep energy intensity relatively low compared to other high-income OECD countries.

Primary energy intensity (toe/GDP thousand USD)*, 1970-2010



*The energy intensity includes the transport sector
** Change in primary energy intensity; Final energy use intensity decreased by -3,4% annually (1990-2011)
Source: The World Bank

Energy intensity has decreased by 2% per year since 1970

Denmark has increased energy efficiency significantly over the past 30 years, with the fastest decrease in the period before 2000 *(please refer to the adjacent chart)*. From 1960 to 1972, energy use almost doubled in Denmark. Since then, it has remained at a stable level despite economic growth. A part of energy savings are offset by a rebound effect. Households are able to consume more energy for the same price or can purchase other goods or services, whose production also require energy.

The 1976 Electricity Supply Act gave the minister for energy the authorisation to take measures to improve the energy efficiency of electricity supply. Denmark focused on increasing efficiency in heating. An important contributor to the increase in energy efficiency was the introduction of district heating and combined heat and power (CHP) production, which increased efficiency in the energy sector.

Energy intensity depends on the following:

1. Efficiency in the energy sector
2. Efficiency of the end users of energy (households, services and industry).

In Denmark, improvements have been continuously made since the 1970s. Both sources for energy intensity reduction (efficiency in the energy sector and end-user efficiency) have contributed to the trend. Underlying strategies and policy choices will be discussed in the next three pages for:

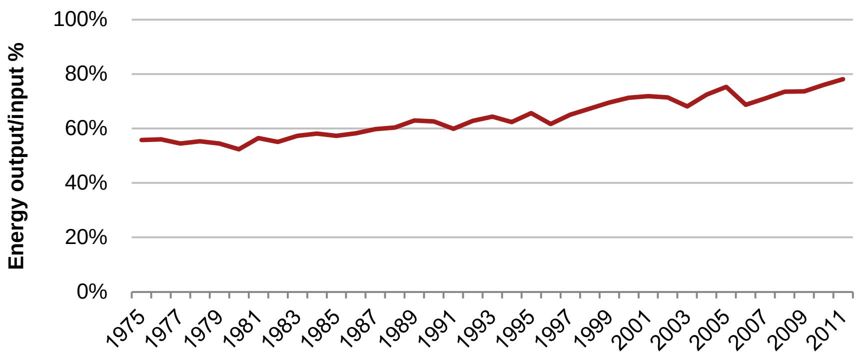
Energy sector + Households, services + Industry

Source: McFormick & Neij (2009)

ENERGY EFFICIENCY

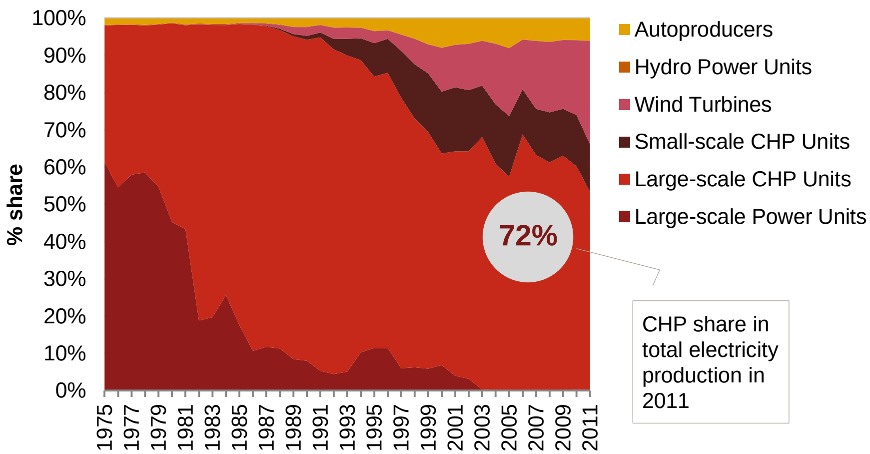
2 Efficiency in the energy sector in Denmark has increased over time from 58% in 1975 to 78% in 2010. The combination of CHPs, district heating and wind power can be regarded as the main drivers of this increase.

Efficiency in the energy sector (total electricity and district heating production), 1975-2011



Source: PwC analysis, based on Danish Energy Agency data

Electricity production by type of producer, 1975-2011



Source: Danish Energy Agency

Improved efficiency in the energy sector

Denmark has significantly increased efficiency in the energy sector, which means that less energy is lost such that resources are used in a more efficient manner.

From the late 1990s, the increased use of renewables directly contributed to energy sector's efficiency, since renewables, like hydro, solar and wind power, have zero energy input.

Before this, CHP production increased efficiency, because the heat that results from electricity production is used instead of being lost. This also means that heat production does not require additional energy inputs. This improves the efficiency from 30-40% to c. 85% (B.KWK, 2013) for a conventional coal-fired power plant. The combination of CHP and district heating was effective because the heat produced in electricity plants could now be easily used for to heat buildings as the infrastructure was already there.

The switch to CHP was supported by various policies. From 1976, power producers needed a licence to produce electricity. Since the early 1980s, only CHP plants have received licences. Demonstration plants for small-scale CHP were developed through government programmes. In the co-generated heat and electricity agreement of 1986, utilities and the government agreed upon realising 450 MW of small-scale CHP power stations. From 2000, power plants larger than 1 MW had to be operated as combined heating plants, including existing plants. An obligation, introduced in 1989, for power suppliers to purchase power from renewable and CHP generation further stimulated a switch to CHPs.

The shift to district heating and CHP was also a shift from centralised to local supply of power and heat. In 1990, a premium for CHP was introduced (0.10 DKK per kWh) to stimulate local consumer-owned CHP. In 2007, about 25% of electricity used was provided though independent CHP producers.

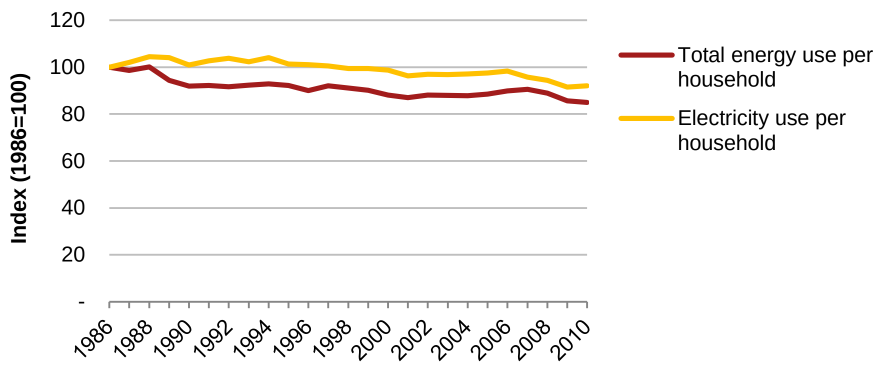
Source: Maegaard (2007), B.KWK (2013)

ENERGY EFFICIENCY

Energy sector | Households, services | Industry

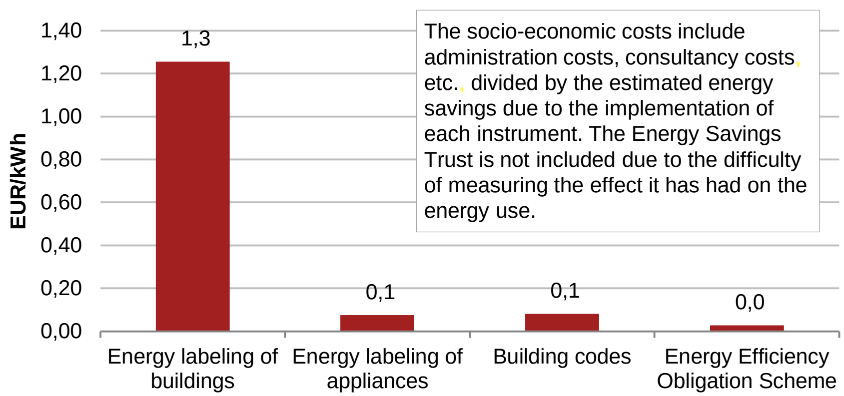
2 Energy efficiency improvements in households and services were stimulated by the government from the 1970s using information measures, subsidies and obligations. Energy labelling is considered to be one of the least successful measures in terms of cost-effectiveness.

Total energy and electricity use per household, 1986-2010



Source: Statistics Denmark; Danish Energy Agency

Socio-economic cost of energy efficiency measures in Denmark (EUR/kWh)



Source: Togeby et al. (2009)

Building Codes

Danish Building Codes include requirements for energy efficiency for all new buildings and contributed significantly to reducing energy consumption. The Codes have been gradually tightened in several stages since the late 1970s, partly driven by EU directives. The Codes set limits on electricity consumption for ventilation and will enforce the use of efficient heat supply systems, such as district heating systems, condensing boiler, solar energy and heat pumps.

Energy labelling

Energy labels that specify energy performance of buildings have existed since 1979 and have been modified several times. Energy labels provide visualisations of energy consumption (categories A to G) and provide information when buildings are sold or let. Energy labelling is mandatory when selling and letting dwellings as well as every five years for large (>1,000m2) buildings. But, the measure has proved be a less cost-efficient instrument than other measures *(please refer to the adjacent graph)*. No significant difference in implemented energy efficiency measures could be found between houses with and without a label.

The energy labelling of appliances was implemented according to EU regulations in 1992 and has been amended several times since.

Energy Savings Trust

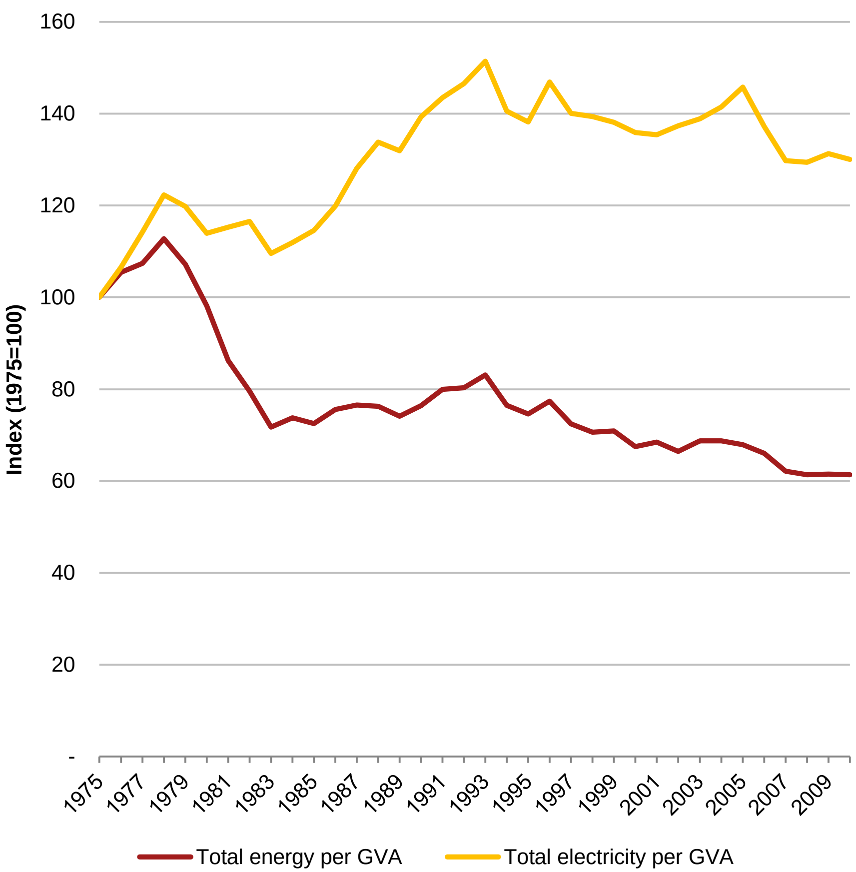
The Danish Energy Savings Trust was founded in 1997. It aims to promote cost-effective electricity savings for households and public institutions. The initial focus of the fund was the reduction of electric heating through a switch to district heating and subsidised natural gas boilers. More recently, the Trust's focus has shifted towards encouraging the use of energy-efficient appliances through information instruments for consumers and subsidies for product development and marketing of the most energy-efficient appliances. Furthermore, municipal and government institutions have agreed to purchase energy-efficient equipment based on the Electricity Savings Trust's 2006 Purchasing Guidelines. The Trust is financed through a €0.01/kWh charge on the electricity consumption of households and public institutions.

ENERGY EFFICIENCY

Energy sector | Households, services | Industry

2 Energy efficiency in industry has greatly improved since the 1970s. The most important drivers are likely to be economic structural changes and taxation combined with energy efficiency incentives.

Total energy and electricity use per GVA of manufacturing industry, 1975-2010



Source: The Danish Energy Agency; Statistics Denmark

Energy efficiency obligation for utilities

Since 1994, utilities received compensation through tariffs to encourage the reduction of energy consumption by their customers. The obligation scheme, which came into force in 2006, consists of an annual binding energy efficiency target for all energy distribution companies (electricity, district heating, natural gas and oil). The companies typically provide information, energy audits or subsidies. Energy companies can recover the costs of the measures through tariffs. This instrument is one of the most cost-efficient instruments, being much more efficient than energy labelling and building codes (Togeby et al. 2009).

The obligation is set for a certain period. The total energy saving target from 2006-2009 was 2.95 PJ per year, which corresponds to 0.7% of consumption in the sectors included (transport is not included)*. From 2010-2012, the target was increased to 6.1 PJ per year, which translates into c. 1.2% of final consumption in the sectors in the corresponding years*. For 2013-2014, it is planned to save 10.7 PJ per year, and in 2015-2020 the target is due to rise to 12.2 PJ per year**.

Tax exemptions for energy-intensive industry

Since the introduction of carbon taxation in 1992, energy-intensive industries have been able to reduce their energy and carbon tax contributions by entering into voluntary agreement to improve energy efficiency. As part of the agreement, companies must implement an energy management system, perform investigations as to where energy efficiency can be improved and implement all related investments with an economic payback period of less than four years. If the agreement is made, companies get a reduction on their energy and CO_2 taxes. Additionally, tax rates were increased gradually so that companies had time to reduce CO_2 emissions.

Sources: * Danish Energy Association; ** Odyssee/Mure (2012); Ericsson (2006).

FUEL MIX & ENERGY EFFICIENCY

1 & 2 To reduce the use of energy and CO_2 emissions, Denmark implemented a taxation system which shifted the tax burden away from income towards the use of resources. Industry is exempted or receives lower tax rates when voluntary energy savings agreements are entered into.

Energy and carbon tax rates in Denmark, 2011

Tax levels: % of total tax charge	Heavy process	Light process	Space heating
With agreement	Energy: 0% CO_2: 3%	Energy: 0% CO_2: 68%	Energy: 78% CO_2: 78%
Without agreement	Energy: 0% CO_2: 25%	Energy: 0% CO_2: 90%	Energy: 100% CO_2: 100%

Sources: Ministry of Taxation

Energy taxes were introduced in the 1970s, a CO_2 tax in 1992

Starting in the 1970s, energy taxes were imposed on the consumption of oil, gas, coal and electricity to reduce a deficit in the National Balance of Payments. In 1986, these taxes were raised considerably, again primarily for fiscal reasons. These were based on the use of coal, gas and oil. However, when used to generate electricity, they were based on the quantity of electricity rather than the primary energy sources, due to an inability to trace this usage back to its sources.

In the Energy Plan 2000, the increased focus of the government on CO_2 emission reduction was made explicit through a CO_2 reduction goal of 20% in the period 1988 to 2005. Subsequently a tax on CO_2 was implemented in 1992 for households. To compensate for the additional taxes, CO_2 taxes were subtracted from energy taxes. In 1993, taxes were also introduced to businesses, although businesses could get a reimbursement of 50% (even more for energy-intensive companies).

The green tax package of 1996 increased incentives to reduce emissions and energy use…

The tax package of 1996 implemented an integrated framework for environmental taxes. Within taxation, a distinction was made between heavy industrial processes, light industrial processes and space heating as purposes for energy use.

This package was designed to have an effect on emissions, while not decreasing the competitiveness of companies. Therefore, energy-intensive companies could get a tax exemption when entering into a voluntary agreement. Additionally, tax rates were increased gradually so that companies had time to reduce CO_2 emissions.

In 1998, energy taxes were increased to dampen an overheated economy, but in 2001, the government decided on a "tax freeze". Since then, only downward adjustments to the tax scheme have been carried out.

… but used exemptions to assure competitiveness of the industry

The green tax package gave energy-intensive companies the option to enter into an agreement with the Danish Energy Agency. As part of the agreement, companies have to implement an energy management system, perform investigations as to where energy efficiency can be improved and implement all related investments with an economic payback period of less than four years. If the agreement is made, companies get a reduction in their energy and CO_2 taxes *(please refer to the table)*.

Sources: The Danish Energy Agency, Ericsson (2006)

Economic Impact of the Energy and Climate Policies

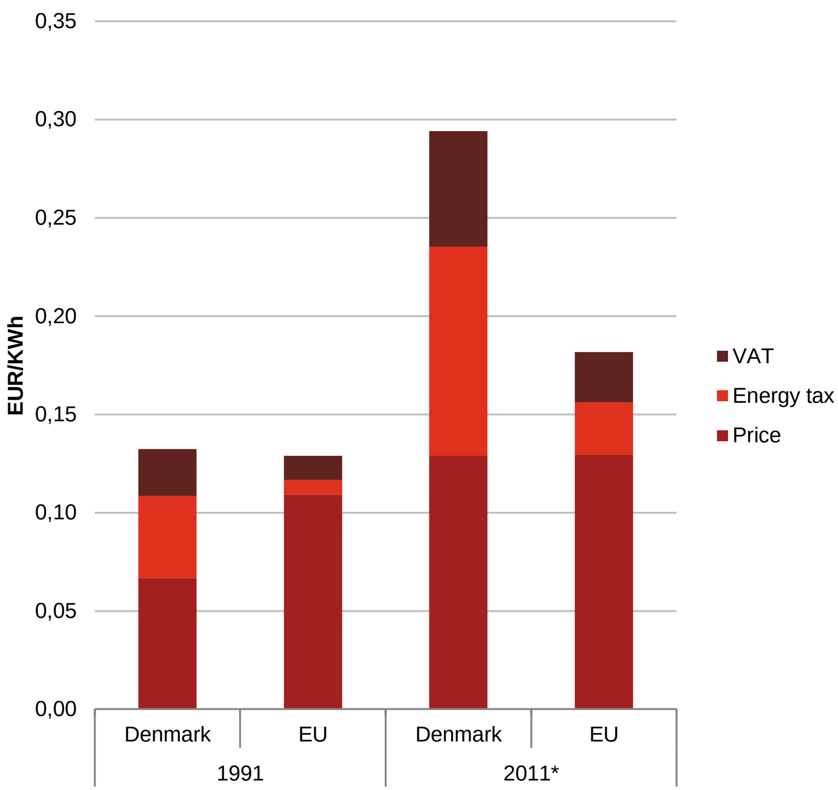
Guide to next section:

Competitiveness	Growth (new industries)
Climate	Security of supply

Danish consumers pay 60% more for electricity than the average European, mainly due to higher taxes. Energy efficiency gains have only partially offset price rises from taxation. Research suggests, however, that society is willing to pay.

Competitiveness | Growth | Climate | Security of supply

Average prices of electricity for households in Denmark and the EU, 1991-2011



* A new methodology was adopted in 2007. Values before and after this data are therefore not fully comparable , but comparisons between countries can be done. 2011 EU data includes 27 Member States, whereas 1991 includes EU-15.

Source: Eurostat

Consumers are paying for renewable investments

Energy prices in Denmark have increased over time and are currently among the highest in the EU. This is mainly due to an increasing tax burden; the actual energy price is close to the EU average. Danish consumers pay higher energy prices to finance R&D in wind, but also benefit from positive technological spillovers and lower costs of compliance with the EU regulation.

The building efficiency measures discussed above, such as support to switch from electric heating to district heating or for efficient domestic appliances, have led to lower energy (including electricity) consumption per household. However, this has not been sufficient to compensated for price increases. Electricity use per household over the same period from 1991 has decreased by 10%. Prices appear to have increased by more than that, although the exact difference cannot be estimated due to changes in the calculation methodology in 2007. Overall, these price rises reduce consumers' purchasing power, all else being equal.

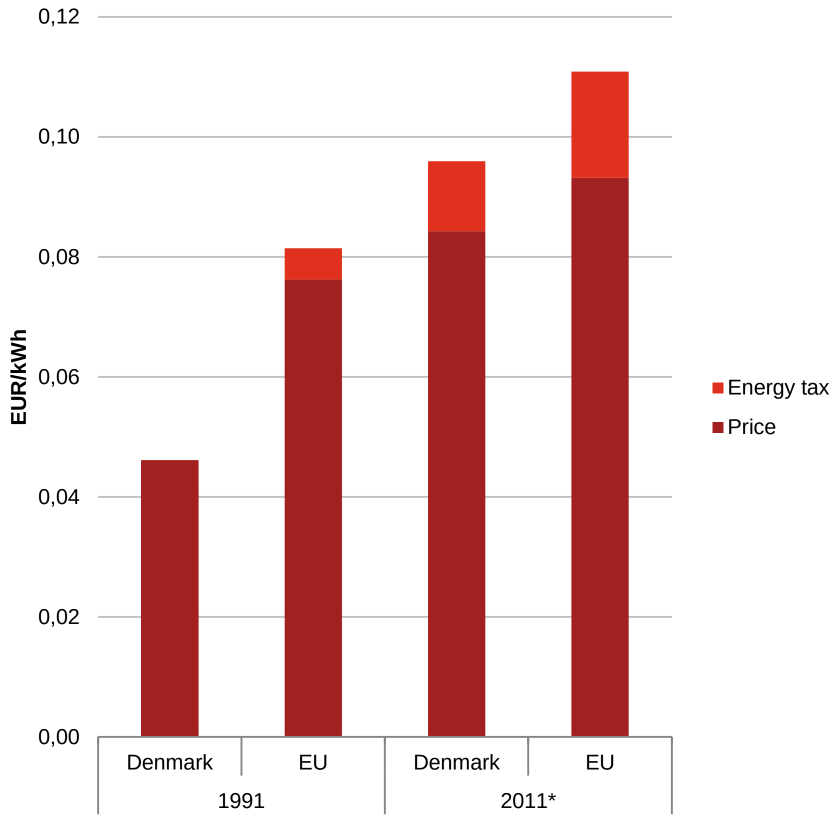
Interestingly, the 2002 Eurobarometer survey "Energy: Issues, Options, and Technologies: Science and Society" revealed that Danish consumers were among the most willing in Europe to pay more for energy produced from renewable sources. This may suggest that despite increasing prices, consumers are willing to support renewable energy expansion. The Danish model of ownership is likely to have contributed to this opinion, since a portion of the revenue from renewable electricity is returned to consumers as owners of windmills.

Source: Danish Energy Agency, Danish Statistics

Industry has experienced rising electricity prices, but they remain lower than the European average. Energy efficiency improvement measures have helped to partially offset the negative effects of rising prices.

Competitiveness | Growth | Climate | Security of supply

Average prices of electricity for industry in Denmark and the EU, 1991-2011



* A new methodology was adopted in 2007. Values before and after this data are therefore not fully comparable, but comparisons between countries can be done. 2011 EU data includes 27 Member States, whereas 1991 includes EU-15.

Source: Eurostat

Industry is paying less than the average

Energy prices increased for industry as well as households. However, the electricity price for industry is currently 13% lower than the EU average. In 1991, the difference was larger still, with Denmark's industry paying around 40% less than the EU-15 average.

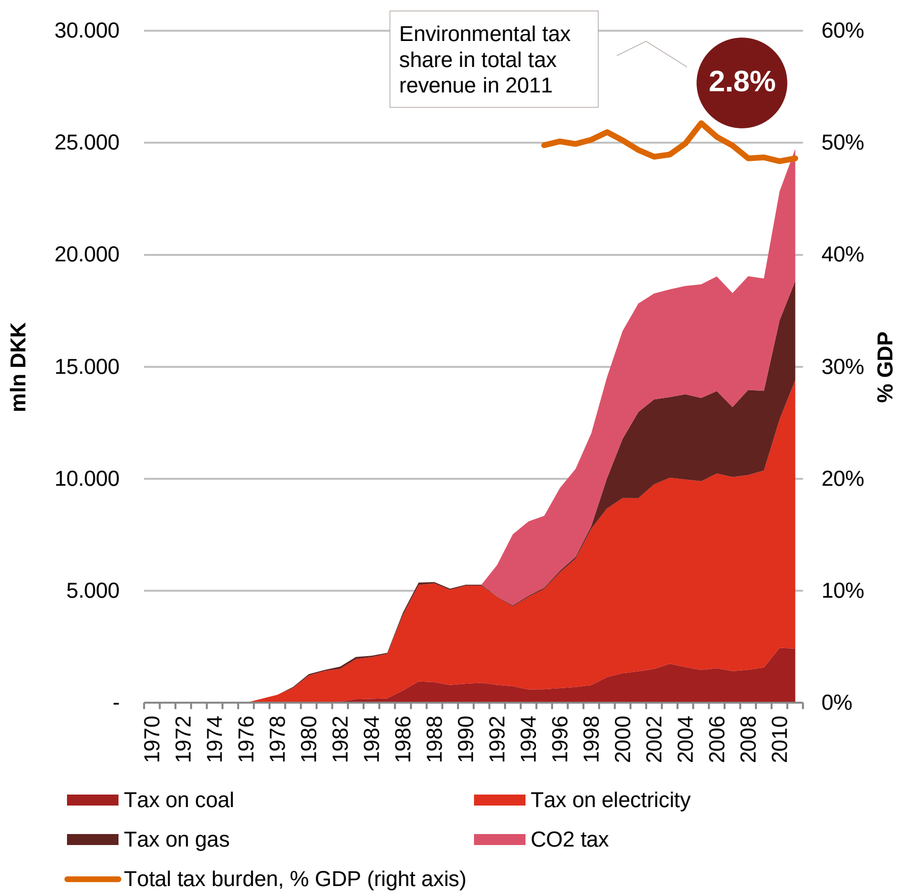
The overall electricity cost burden has, on average, increased. Between 1991 and 2010, electricity use per unit of GVA in the manufacturing sector decreased by around 9% (the quantity effect), but this was offset by significantly greater electricity price rises (the price effect).

In Denmark, industrial production processes were subjected to a CO2 tax from 1993. This coincided with the decoupling of both energy consumption and CO_2 emissions from GVA in four Danish energy-intensive industries (pulp and paper, basic chemicals, glass, and cement and tiles), according to research on the decoupling of industrial energy consumption (Enevoldsen et al., 2007). With the exception of the chemical industry, these sectors grew in Denmark over the time period (1993-2001), whereas most of their Swedish and Norwegian counterparts stagnated. This suggests that reduced energy intensity may increase industry's competitive advantage during periods with volatile energy prices.

Since the introduction of a CO_2 tax in 1992 and green tax optimisation in 1995, Denmark has significantly increased its revenue from environmental taxes. However, they still only constitute about 1.4% of GDP or 2.8% of total tax revenue. Higher taxes partially cover incentives for energy efficiency.

Competitiveness | Growth | Climate | Security of supply

Environmental tax revenue and total tax burden in Denmark, 1970-2011



Source: Danish Ministry of Taxation

Total tax burden stayed the same

Environmental tax revenues (energy taxes on coal and gas, CO_2 tax and electricity tax) have increased significantly since the early 1990s. In 1995, environmental tax revenue accounted for c. 1.6% of total tax revenue in Denmark. By 2011, that share had increased to 2.8%. At the same time, the total tax burden (measured in total tax revenue as a percentage of GDP) did not increase over the same period of time. This suggests that increases in environmental taxes did not result in a higher overall tax burden, instead there was a shift between objects of taxation. But, on a micro level, companies and sectors may still experience an increased tax burden, depending on the mix of production factors used (e.g. labour, capital, natural resources).

Tax revenues are partially used to stimulate energy efficiency

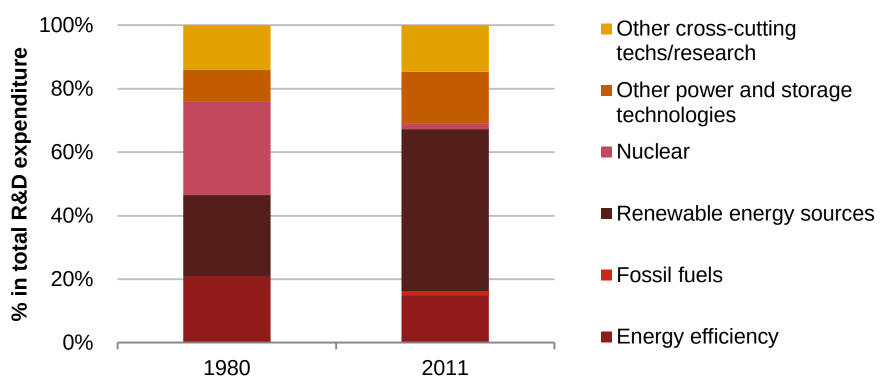
Revenues from the green tax package have been used in two ways. Firstly, they have been used to reduce taxes on labour and income. This has shifted the burden towards the resources used for production and away from the labour market (60% of the taxes). Secondly, revenues have been used to subsidise energy efficiency measures (40% of the taxes): 30% of the investment costs were subsidised and thereby reduced the investments of companies.

Overall, the taxation system has contributed to lower CO_2 emissions and higher energy efficiency. Any effects on the overall economy have not been conspicuous, since tax revenue has been redirected back to the companies in such a way that overall costs remain approximately constant. However, the implementation of green taxes has altered the relative tax burden between sectors. In general, industry has experienced a higher burden than agriculture, trade and services.

The Danish government has sought to stimulate the renewable technology industry through R&D support to help investments flow back into the economy.

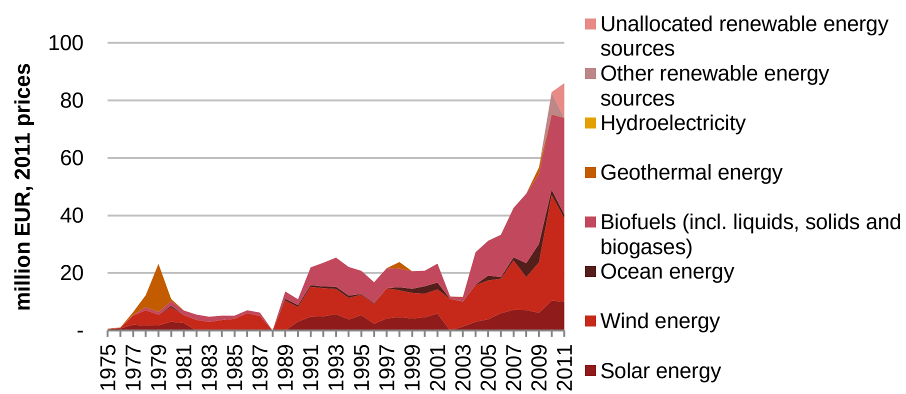
Competitiveness | Growth | Climate | Security of supply

R&D government investments in Denmark



Source: IEA

R&D investments for renewables (m EUR) in Denmark



Source: IEA

Supply-led stimulation of renewable energy technology

The Danish government has actively stimulated the renewable and energy efficiency technology industry, to increase the extent to which investments flow back into the Danish economy.

In the early 1970s, R&D support to the wind industry helped to create the standard design of the three-bladed windmill (Krohn, 2002). Manufacturers increased blade size during the 1980s as they became more experienced.

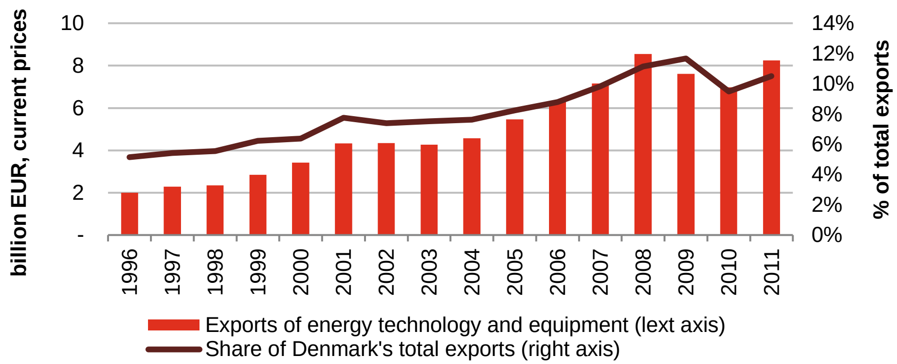
The Danish government has increased R&D investments over time and has shifted the focus to renewable related research over 1980-2011. Following a reduction in R&D investment by the government, after 2001 investment in R&D has grown at its highest ever rate. In 2008, the parliament agreed to increase the R&D budget.

The early technological support and the experience the industry gained through increased domestic demand is considered to have given the industry a competitive advantage over foreign manufacturers. When global demand increased, Denmark was strategically places to cater to it.

The early technological support and the experience the renewables industry gained through increased domestic demand is considered to have given the industry a competitive advantage over foreign manufacturers. As global demand increased, Denmark became a supplier of choice.

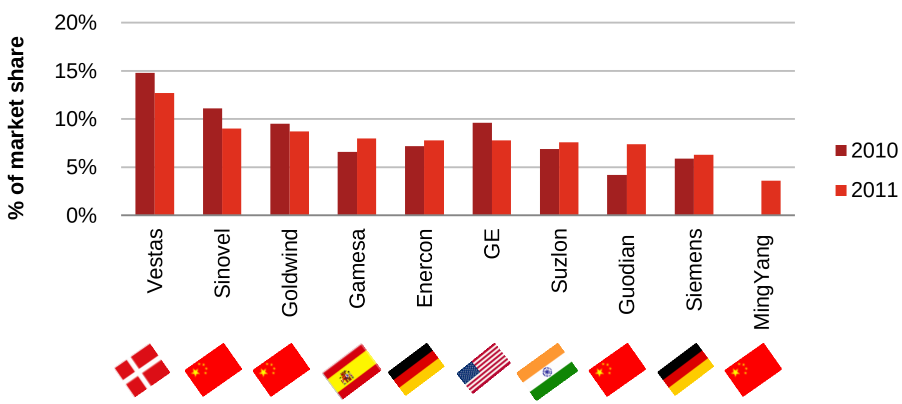
Competitiveness | Growth | Climate | Security of supply

Energy Technology exports* (bn EUR) in Denmark



Source: The Danish Energy Agency (2011)

Market shares of top 10 wind turbine producers



Source: BTM Wind Report World Market Update 2011

Increased global demand

As global demand rose, largely due to foreign government incentives, the Danish renewables industry was very well positioned to supply the required capacity. The Danish share of global wind turbine production rose to about 50% in 2002 (Krohn, 2002). The Danish company Vestas currently has a market share of about 12.7%. Energy technology exports, which includes windmills*, contributed about 11% to total Danish exports in 2011.

The industry now faces challenges due to increased competitive pressure from Chinese firms with low cost labour.

Increasing competition from China

The industry faces challenges due to increased competitive pressure from China. Due to low wages and a catch-up in technology development, Chinese wind turbine manufacturers have been gaining market share over decade. Currently, Chinese manufacturers are world leaders in terms of installed wind capacity per year. To remain competitive, Danish wind industry must innovate at a higher pace, provide higher quality and/or reduce costs by moving production to low-cost countries.

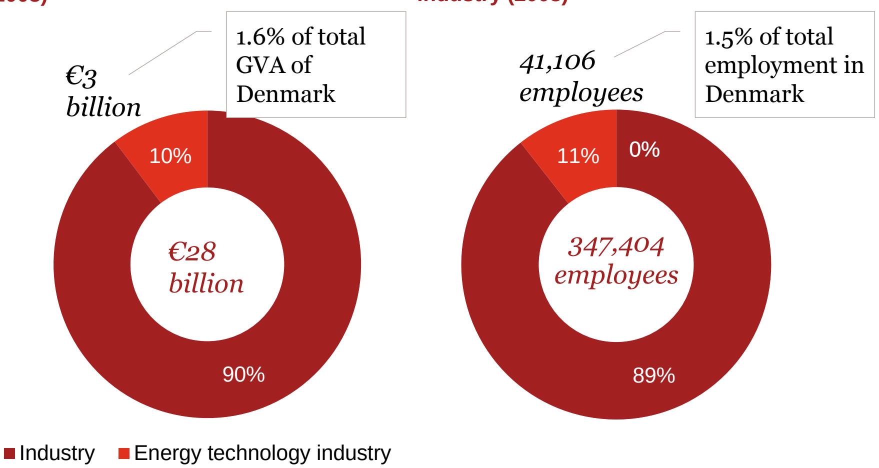
*We use the energy technology sector as a proxy for the economic impact of investments in renewable energy and efficiency technologies. This may include some companies not focused on renewables or energy efficiency, and might exclude some relevant industries focused on increasing end user efficiency, such as insulation companies.

The energy efficiency and renewable industries are estimated to contribute €3bn (1.6%) to the total gross value added of the Danish economy. They also employ 1.5% of the labour force. In addition, there are indirect economic effects not represented in these numbers.

Competitiveness | Growth | Climate | Security of supply

Value added of the Danish industry (2008)

Number of employees in the Danish industry (2008)



Source: The Danish Energy Agency (2011),

Measuring the economic impact of renewable energy and energy efficiency

Investments in a cleaner or more efficient electricity and heating system impact a variety of companies, such as those in the energy technology industry (for renewable technologies or efficiency in the energy sector), or companies focused on increasing end-user efficiency (such as insulation or construction companies, or lighting manufacturers). Since these companies work across different sectors of the economy, relevant statistics are not currently available at this level of detail. The Danish Energy Agency has recently started publishing green product statistics. Since this is relatively new, data on the relevant green business areas are not yet reliable enough to use in this decarbonisation study.

We use an earlier publication from the Danish Energy Agency concerning the energy technology sector as a proxy for the economic impact of investments in renewable energy and efficiency technologies. This may include some companies not focused on renewables or energy efficiency, and might exclude some relevant industries focused on increasing end user efficiency, such as insulation companies.

Direct economic effects - value added and employment

According to a study by the Danish Energy Agency (2010), the energy technology industry, which includes all goods used for the extraction, processing and production of energy, contributes 10% to the gross value added (GVA) generated by the Industrial sector in Denmark, or about 1.6% of total GVA in the Danish economy.

The energy technology industry also contributes 1.5% of total Danish employment. Not all of this employment necessarily increases welfare, as it may crowd out jobs in other industries. Welfare gain could therefore be limited. However, employment effects are more likely to be relevant when unemployment is high.

Indirect economic effects - spillovers to other industries

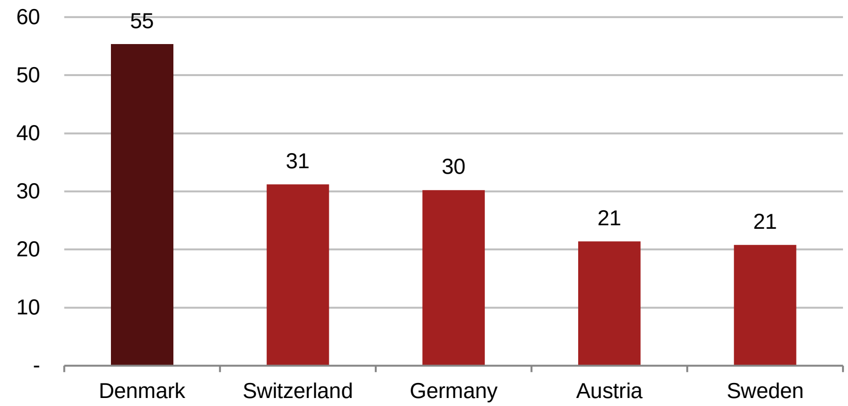
The effects on GVA and employment described above do not include the indirect effects of investment in renewable and energy efficiency technologies. Companies such as wind turbine manufacturers must purchase raw materials, such as steel and electrical components, as well as various services, from other companies to be able to produce their goods. This generates, amongst other things, further employment. However, these effects are hard to quantify due to methodological issues and lack of data. Nonetheless, they are likely to raise the contribution to national employment by several times, known as multiplier effects. We discuss innovation effects, as one of the examples of indirect effects, on the next page.

Source: Danish Energy Agency, Energy industry analysis

Investments can have effects on knowledge and innovation. Due to the nature of investment in new technologies, technological development was required to reduce the costs of renewable technologies.

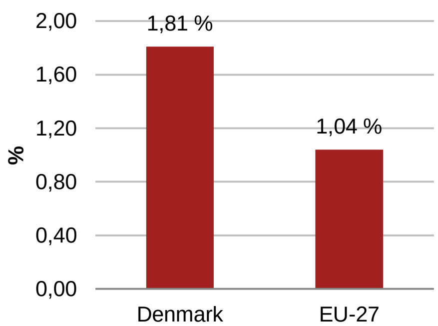
Competitiveness | **Growth**
Climate | Security of supply

Top 5 countries patent applications in renewable energy technologies per GDP (1970-2010)

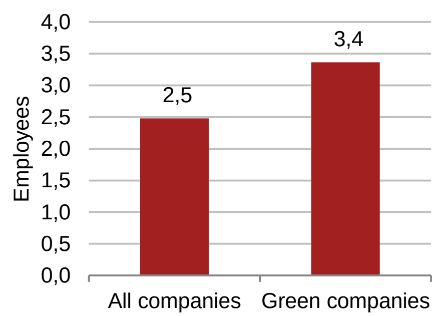


Source: Johnstone et al. (2009)

Proportion of R&D personnel (% of labor force), 2010



R&D employees per business in Denmark (2010)



Source: Eurostat; Green Production in Denmark (2012)

Increased innovation effort among clean technology producers

Denmark, as a high-income nation, cannot compete on cost alone with industries in countries where low production costs provide a decisive competitive advantage. Denmark must therefore rely on innovation to create new sources of economic growth.

Denmark has stimulated the development of its renewables and energy efficiency technology industries through R&D policies on the supply side and decarbonisation policies on the demand side.

This is, firstly, supported by Denmark having a higher percentage of personnel working in R&D than the EU-27 average. In Denmark, green companies (those that produce at least one green product) have a higher proportion of R&D employees than the average. This reflects the strong connection between R&D and green industry. Related to this, wages and educational levels are higher in Denmark's green industry than other sectors, making it an attractive and competitive industry in which to work. Secondly, Denmark has the greatest number of patents applications in renewable energy over the period 1970-2010 in the world per unit of GDP. Both features denote Denmark's search for continued innovation, as a way to remain competitive.

The deployment of decarbonisation policies resulted in large reductions in CO_2 emissions after 1990. Efficiency gains, partly driven by autonomous change, have contributed the most. The contribution of fuel mix changes to CO_2 reductions was more closely related to decarbonisation policies than efficiency gains were.

Competitiveness | Growth | Climate | Security of supply

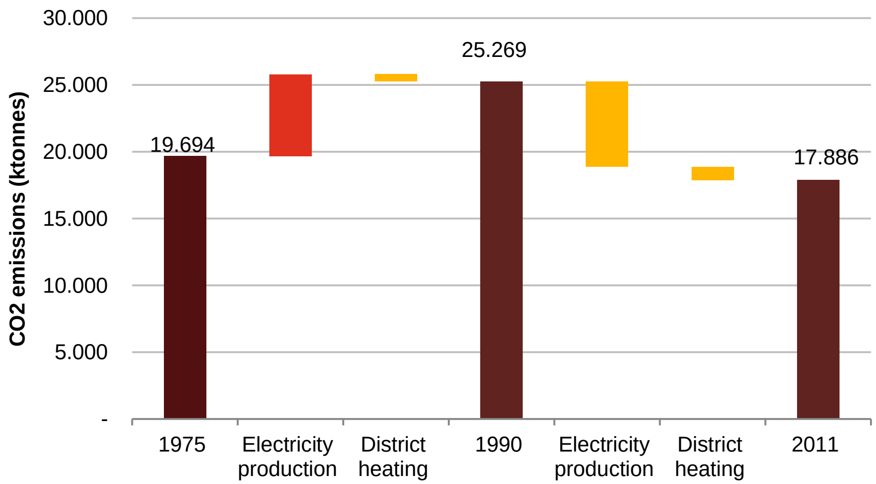
Avoided CO_2 emissions as an important economic benefit

After an increase in CO_2 emissions during the period prior to 1990, due to the increased use of coal in electricity production, energy sector CO_2 emissions started to decrease from the 1990s *(please refer to figure below)*.

If the sector had continued to produce energy using the same fuel mix and energy efficiency level as existed in 1990, CO_2 emissions would have increased by 54% as GDP rose *(please refer to figure on the right)*. Through energy efficiency gains and fuel mix changes, about 21 m tonnes of CO_2 emissions were avoided.

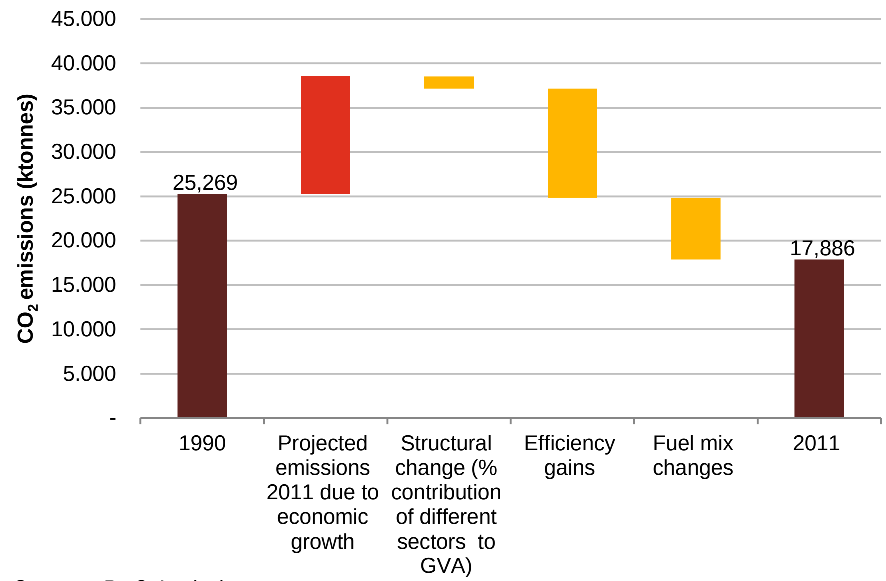
This reduction in carbon emissions was stimulated via the energy and climate policies implemented by the government. Energy efficiency gains (transmission efficiency as well as end user efficiency) have contributed the most to emissions reductions. Presumably higher energy prices provided incentives to reduce energy consumption, including by investing in energy efficiency measures. Changes in energy efficiency, however, are also stimulated autonomously. Product specifications and user demands change over time; these are not necessarily driven by government policies.

Change in observed CO_2 emissions in the energy sector, 1975-2011



Sources: The Danish Energy Agency

Avoided CO_2 emissions for the energy sector projected from 1990 to 2011, and factors mitigating these CO_2 emissions

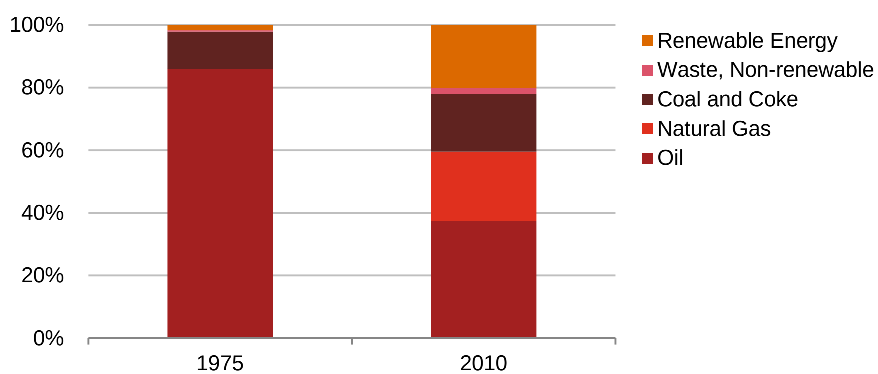


Sources: PwC Analysis

Alongside other economic trends, policy choices that increased the security of Denmark's energy supply have improved the country's competitive position. Denmark is now more resistant to oil price shocks than before these policies were enacted, benefitting the economy.

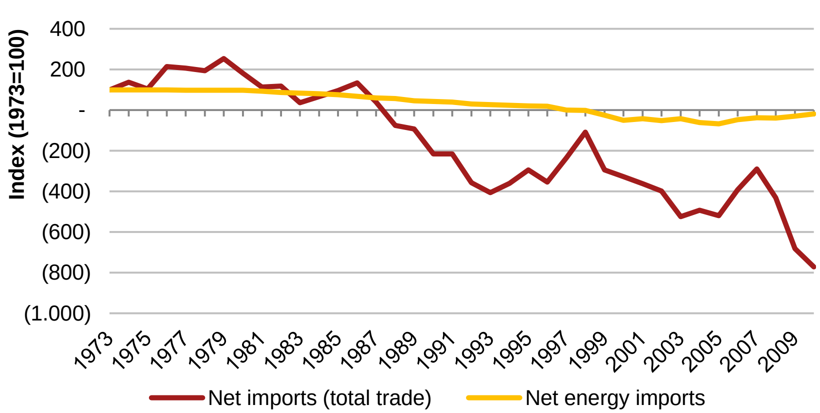
Competitiveness | Growth | Climate | Security of supply

Total primary fuel mix in Denmark (for total energy use)



Source: Danish Energy Agency

Net imports (% of GDP) and net energy imports (% share of energy consumption) in value (indexed), 1973-2010*



*Negative values in certain periods imply that the country became a net exporter

Source: Statistics Denmark; Danish Energy Agency

The oil crisis severely affected Denmark

Denmark was highly dependent on oil at the time of the oil crisis. Until 1973, companies and customers could choose their sources of energy, mainly using the cheapest ones available, oil and coal. Over 90% of total domestic energy use was provided by oil (or 65% for electricity production was oil-fuelled) in 1975. This dependency led it economy to suffer at an above-average level during the oil crisis. This resulted in an economic downturn for up to two years afterwards, with economic growth falling to -1%.

The Danish government reacted by developing policies to decrease this oil dependency, actively steering towards a more diversified domestic fuel mix and increasing energy efficiency.

Fuel mix diversification and domestic energy production

A significant reduction in oil use and an overall fuel mix diversification helped shield Denmark's industry against price shocks. The country is subsequently less vulnerable to price variations. As a result, its industry has a competitive advantage over industries in foreign countries which are still largely dependent on fossil fuels and/or energy.

Denmark was already a net exporter of goods and services in the late 1980s and has strengthened this position ever since. Denmark became a net energy exporter in the late 1990s. Security of supply policies, which have at the same time impacted decarbonisation, are very likely to have contributed to that.

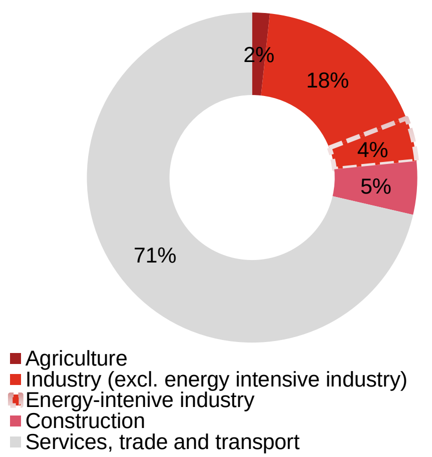
Overall, the security of supply of energy has increased, thereby reducing the economy's vulnerability to fossil fuel price shocks.

Case Study Sweden

Decarbonisation in Sweden*: Sweden's decarbonisation is characterised by a high level of nuclear power consumption since the 1970s and large share of hydro power. Ongoing debate about the future of nuclear and limited hydro power expansion made energy security a priority throughout in recent decades, with a strong focus on energy efficiency and renewables. Carbon and energy tax exemptions for biomass turned it into the most competitive fuel for heating and further decarbonised the country's fuel mix.*

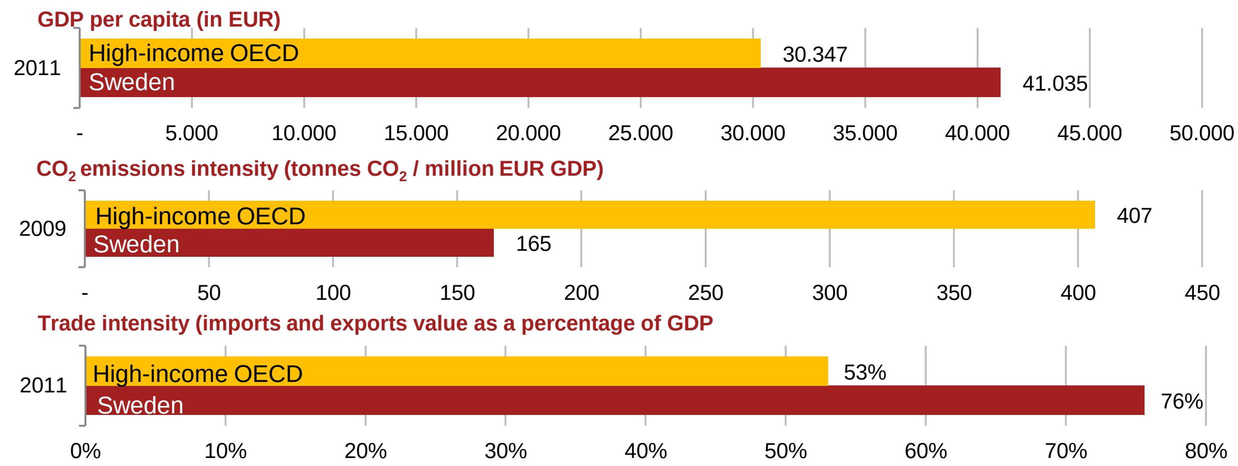
The economic impact of decarbonisation policies: *Electricity prices in Sweden are similar to the European average and even lower for industrial consumers. Energy tax exemptions and reduced CO_2 tax rates for energy-intensive industries have helped to maintain its strong competitiveness (exports grew by 8.0% annually in 1977-2011). The environmental industry is estimated to have contributed 2.1% to gross value added (GVA) and 1.6% to total employment in Sweden in 2010. Renewable energy production accounted for 0.8% of total GVA in 2010.*

Gross Value Added by sector in Sweden 2010



Source: Eurostat, Statistics Sweden
Energy-intensive industries include manufacturing of paper, products, chemicals, (basic) metals and coke/refined petroleum products

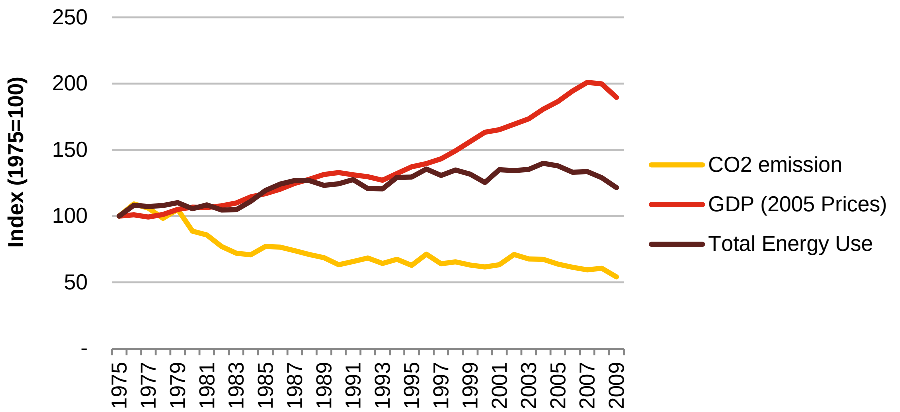
GDP 2011: €420 billion| Population: 9.45 million



Source: The World Bank

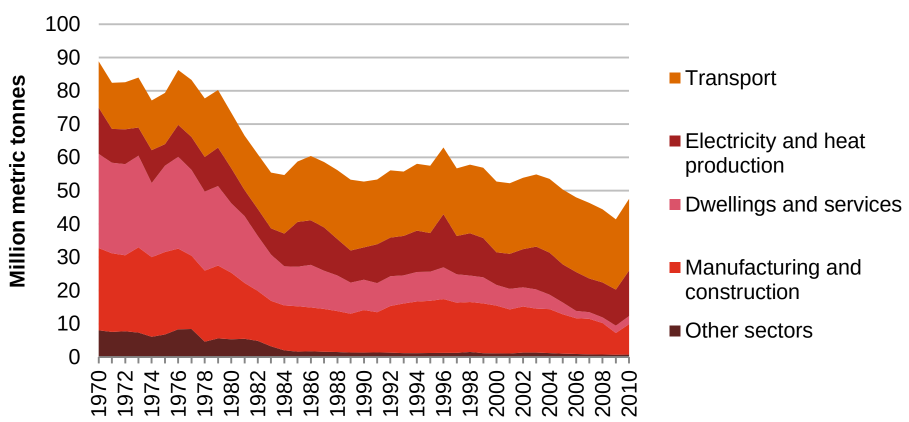
Sweden achieved economic growth while at the same time reducing emissions of CO_2. This was mainly caused by fuel mix changes, when nuclear capacity was built to replace oil-fuelled power plants. Energy use was decoupled from GDP in the late 1990s due to structural changes and efficiency improvements.

GDP, energy use and CO_2 emissions in Sweden, 1975-2009



Source: The World Bank

CO_2 emissions per sector in Sweden, 1970-2010



Source: The World Bank

Sweden has decoupled its economic growth from carbon emissions

The Swedish economy doubled in size from 1975 till 2010. However, CO_2 emissions have in general been decreasing since the late 1970s (absolute decoupling). Energy use is relatively decoupled from GDP. According to our analysis, during 1975 – 2009, a 1.0% growth in GDP coincided with a 0.7% decrease in CO_2 emissions and a 0.7% increase in energy use.

The reduction of oil use and expansion of nuclear power had already resulted in a lower CO_2 intensity by the early 1980s. Since then, emissions have been decreasing gradually mainly due to the increasing use of biofuels.

Improvement in energy efficiency, starting in the 1990s, was the major driver of decoupling GDP from energy use. Industrial users have significantly improved their energy efficiency, stimulated by increased carbon tax rates. Structural changes in the economy have also changed CO_2 intensity. The general trend towards a service-based economy has reduced energy use and carbon emissions.

Energy sector responsible for 30% of carbon emissions

In Sweden, the largest emitter of CO_2 is the transport sector, with approximately 45% of total CO_2 emitted in the country. Sweden's energy sector (electricity and heat production) emits nearly 30% of carbon emissions, followed by the industry, which is traditionally energy-intensive. Major improvements have been made in the residential and service sector, where emissions decreased by about 6% every year since 1970.

The Swedish government has put considerable effort into increasing energy security for its energy-intensive industries, relatively high electricity consumption through stimulating of fuel switching (from oil to power), and energy efficiency improvements. This has lead to a significant decarbonisation in the energy sector compared to other countries.

In the rest of this country case study, we focus on electricity and heat production and end-user efficiency connected to electricity and heat demand, key drivers of carbon emission reduction.

Energy and Climate Policies

Guide to next section:

1 *FUEL MIX*	2 *ENERGY EFFICIENCY*
Electricity	Energy sector
Heat	Households, services
	Industry

Political vision – Nuclear power has been the Swedish response to oil dependency. After the decision to phase out nuclear plants in 1980, the policy focus shifted towards energy efficiency and increased use of renewables by applying policies that drive demand for renewables.

Evolution of the focus of energy policies in Sweden

International events

- '73 – First oil crisis
- '79 – Second oil crisis, Nuclear accident in US
- '80
- '86 – Chernobyl disaster in Ukraine
- '91
- '96 – First EU electricity and gas liberalisation directive
- '97 – Kyoto Protocol; adopted in 1997, in force in 2005
- '02
- '05 – Introduction of the EU ETS
- '07 – EU Council adopts 20-20-20 goals
- '08 – Global financial crisis

Phase

1. *Nuclear capacity build-up and increasing power use*
2. *Taxation-driven decarbonisation*
3. *Market mechanism for renewables*

Policy focus

Security of supply

Until 1991

Until the 1960s, Sweden relied almost exclusively on hydroelectricity to power economic growth. However, the expansion of hydropower already ended in the late 1950s for environmental protection reasons.

The government required alternative energy sources to meet rising future electricity demand and reduce its dependency on oil. Sweden lacked sufficient domestic gas and coal resources, having only small coal deposits. Nuclear provided a strong option, as Sweden had been investing in nuclear research since the 1950s.

Yet, the future of nuclear became unclear after the nuclear accident in the US in 1979. In 1980, the government held a referendum on phasing out nuclear plants. Ambitious nuclear plans were cancelled and 12 out of 24 reactors originally planned were built during 1970-1980s. However, this was still enough to nearly completely phase out oil.

Efficiency and renewable energy

1991-2002

The focus of energy and climate policies turned towards decarbonisation through renewables other than hydro and increased energy efficiency.

Swedish tax reform in 1991 changed the incentives in the energy sector. Carbon emissions were taxed and the tax rate has since been raised significantly to facilitate further reduction of fossil fuel use, especially in the heat sector.

In 1997, the decision to close the oldest reactor in 1999 was made, yet the final decommissioning has been extended until 2012-2025. Originally, the chosen strategy in the referendum was to phase out by 2010.

In order to replace the lost capacity, the government started stimulating renewables with more demand-boosting measures, such as tax exemptions for biomass, and supply-boosting instruments, such as renewable energy investment grants.

Decarbonisation and security of supply

2002-today

The Swedish energy strategy, approved in 2002, expresses a clear goal to ensure security of supply with a strong focus on renewable energy sources. A market-based mechanism – green certificates system – was introduced in 2003 to stimulate new capacity in renewable power production with a more long-term focus than the subsidies it replaced.

The adoption of the EU energy and climate package made various energy efficiency and renewable energy requirements binding.

Policies to secure Sweden's energy supply abolished the ban on the expansion of nuclear energy capacity in 2010. New reactors are allowed to be established at current sites. Nonetheless, renewable energy is regarded as a key instrument for diversifying Sweden's fuel mix.

Political context

Political uncertainty about the future of nuclear power

Period	Government
1969-1976	Social Democrats
1976-1978	Centre Party, Moderate Party and Liberal People's Party
1978-1979	Liberal People's Party
1979-1981	Centre Party, Moderate Party and Liberal People's Party
1982-1991	Social Democrats
1991-1994	Moderate Party, Liberal People's Party, Centre Party and Christian Democrats

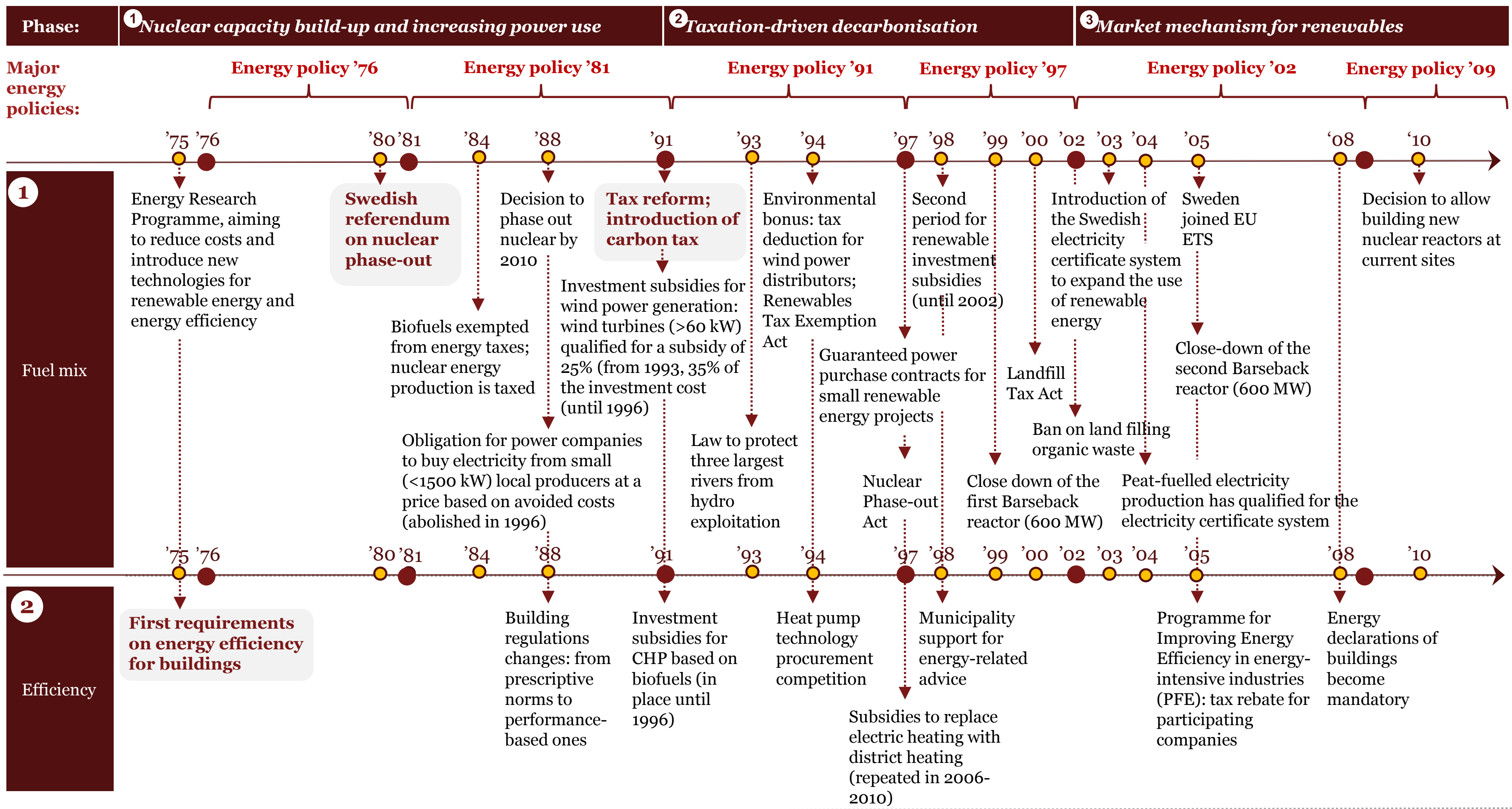
Nuclear power is a major political issue in Sweden. The right-centre parties (Moderate Party, Liberal People's Party and Christian Democrats) are generally pro-nuclear power. The Social Democrats, the party that formed the government when the first nuclear reactor was built in 1972, now supports the phase-out of nuclear power plants. In 1978, the cabinet fell due to disagreement between the Moderate and Liberal People's Parties and the Centre Party, which was against nuclear power. The Chernobyl's disaster strengthened political will to eventually stop using nuclear power.

Political agreement

Period	Government
1994-2006	Social Democrats
2006-	Moderate Party, Centre Party, Liberal People's Party and Christian Democrats

This period marked a stronger focus on renewables. In 2010, the Centre Party voted in favour of the replacement of old nuclear reactors with newer ones to reach political consensus. Yet, renewables remain a priority.

Implemented policy instruments – Until the 1990s, the most important measures were requirements for buildings' efficiency and licences to build nuclear power plants. Renewables became important after the 1991 tax reform, which imposed relatively high carbon tax levels.



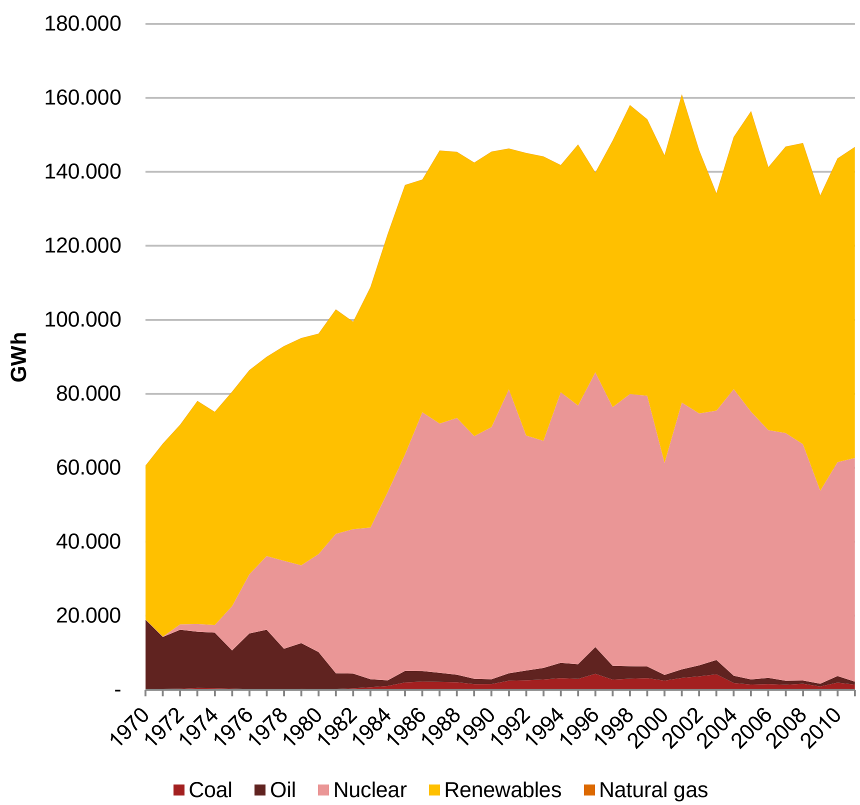
Source: IEA (policies and measures database); Swedish Energy Agency, Swedish Statistics

FUEL MIX

1 Sweden's electricity fuel mix is dominated by renewables (mainly hydro) and nuclear power. Climate change awareness since the mid-1990s has further strengthened the need to increase renewable energy capacity. Today, fossil fuels are hardly used for electricity generation.

Electricity | Heat

Electricity production by fuel, 1970-2011



Source: The World Bank

Low carbon fuel mix for electricity production

During 1970s and 1980s, after the oil crisis, security of supply drove Swedish energy policy. Given the limited domestic alternatives, the chosen strategy was nuclear power, which complemented the dominant hydropower resources.

The commissioning of 12 nuclear reactors during 1970s and 1980s in Sweden *(please refer to next page for the case study on nuclear power development in Sweden)* significantly expanded domestic power production capacity. After the last reactor had been built, the fuel mix of electricity production did not change much.

Renewables account for 57% of total electricity fuel mix *(please refer to pages 49-50 for more information on renewable policies)*. Renewable energy is dominated by hydro power. Differences in precipitation between years cause the amount of hydroelectricity generated to vary. The shortages are normally covered with imports.

Fossil fuel use (which was mainly oil) for electricity generation has fallen considerably since early 1980s and has remained limited ever since due to the lack of domestic coal or gas resources in Sweden and traditionally strong environmental awareness.

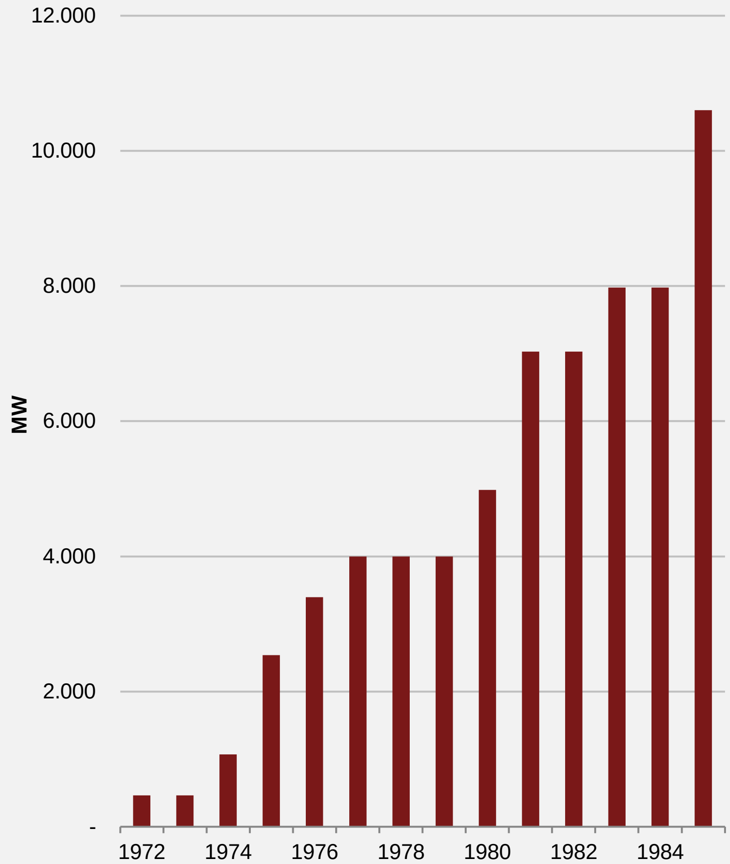
Sources: Kamp et al. Exploring Energy Transition Pathways: Insights from Denmark and Sweden (2010); Energy in Sweden 2011, The Swedish Energy Agency

FUEL MIX

Electricity | Heat

1 *Nuclear case study* – In Sweden, decarbonisation was largely achieved by introducing nuclear power. Newly built nuclear reactors during the 1970s and 1980s replaced oil-fuelled power plants and significantly expanded electricity production capacity in the country.

Commissioned nuclear capacity (MW) in Sweden, 1972-1985



Source: World Nuclear Association: http://www.world-nuclear.org/info/inf42.html

Development of nuclear power

Nuclear power in Sweden has a long history. Political parties expressed support for it as early as the 1950s. The first nuclear research programme in the 1950s was targeted at nuclear weapon development. These ambitions were soon abandoned and commercial actors realised that nuclear power could become a solution to Swedish energy security. Energy-intensive industries were largely in favour of nuclear power in Sweden, due to a common belief that this would guarantee lower electricity prices.

In 1960s, 24 reactors were planned to be built. However, amongst political parties, opinions on nuclear power were divided. Anti-nuclear arguments were based on considerations surrounding reactor accidents, long-term human health effects and nuclear waste. The Three Mile Island accident in the US in 1979 only strengthened the debate and raised serious concerns, which were made official in the 1980 referendum. There option to phase out nuclear was suggested without any option to keep it. Voters preferred to phase out nuclear power when technical and economic lifetime of power plants came to an end. Additionally, the planned 24 reactors could not all be built; only 12 of them were ever commissioned. Total nuclear capacity reached nearly 10,600 MW in 1985.

Political debate and public opinion

The referendum did not put an end to political debates. The initial plan had been to phase out nuclear plants by 2010. Yet, with every change of the government, the position changed. The phase-out debate once again strengthened after the disaster in Chernobyl, with Sweden experiencing the effects of radiation. In 1988, the Parliament decided that the phase-out would begin by shutting down two units in 1995 and 1996. The Nuclear Phase-out Act was signed in 1997 with an obligation to close the oldest reactor in 1999 but extend the lifetime of others until 2012-2025. In the end, two reactors (with combined capacity of 1,200 MW) were shut down in 1999 and 2005. In 2010, the government agreed to allow the building of new reactors at the current sites, on the grounds of mitigating climate change. This means that nuclear plants are likely to remain one of the major producers of electricity in the country. Interestingly, public opinion is generally pro-nuclear in Sweden. This support has even increased after the 1986 Chernobyl accident, from 12% supporting nuclear use in 1986 to 51% in 2009).

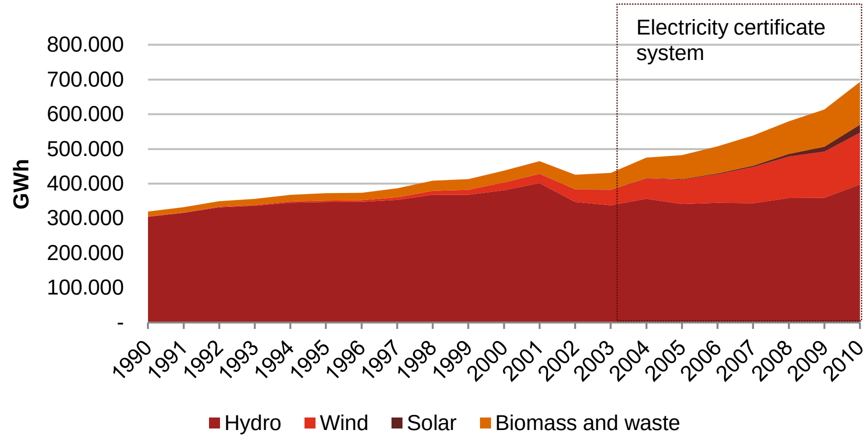
Source: Kåberger, T. *History of nuclear power in Sweden*, 2007; Holmberg and Hedberg Party Influence on Nuclear Power Opinion in Sweden 2011

FUEL MIX

Electricity | Heat

1 Most renewable electricity comes from hydro power and, more recently, from biomass. An initial focus on extensive R&D programmes had little impact on the actual growth of renewables. Demand for renewable electricity was stimulated by subsidies, later replaced by quota obligations.

Renewable electricity production by type, 1990-2010



Source: Country Factsheets 2012, Sweden (European Commission)

Large R&D investments in renewables during 1970-1980s

In 1975, Sweden started with the first Energy Research Programme. The goal of this programme was to reduce the costs of technology and introduce new technologies for renewable energy and energy efficiency. Currently, the budget is about SEK1.3bn (€130m).

Limited growth for hydropower

After hydro power had expanded significantly by the 1950s, it became a subject of environmental debates and protests against the exploitation of rivers. With increasing pressure from society, political coordination switched from fostering hydro power to restricting further developments. In 1993, a law was passed protecting the last four most important unharnessed rivers. Currently, only small-scale hydro power plants are allowed, limiting future potential for hydro power.

From supply to demand-stimulating renewable energy policies

Subsidies for investments in wind power, CHPs and small-scale hydro

In the 1990s, the government started stimulating the supply of renewable energy by introducing investment subsidies. During 1991-1996, investment in CHP based on biofuels was eligible for investment subsidies too. Until 1996, wind power projects (above 60 kW) were eligible for 35% investment subsidies, calculated on the basis of total project costs excluding land. In 1998, funding was renewed, but at a reduced subsidy level of 15%, and with a limit on the available funds. In 1998, for the first time, a 15% subsidy was introduced for small hydro plants with a capacity between 100 and 1,500 kW. The overall effect of subsidies has been small due to the lack of continuity.

Electricity certificates facilitate growth of renewables

In 2003, the government introduced an electricity certificate system to replace renewable subsidies. The instrument has spurred demand for renewables. Beforehand, the only demand-stimulating policy, introduced in 1988, was an obligation for power companies to buy renewable electricity from small (<1,500 kW) local producers at a price based on the avoided costs of producing the same amount of electricity themselves. In 1997, it was replaced with guaranteed power purchase contracts for small renewable energy projects.

With the electricity certificate system, producers of renewable electricity receive one electricity certificate for each MWh of electricity produced in newly installed capacity. Electricity suppliers and the industry are imposed with obligations to buy them. The price is determined by supply and demand. But, in the end, electricity consumers pay the price via their bills. Electricity-intensive industries are exempted from quota obligations for electricity used in their manufacturing processes to maintain their competitiveness. In 2010, utilities were required to purchase certificates corresponding to 17.9% of their electricity use, up from 7.4% in 2003. This system has resulted in increased use of biomass and wind power.

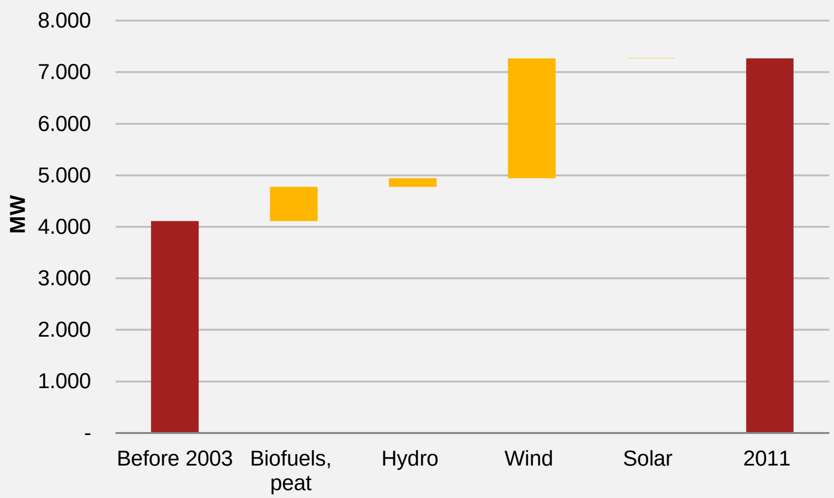
Sources: Energy in Sweden 2011; Nilsson et al. Seeing the wood for the trees: 25 years of renewable energy policy in Sweden (2004); The Swedish electricity and natural gas markets, 2010; Helby, P. Renewable energy projects in Sweden: an overview of subsidies, taxation, ownership and finance (1998)

FUEL MIX

1 *Wind case study* – Wind power in Sweden only accounts for 4% of total electricity production. This is a result of a lack of a long-term policy focus and excess nuclear power capacity, leading to low electricity prices. The sector has shown positive signs after the introduction of electricity certificate system.

Electricity | Heat

Installed capacity (MW) in renewable energy plants, commissioned before 2003 and during 2003-2011



Source: The electricity certificate system 2012, The Swedish Energy Agency

Poor incentives for investments in wind power

Wind power has a very small share at present, only about 4% of total electricity production. The development of wind power capacity, as well as other renewables, was affected by the decision in the 1970s to significantly expand nuclear power generation to meet future energy demand. Excess capacity in the market reduced electricity wholesale prices, so that wind power generation could not be profitable without any feed-in tariffs.

Government's lack of commitment to wind power development

In contrast to Denmark's low-cost, step-by-step learning curve for turbine development, starting with low-capacity machines, the government and Swedish turbine manufacturers focused on large wind mills (larger than 1 MW) with two blades, for which the market was not yet ready. Most of the turbines were imported. Moreover, the Swedish government tried to pass responsibility for national wind power expansion to some of the large utilities in the 1980s, but they did not commit to such a goal.

Investment subsidies for wind power production were introduced in 1991 and granted until 1996. A new period of subsidies was announced in 1998 to run until 2002. Clearly, subsidies have lacked continuity. At the same time, wind power generation has not been favoured through carbon taxes as fuels for power production are exempt.

Introduction of the certificate system

The government took action to reverse the situation in renewable power generation by introducing a "green" certificate system to the electricity market in 2003. Since then, wind power has been a fast-growing sector. Wind power capacity expanded by 6.5 times since 2003 and reached 2688 MW in 2011. About 74% of the renewable energy capacity installed as of 2003 was from wind power installations, followed by 21% of biofuels and peat installations. This indicates that the electricity certificate system is a more effective instrument for stimulating wind power growth, as it likely creates the necessary incentives for investments in new installations, unlike subsidies prior to the system. However, only cheaper renewables get access to the market. New technologies in a less mature phase do not get sufficient support with this system. Extra support therefore has to be given to more expensive renewable technologies. For instance the government allocated SEK 212m (€23m) for investments in solar 2009-2012. There is a second period of investment subsidies 2013-2016.

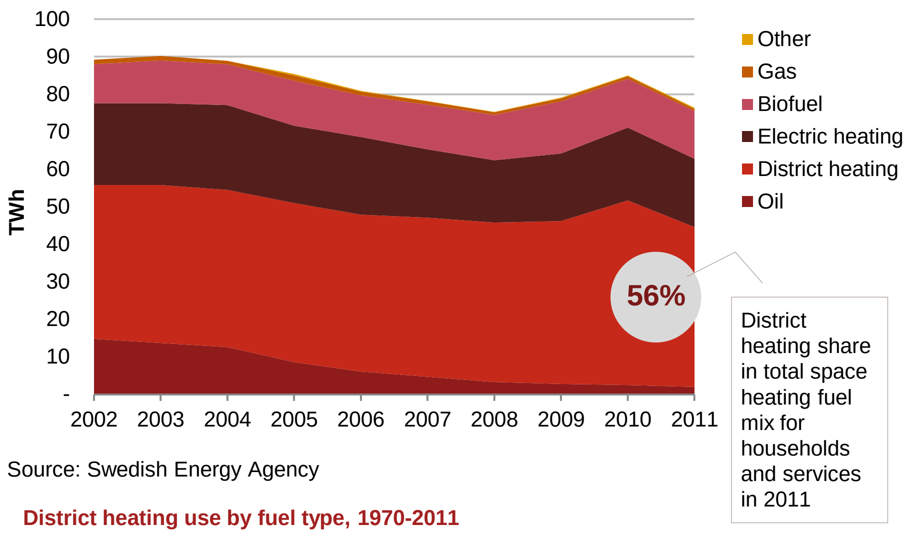
Source: The electricity certificate system 2012

FUEL MIX

Electricity | Heat

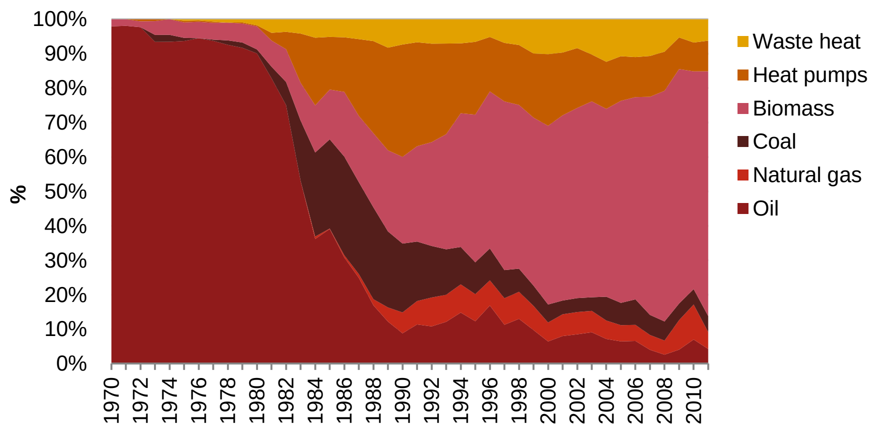
1 Sweden has significantly improved the fuel mix used in district heating. Previously fuelled mainly by oil, it now largely relies on biofuels, with the transition period being dominated by coal and heat pumps.

Space heating use by source, 2002-2011



Source: Swedish Energy Agency

District heating use by fuel type, 1970-2011



Source: Swedish Energy Agency

Heat sector dominated by electricity and district heating

The rapid expansion of nuclear power resulted in excessive and cheap electricity supply. However, electric heating used in households has increased about 5.2 times from 1970 to 1990. When electricity prices started rising, electricity heating became less popular; subsidies were provided to switch to district heating. District heating now accounts for nearly 56% of the total fuel mix for space heating in households and services (industry data is unavailable).

Fuel diversification in district heating

The Swedish state has stimulated the reduction of oil use in district heating through fuel diversification, relying mainly on renewable energy sources — industrial waste heat and ground heat (heat pumps) and biofuel.

Investments in heat pump technology

Heat pumps has started gaining market share in mid 1980s. The development of heating pumps has been supported by investments subsidies (until 1985) and technology procurement programmes (in 1994). Electricity prices were also favourable and acted as an incentive. At present, there are no direct subsidies to install heat pumps.

Tax exemptions for biomass

Biomass was exempted from energy, and later carbon, taxes, which made it the most competitive fuel in district heating applications. Biomass has replaced the coal and large heat pumps previously used to produce district heating *(please refer to page 56 for the explanation on the tax system).*

Landfill tax and ban on organic waste land filling

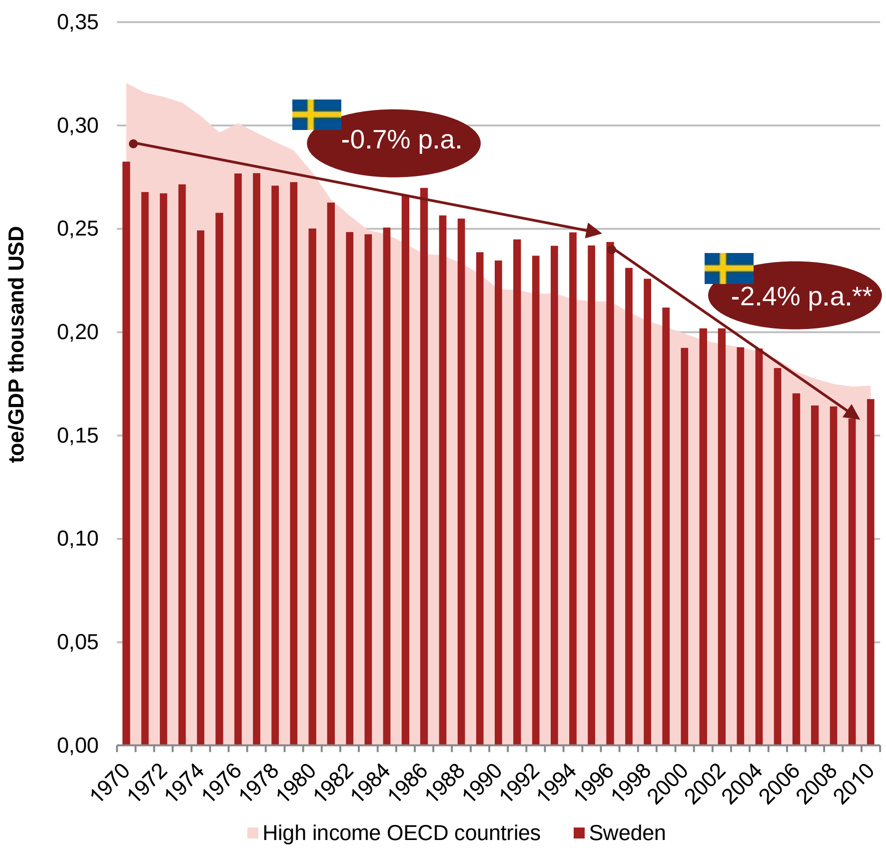
As well as the biofuels expansion, there has been a large increase in waste incineration in the past few years. It now constitutes c.18% of all fuel used for heat production. This development has mainly been driven by the Landfill Tax Act that came into force in 2000, whereby all materials entering landfill facilities are taxed, and a ban on landfilling combustible and organic waste since 2002.

Sources: Swedish Energy Agency, Kamp et al. Exploring Energy Transition Pathways: insights from Denmark and Sweden(2010); Swedish ground source heat pump case study 2011

ENERGY EFFICIENCY

2 After the significant nuclear expansion of the 1970s and 1980s, Sweden's energy intensity exceeded the average of high-income OECD countries. But, from the 1990s, high energy and carbon taxation combined with efficiency measures have helped to reduce it to the average level.

Primary energy intensity (toe/GDP thousand USD)*, 1970-2009



*The energy intensity includes the transport sector
**** Change in primary energy intensity; Final energy use intensity decreased by - 2,7% annually (1990-2011)

Source: The World Bank

Energy intensity has decreased since 1970

Energy efficiency became an important pillar in the Swedish energy politics since the 1970s, when nuclear debates intensified. Reducing energy demand was a means to improve security of supply.

Yet, after a significant expansion of nuclear capacity that resulted in low electricity prices, the energy intensity in Sweden did not improve significantly until early 1990s. When energy prices started increasing due to taxation, the country started reducing its energy intensity at a rate of 2.4% per year to reach the level of the high-income OECD countries in 2009. Various financial incentives (in a form of subsidies and investment grants), obligations and information measures (building and appliance labelling), and environmental taxes (energy and carbon taxes) are likely to have affected both industrial and household/services energy consumption. A part of energy savings is offset by a so-called rebound effect, which means that decreased energy costs enable households to increase consumption of energy or other goods and services.

In 2006, the government signed A National Programme for Energy Efficiency and Energy-Smart Construction, where it was agreed that energy use in residential buildings and commercial premises should be reduced by 20% by 2020 and 50% by 2050 relative to energy use in 1995.

Energy intensity depends on the following:

1. Efficiency in the energy sector
2. Efficiency of end-users of energy (households, services and industry).

In Sweden, the most improvement has been made in the energy efficiency of end users. The energy sector's efficiency, which reflects the end energy extracted from primary energy carriers, did not change. Underlying strategies and policy choices will be discussed in the next three pages for:

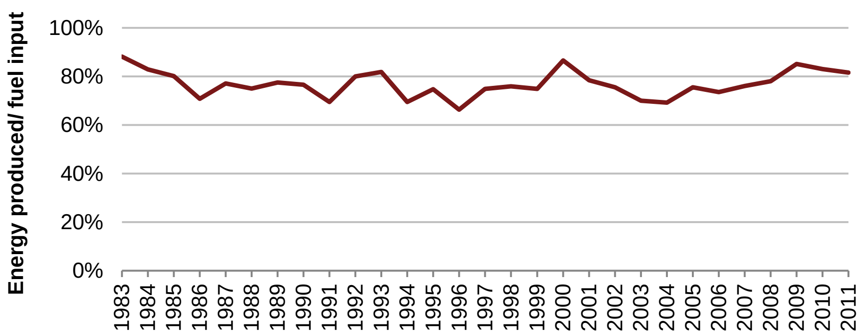
Energy sector + Households, services + Industry

ENERGY EFFICIENCY

2 Efficiency in the energy sector has not improved since the introduction of nuclear power plants. Therefore, no CO_2 emission savings have taken place due to a more efficient energy transformation process. The potential of CHP plants remains limited.

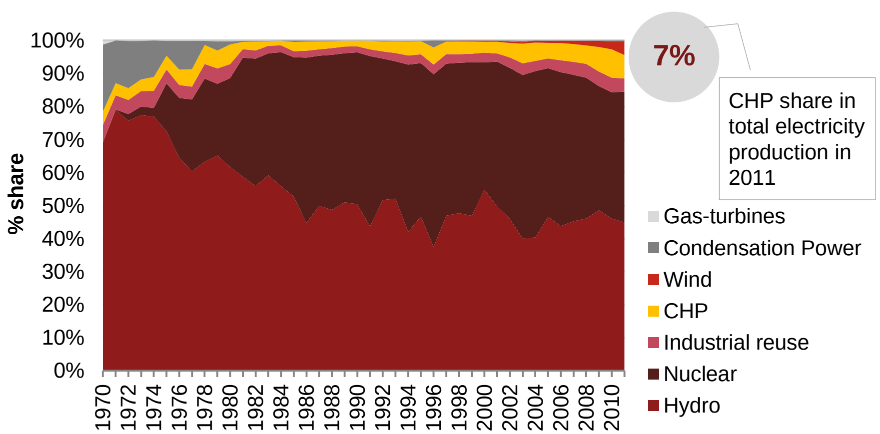
Energy sector | Households, services | Industry

Efficiency in the energy sector (total electricity and district heat production), 1983-2011



Source: PwC analysis, based on Swedish Energy Agency data

Electricity production per type of producer in Sweden, 1970-2011



Source: Swedish Energy Agency

Stable efficiency in the energy sector

The energy sector's efficiency did not change significantly over the period between 1983 and 2011. It is still arguably quite high, however, due to a large share of hydro power. Hydro power has a given 100% efficiency, meaning that no energy losses occur.

Limited CHP utilisation

A specific aspect of the energy sector in Sweden is the poor utilisation of CHP potential. One reason for this is that CHP generation has faced competition from nuclear power. Low carbon emissions due to low degree of combustion for electricity production in Sweden have also contributed to weaker incentives to build CHP plants. Additionally, installed heat pumps reduce the demand for district heating. Lastly, the load for district heating systems is too diverse for many CHP plants to operate economically.

In 1991, the government introduced investment subsidies for CHP based on biofuels (in place until 1996). Yet, only about 7% of electricity is produced in CHP plants. The current taxation system provides reduced rates for heat generation from CHP. New CHP plants run mainly on bioenergy, as the focus of the energy policy has already moved to lower carbon solutions. Alternatively, peat, natural gas, oil and coal are used. But, all in all, the potential for CHP plants remains limited.

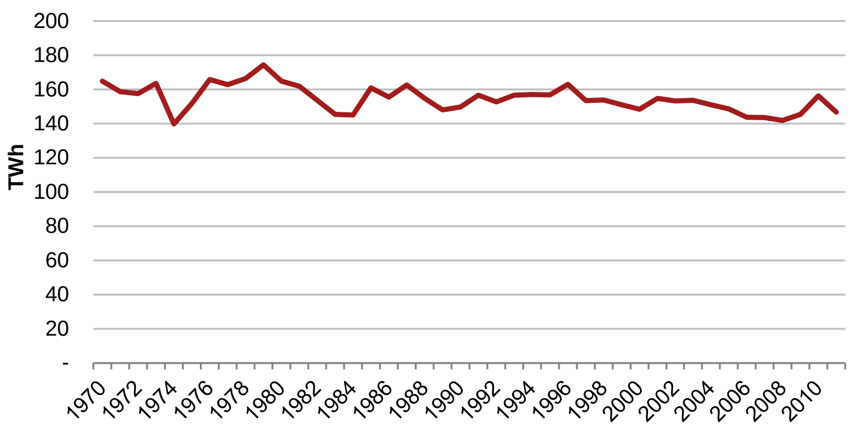
Source: European Summary Report on CHP support schemes, 2010

ENERGY EFFICIENCY

2 The government has adopted financial, regulatory and information measures to stimulate energy efficiency in dwellings. Expansion of district heating and energy-efficient buildings have become priorities, but electricity consumption has not decreased.

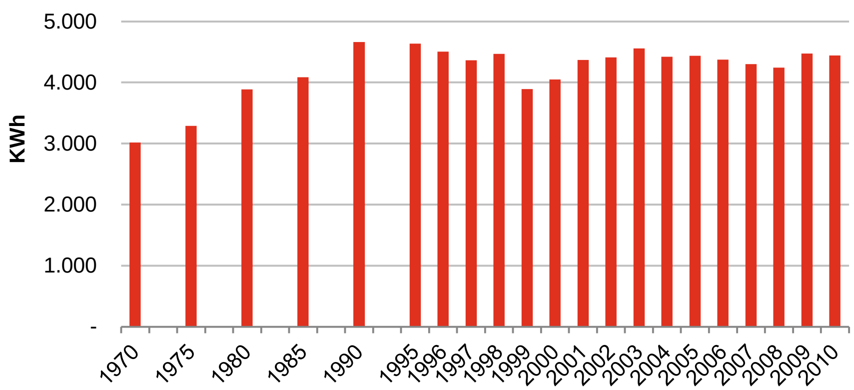
Energy sector | **Households, services** | Industry

Total energy consumption in household and services (1970-2011)



Source: Swedish Energy Agency

Electricity consumption per household (excluding electricity used for heating), 1970-2010



Source: Swedish Energy Agency, Swedish Statistics

Total energy consumption decreased, electricity use increased

Energy efficiency has greatly improved in households and services. Total energy use decreased by -0.3% during 1970-2011, despite the increasing number of users. At the same time, household electricity use increased from 1970, but it stayed stable since the start of the 1990s.

Building regulations implemented in the 1970s

The first requirements for energy efficiency in buildings were introduced in 1975. The requirements were mainly related to specific technologies (e.g. boilers) and their efficiency. Regulations shifted to performance-based measures in 1988, when requirements were set for the efficiency of entire buildings. But, it has become more challenging to verify compliance, as performance-based codes require more complex calculations and no strategic evaluation plan was developed. Since 2008, owners are required to declare the energy use of their buildings (energy labelling). Declarations entail proposals for improvements, assessed by authorised energy experts.

Investment grants to improve energy efficiency since 1977

Insulation, energy measures, maintenance measures and solar heating systems have been subsidised by the government since 1977. Typically, around 30% of the costs could be reimbursed. The government has also provided subsidies to switch to district heating (in the late 1990s and then 2006-2010).

Energy counselling in municipalities since 1998

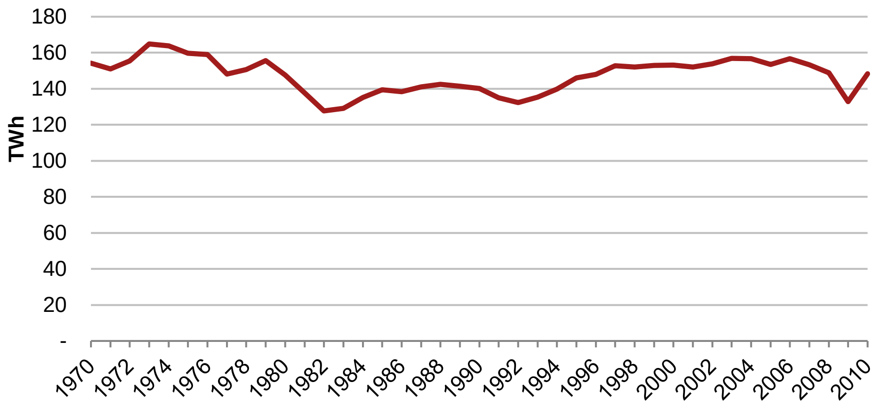
Since 1998, a large share municipalities in Sweden have provided energy and climate advisers to households and companies. Their role is to give free advice on energy efficiency as well as government grants in fields including energy, heating systems, and bioenergy. Yet, the effectiveness of this programme is questionable, as it set no specific targets.

Source: ODYSSEE-MURE 2010 *Energy efficiency policy and measures in Sweden*

ENERGY EFFICIENCY

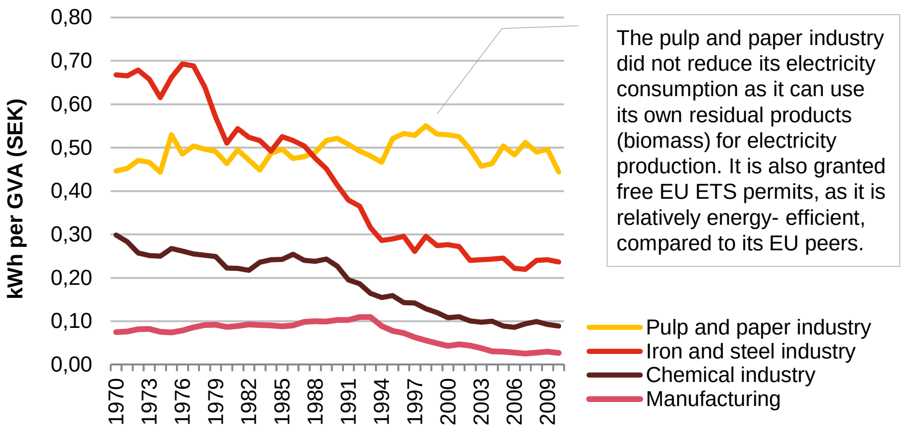
2 There have been large improvements in the energy intensity of most energy-intensive industries. The most important drivers were energy taxes, rising electricity prices and carbon taxes.

Total energy consumption in industry, 1970-2010



Source: Swedish Energy Agency

Industry specific electricity use (kWh per value added), 1970-2011



Source: Swedish Energy Agency

Energy efficiency improved in industry

Total energy consumption has fluctuated between 130TWh and 160Twh in the last three decades. Swedish energy-intensive industries have significantly reduced electricity consumption per unit of production value added. The average reduction was c. 3% p.a. in iron and steel, chemical and manufacturing industries, except for the pulp and paper industry *(please refer to the adjacent chart)*. The trend is mainly due to energy taxation, which was later complemented with carbon taxes and increasing electricity prices.

Tax reductions and exemptions

As previously mentioned, the Swedish tax system has been designed so that an industry, particularly an energy-intensive industry, is granted favourable conditions to prevent carbon leakage and competitive pressure from countries with less stringent carbon or energy taxation. On the one hand, it gives a competitive advantage to the industry but, on the other hand, it may slow down improvements in energy efficiency. But, the taxes that the industry pays relate to the general carbon tax rate, so that if the full tax rate increases, the industry will also have to pay more.

Energy efficiency programme for energy-intensive industries

In 2005, the programme for Improving Energy Efficiency in energy-intensive industries was introduced. Participating companies have invested over SEK 700m (€78m) in the more than 1,200 electricity efficiency improvement measures implemented during the programme period. In return, they are granted tax rebates.

These measures alone have generated savings of SEK 430m p.a. (€48m). The average payback time for the measures is 1.5 years. In addition to the direct improvement in the use of electricity, the companies have also been able to increase their internal electricity production by 1 TWh p.a. through processes such as discharging process steam or making turbines more efficient.

Source: Energy in Sweden 2011

FUEL MIX & ENERGY EFFICIENCY

1 & 2 One of the most important policies in Sweden has been energy and carbon taxation. The government has adopted high levels of carbon taxation to discourage the use of fossil fuels for heat production. It has also created incentives to foster biomass use.

Current energy and carbon rates (excl. transportation sector) in Sweden, 2012

	CO2 tax	Energy tax		
		Coal	Natural gas	Oil
1. Heat production/fuel combustion for heat				
Fossil fuel	€114/tonne	€69/ m3	€100/ 1000 m3	€91/ tonne
Biofuel, peat	€0/tonne	-	-	-
In industry; agriculture; forestry; cogeneration	30%*	30%	30%	30%
2. Electricity production				
All sources	0	0	0	0
3. Electricity consumption				
Industry and agriculture	0	0.06 cents/kWh		
North Sweden	0	2.13 cents/kWh		
South Sweden	0	3.21 cents/kWh		
4. Nuclear capacity				
Maximum thermal power	-	0.67 cents/kWh		

* Only industry and cogeneration that are outside the EU ETS pay 30% of the carbon tax rate; otherwise, only energy tax is applied

Sources: Ministry of Finance; Ministry of Environment

Energy and carbon taxations are important fiscal instruments

First introduced in 1957, energy taxes have a long history in Sweden. The goal of energy taxes is to encourage energy efficiency improvements. Tax differentials between different fuels can have an impact on the fuel mix and power use. In Sweden, high oil taxes led to the increased use of coal, electricity and biomass during the 1980s.

Sweden introduced a carbon tax of SEK 250 (€28) per metric tonne in 1991 as a part of a broader tax system reform in which general energy taxes were reduced and the VAT was extended to energy. The tax applies to heat production (district heating, cogeneration, and heat production in industry, households and the service sector). Carbon taxation serves the purpose of encouraging a cleaner fuel mix, and mainly using renewables. Sweden has increased the carbon tax in steps, reaching €114/tonne CO_2 in 2012. In comparison, the carbon price in the EU ETS has fluctuated below €10/tonne since the end of 2011.

Biomass favoured in the fuel mix for heating

Biofuel was exempted from taxes and this radically improved the competitiveness of biomass energy generation. In (district) heating applications, biomass became the least costly fuel. Other fuels used for district heating generation bear the full tax rate.

Households and services fully taxed

In Sweden, households and the service sector pay the full CO_2 tax rate. This has led to reduced energy use in households and the service sector and a switch to electric or district heating.

Industry's competitiveness is safeguarded

Industry and cogeneration pay reduced carbon and energy tax rates. Until 2011, the industrial sector was granted a full energy tax rebate for fossil fuels used in manufacturing processes. In 2011, the energy tax exemption was changed to 30% of the standard tax rate. The carbon tax also applied, but at a reduced rate.

Sources: Sweden: inventory of estimated budgetary support and tax expenditures for fossil fuels, OECD 2010; IEA energy policy review Sweden 2013

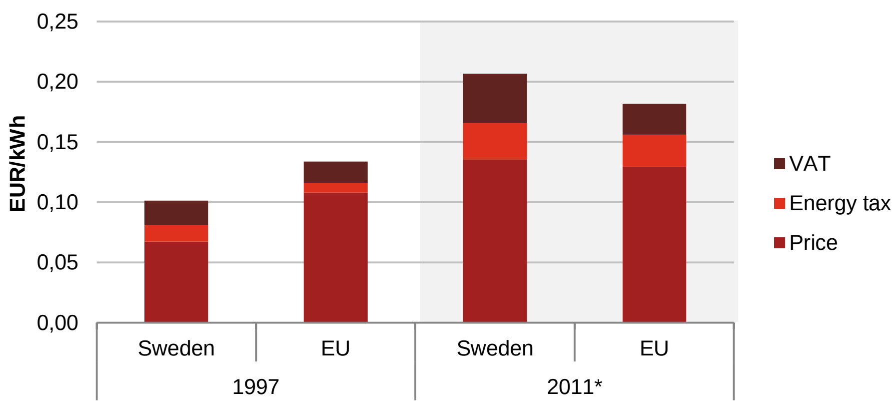
Economic Impact of the Energy and Climate Policies

Guide to next section:

Competitiveness	Growth (new industries)
Climate	Security of supply

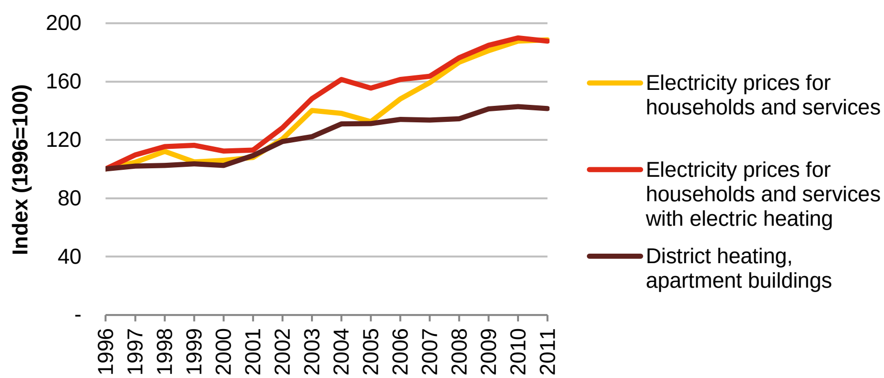
Swedish consumers are paying 10% more than the average European consumer. The average electricity bill has increased over the years, as both electricity prices and consumption have risen.

Electricity prices for domestic consumers in 1997 and 2011*



Source: Eurostat

Energy prices for households in Sweden (indexed), 1996-2011



Source: Statistics Sweden

* A new methodology was adopted in 2007, so values before 2007 are not comparable.
2011 EU data includes 27 Member States, whereas 1997 includes EU-15

Consumers are paying higher energy bills

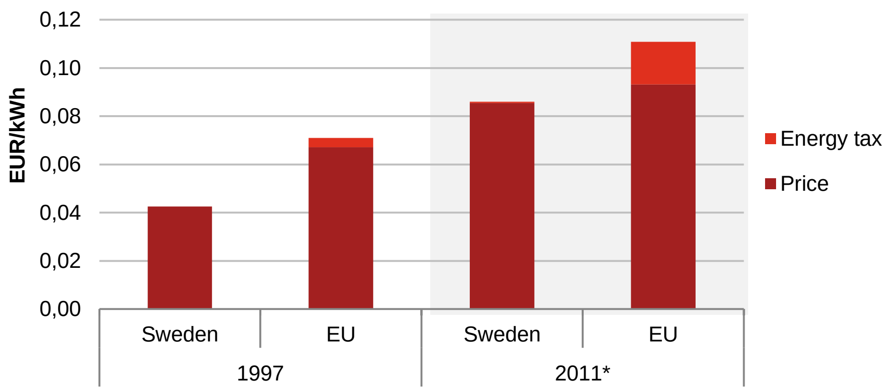
As we have seen earlier, the average electricity consumption per household has increased since 1970. Electricity prices have risen too. Compared to 1997 (the earliest available year), consumers are paying over 100% more. This means that the average electricity bill has increased in Sweden. The prices are also affected by temperature swings, as some years are exceptionally cold or dry and that causes electricity prices to rise. But on average the price trend is upwards *(please refer to the adjacent graph with energy prices for households in 1996-2011).*

The building efficiency measures (for instance, support to switch from electric heating to district heating or efficient domestic appliances) discussed earlier have contributed to stable electricity demand n households. But this is partially explained by the increasing use of various domestic appliances, which offset efficiency gains.

District heating prices have also increased in the period between 1996 and 2011, yet at a more moderate pace. Since the price for electric heating (cents/kWh) is about 80% higher than the price for district heating, consumers have an incentive to choose district heating systems over electricity heating for their homes, or, alternatively, heat pumps, which is a more economical option than pure electric heating, where electricity prices are rising.

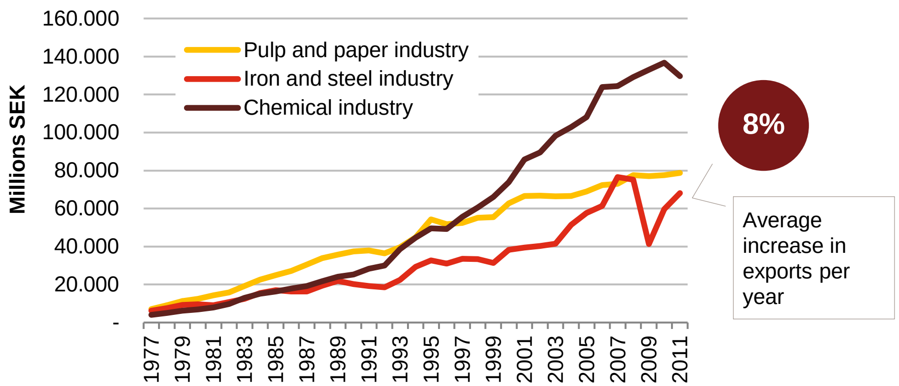
Nuclear and hydro power exploitation enabled access to relatively cheap electricity in Sweden. Industry, which is traditionally energy-intensive, is paying less than the European average and has maintained its competitiveness.

Electricity prices for industrial consumers in 1997 and 2011



Source: Eurostat

Exports of energy-intensive industries (million SEK), 1977-2011



Source: Statistics Sweden

* A new methodology was adopted in 2007, so values before 2007 are not comparable. 2011 EU data includes 27 Member States, whereas 1997 includes EU-15

Industry competitive despite increasing electricity prices

The government's choice to invest in nuclear capacity expansion mainly served the purpose to ensure low electricity prices for industrial use and to prevent any price shocks due to dependence on energy imports.

The pulp and paper industry controls much of the biomass flow as both producer and user of wood and by-products. As a result, this industry is an important player in the energy market and has a strong interest in low fuel and electricity costs. Support for nuclear power development has therefore been strong; it was believed that it could guarantee lower electricity prices.

However, the average price has increased over time, particularly after the introduction of the electricity certificate systems and due to gradually increasing taxation (industry is paying reduced rates, but these still depend on the full rate). Still, Swedish industry pays 20% less than European average electricity prices. The low cost of produced electrical energy balances the traditionally expensive cost of the Swedish workforce, therefore making Swedish production competitive on the world market.

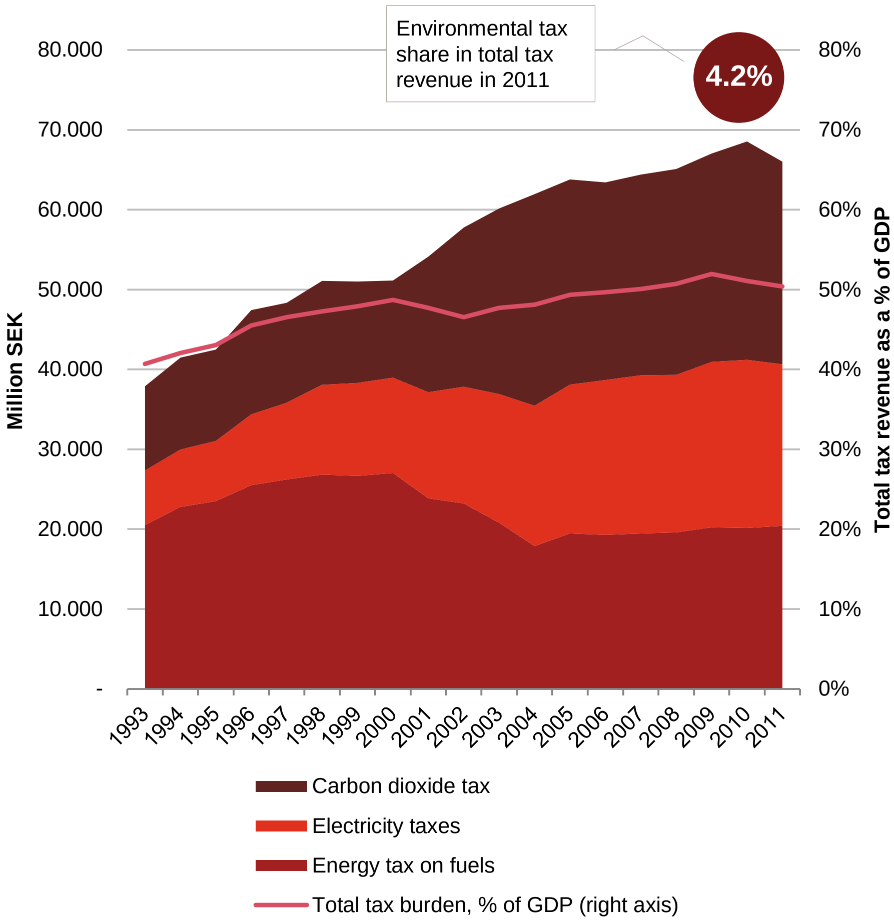
Combined with significant efficiency gains (stimulated by taxation and government's energy efficiency programme), Swedish industry has benefited from energy policies, such that energy-intensive industries have experienced 8% p.a. export growth since 1977. In comparison, GDP over the same period has increased by 2% p.a..

Around 5% of the total labour force is employed in energy-intensive industry, creating 19% of industry's GVA in 2010. Maintaining electricity prices at relatively low levels is therefore crucially important. Sweden had to complement hydro power with another source of energy that would increase neither electricity prices nor carbon emissions. Nuclear power policy, as a very important part of the Swedish energy strategy, has allowed the country to increase its domestic energy production at a rather low cost and at the same time reduce carbon emissions. At the same time, favourable taxation, combined with the financial support, has allowed industry to modernise.

Competitiveness | Growth | Climate | Security of supply

The Swedish environmental tax burden is one of the highest in Europe. The 1991 tax reform changed the fiscal landscape: labour taxes were reduced, while indirect and environmental taxes were raised. CO_2 taxes became an effective instrument to stimulate energy efficiency and renewable investments.

Environmental taxes and their share in GDP in Sweden, 1993-2011



Source: Statistics Sweden

Tax reform to stimulate employment

Sweden's 1991 tax reform was the first shift in the tax base from traditional factors (income) to pollution. The background for the tax was a combination of very high marginal income tax rates and rising environmental awareness. This tax shift is traditionally considered a "double dividend", as it is believed to both stimulate employment and discourage pollution.

Total tax burden increased

Total tax receipts from energy, carbon and electricity taxation have increased over the years in absolute terms. Sweden's total tax burden, measured as total tax revenue as a percentage of GDP, has also steadily increased during 1993-2011. But the share of environmental tax revenue in total tax revenue has declined from 4.9% in 1993 to 4.2% in 2011. This suggests that at a macro level environmental taxation is unlikely to be a driver for the increased tax burden in Sweden. But, on a micro level, companies and sectors can still experience high environmental tax burdens, depending on the mix of production factors used (e.g. labour, capital, natural resources).

In 1993, successful lobbying by energy-intensive industries claiming that the competitiveness of Swedish firms and, therefore, employment in Sweden were was being hurt prompted the government to reduce environmental taxes for industry. This has since changed, and energy-intensive industries' tax rates have now increased substantially.

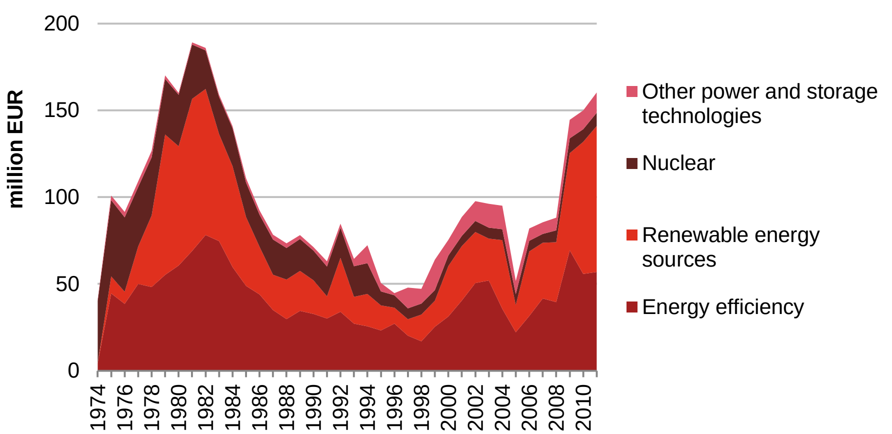
Hoerner and Bosquet (2001) estimate that for households, environmental taxes reduce their real incomes, depending on their use of energy. Richer households bear the highest costs, given their greater use of fossil fuels. It is important to bear in mind that these calculations do not include the value of environmental benefits, such as the avoided costs of climate change or air pollution.

Source: Hoerner and Bosquet Environmental Tax Reform: The European Experience (2001)

The government chose a supply-led strategy to promote renewables in the 1980s, investing in R&D. This did not result in changes in the energy balance, yet is considered an important foundation for the later expansion of biomass-fuelled plants after recent tax reforms.

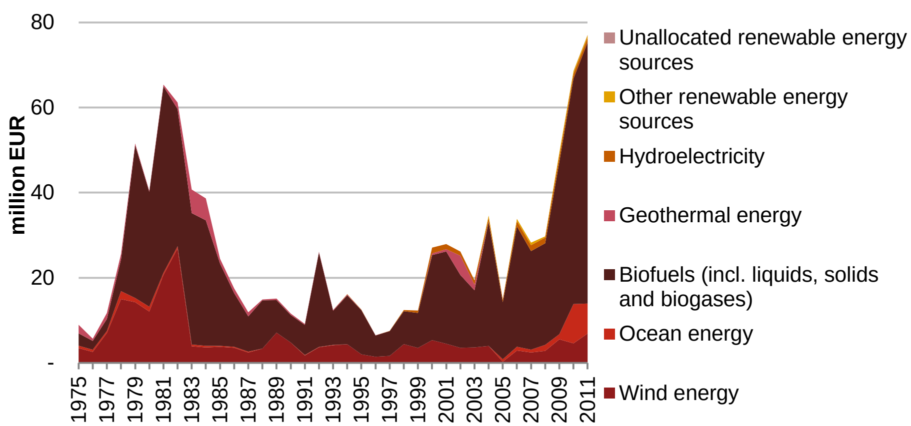
Competitiveness | Growth | Climate | Security of supply

R&D budget in Sweden, 1974-2011



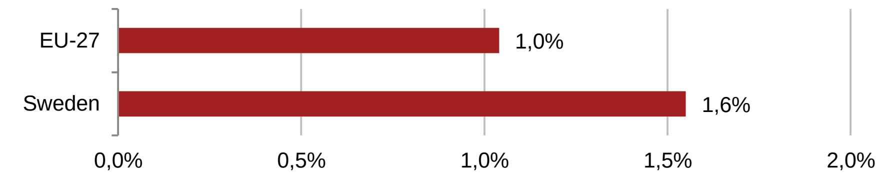
Source: IEA

R&D budget for renewable energy sources, 1975-2010



Source: IEA

Share of R&D personnel (% labour force), 2010



Source: OECD Statistics

Biomass applications have been developed the most

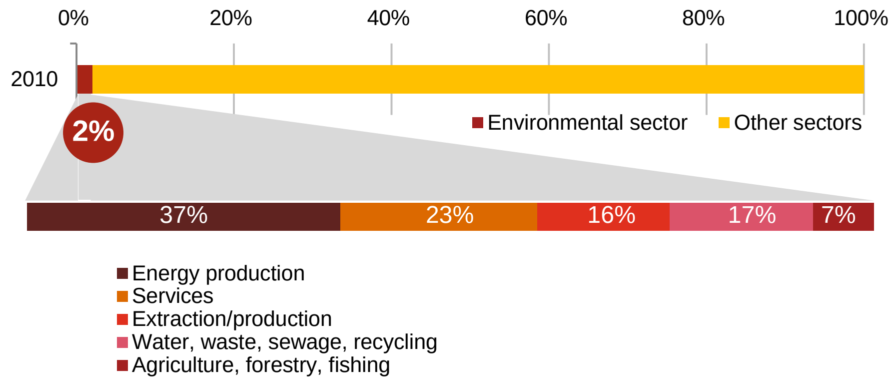
Investments in R&D have been traditionally large in Sweden. This results in a larger proportion of R&D personnel in Swedish companies (c. 1.6% of total labour force) relative to the EU average (c. 1.0% of total labour force).

In the late 1970s, the focus of R&D shifted from nuclear to renewable energy. Over time, a large share (c. 35% in 2011) has been invested in efficiency research and development. Currently, c. 73% of investment in renewable energy R&D has been devoted to biofuels research. Overall, between 1974 and 2011, around 50% of funds have been invested to develop biofuel equipment and improve production processes. Combined with tax incentives for biofuel use, investment has enabled the large-scale use of biomass for district heating. However, since biofuels are largely by-products of the forestry industry, no new manufacturing activities were created.

When it comes to the technological advancement of biofuel-based plants, the government has adopted a strategy of technology procurement programmes. However, this is not limited to domestic industrial producers, so the overall domestic effect of investment in biomass research is very hard to capture.

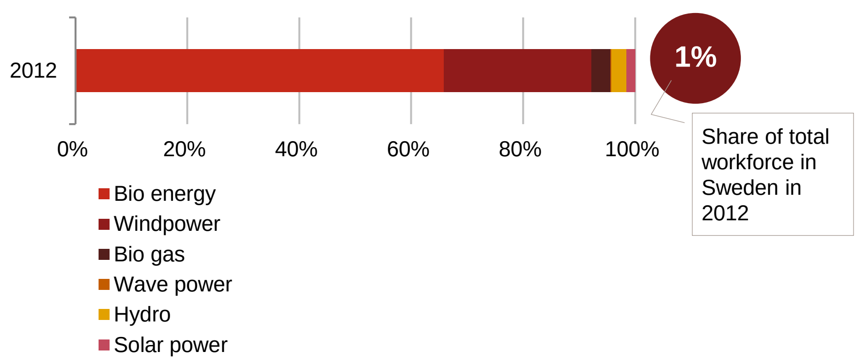
The gross value added (GVA) of the broader environmental sector in Sweden is about 2.1% of total GVA with 1.6% of the workforce employed in the sector. Employment in the renewables sector is relatively small (1%) as generation is capital-intensive.

Gross value added (% total) in Sweden, 2010



Source: Statistics on the environmental sector 2010

Employment (number of people) in renewable energy sector in Sweden, 2012



Source: Greenpeace Green Jobs report 2012

The broader environmental sector is contributing 2.1% to GVA

According to the Swedish agency for growth policy analysis, 69,000 people are employed in the environmental sector, which includes a broader range of "green" activities than renewable energy alone). Although the environmental sector appears quite small and in 2010 accounted for about 1.6 % of the total workforce, its value added was estimated at SEK 60.6bn (€6.7bn), which translates into c. 2.1% of GVA. Renewable energy production alone contributes 0.8% to total GVA and 1.0% to employment.

Generating employment

Bioenergy and wind as the largest sources for employment

The largest share of employees in the renewable energy production industry is in the bioenergy industry (25,000 jobs, or 66% of all jobs in renewables). These jobs are found in several different sectors such as agriculture, forestry, transport and industry. A branch of bioenergy is biogas, which has an additional 1,300 employees*.

The wind industry is the second-largest renewable energy employer, with about 10,000 employees in Sweden, which is just under a half the number of employees in the neighbouring Danish wind industry.

The dominant hydro power sector has not provided employment

Although hydro power is the largest provider of electricity in Sweden, it only has around 1,000 employees. However, besides the 1,000 directly employed in hydro power, it supports related jobs in renovation and research for increased hydro power efficiency.

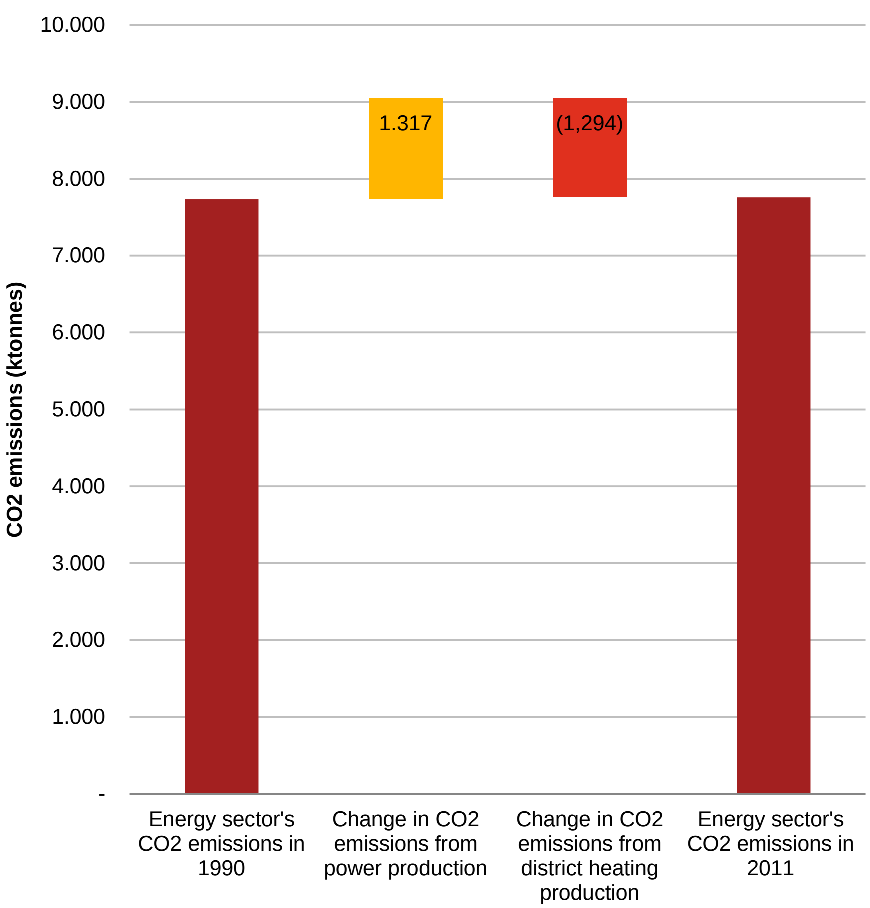
It is important to remember that "green" jobs are to some extent also replacing jobs in conventional power production; but, employment in the renewable energy and energy efficiency industries provides a "double" dividend – it is contributing to decarbonisation and environment, as well as enhancing the general economic welfare.

Source: Greenpeace Green Jobs report 2012; *Energigas Sverige; Swedish Agency for Growth Policy Analysis; Statistics Sweden for the Environmental sector

Deployed decarbonisation policies have resulted in considerable avoided CO_2 emissions. This is principally due to decisions on electricity production technologies, and thereby the fuel mix.

Competitiveness | Growth | Climate | Security of supply

Change in observed CO_2 emissions in the energy sector, 1990-2011



Sources: PwC analysis, based on The Swedish Energy Agency data

Electricity sector to contribute to large CO_2 savings

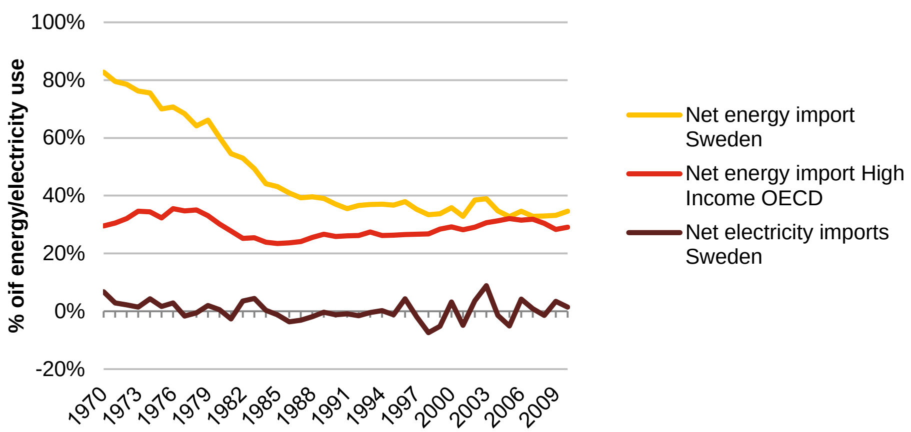
Since late 1970s Sweden has significantly reduced its CO_2 emissions in the energy sector, in relation to the amount of energy produced to fuel economic growth. As mentioned earlier, the additional energy needed to fuel economic growth has been produced by nuclear and hydro power. Therefore, economic growth has been realised without substantially increasing the CO_2 emissions of the energy sector. Currently, the majority of the CO_2 emissions in the energy sector is related to district heat production, but the share has been decreasing – around 80% in 1990 and 64% in 2011.

Since 1990, emissions from electricity production have increased *(please refer to the adjacent graph)* because relatively more peat, waste and fossil fuels have been used in production. As the growth in emissions from electricity production since 1990 almost equals the reduction of emissions from in district heating production since 1990, due to a shift from fossil fuel to biomass, total emissions are fairly similar in 1990 and 2011.

The amount of CO_2 that is emitted by the energy sector of Sweden is substantially lower than that of comparable countries. If the sector had continued to produce electricity and heat with the fuel mix from the 1970s, current CO_2 emissions would have likely been significantly higher.

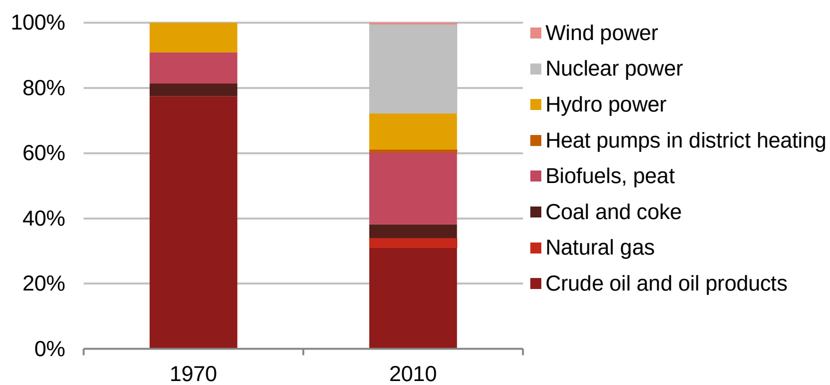
Better security of supply was achieved through domestic energy production and fuel mix diversification. It allows more control over production costs for domestic industry. A secure energy supply protected Sweden from very high inflation and improved the country's competitive position.

Total net energy and electricity imports, 1970-2010



Source: The World Bank, Swedish Energy Agency

Primary fuel mix of total energy use (incl. transport) in Sweden



Source: Swedish Energy Agency

Reduced dependency on foreign oil

The oil crisis in 1973 was one of the major global events that prompted many oil-dependent economies to take measures to address security of supply. Sweden started to play the expansion of domestic energy production capacity even before the oil crisis (in 1960-1970s). Still, in the early 1970s, imported energy constituted c. 80% of the energy use. As we have seen, Sweden managed to decrease its dependency on oil relatively quickly in the 1980s. In 1990, imports accounted for c. 35% of energy use in the country (80% in 1970) and have stabilised since then. Currently, Swedish net energy imports are comparable to the average energy import dependency in high-income OECD countries.

Fuel mix diversification

Security of supply also means a diversified fuel mix. Sweden largely depended on oil in the 1970s. In 2010, the fuel mix consisted of oil, nuclear, biofuel and peat, hydro and, to a lesser extent, wind, coal and natural gas.

The improved trade balance this entailed — Sweden became a net exporter since 1983 — signals that energy sector development and policies have not hindered the competitiveness of the country.

Case Study Germany

Decarbonisation in Germany *– Germany has decarbonised its economy through an increased use of renewable energy and energy efficiency. Nuclear capacity expanded until 1989 to improve security of supply, which also contributed to decarbonisation. As nuclear energy is phased out, Germany faces new challenges in maintaining the current efforts to reduce total greenhouse gases by 40% by 2020 compared to 1990.*

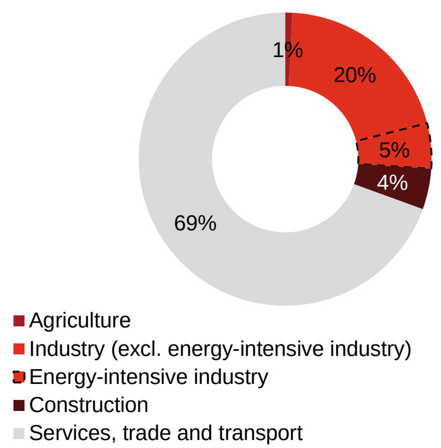
The economic impact of decarbonisation:

The competitiveness of industries affected by the policies is protected through tax exemptions. The tax burden mainly lies on consumers.

Germany has actively aimed at promoting new industrial activity through long-term supply stimulating policy measures. The renewable energy industry is estimated to contribute 1.7% to the value added generated in the economy and about 1% to employment.

Decarbonisation has resulted in avoided costs of CO_2 emissions, which are estimated at €7.4-€7.8 billion in 2009. Security of energy supply increased due to a diversification of the fuel mix. Germany still largely depends on foreign imports of primary energy, but currently is a net exporter of electricity.

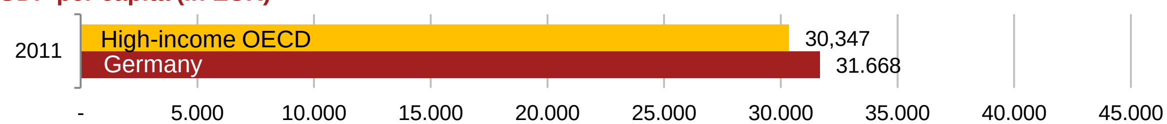
Gross value added by sector in Germany (2010)



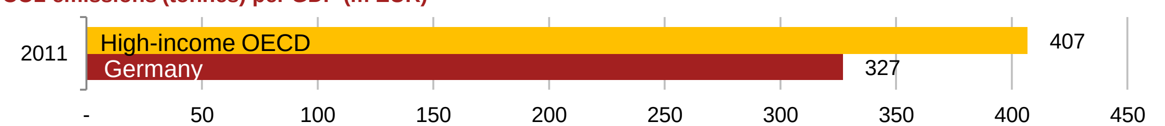
Source: Eurostat, Federal Statistical Office
Energy-intensive industries include manufacturing of paper, products, chemicals, (basic) metals and coke/refined petroleum products

GDP 2011: €2.59 trillion| Population: 81.8 million

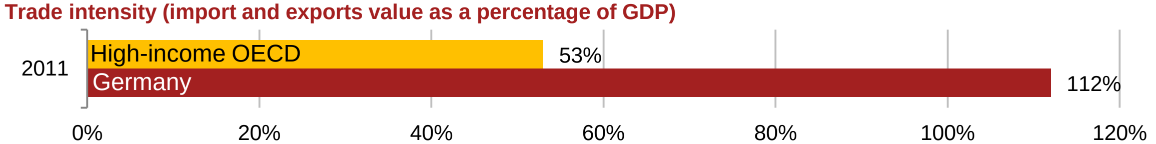
GDP per capita (in EUR)



CO2 emissions (tonnes) per GDP (m EUR)



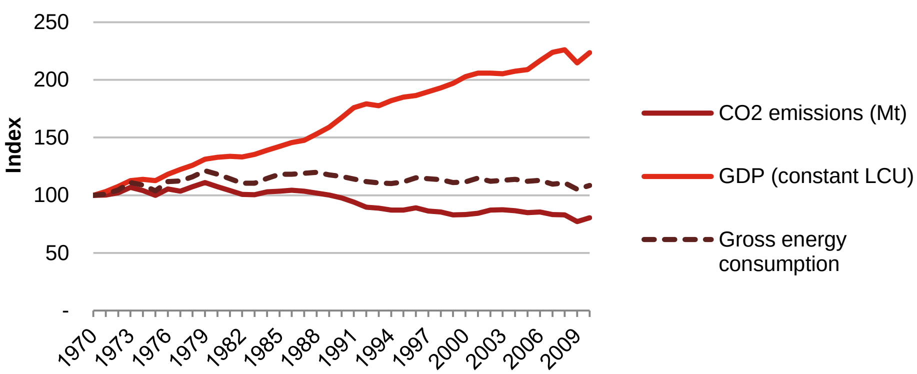
Trade intensity (import and exports value as a percentage of GDP)



Source: The World Bank

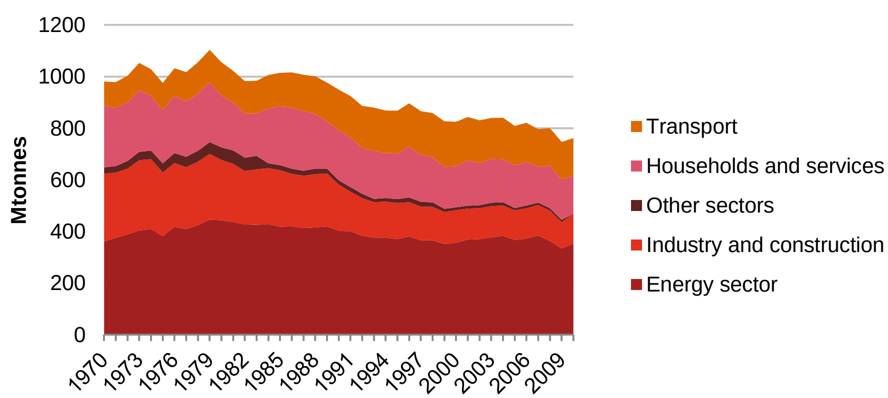
Germany has decoupled its economic growth from the country's carbon emissions. CO_2 emissions have been decreasing from the 1980s, mainly due to energy efficiency gains of end-users and changes in the fuel mix used.

GDP and CO_2 emissions in Germany, 1970-2010*



Sources: The World Bank and BMWi (2012),

CO_2 emissions per sector (1970-2010)



Sources: The World Bank

*The historical CO_2 emissions of Germany have to be interpreted with care due to the reunification and consolidation of data

Germany's CO_2 emissions have decoupled from economic growth

The German economy doubled in size over 1970-2011, while CO_2 emissions have decreased and energy use stabilised. Over 1975-2009 absolute decoupling has occurred for emissions and energy use. According to our high level analysis, the growth in GDP in this period coincided with a 0.9% annual decrease in CO_2 emissions and a 0.4% annual decrease in energy use.

Decoupling was mainly driven by the end-user sectors

All end-user sectors have been able to decrease their carbon emissions, except for the transport sector, where carbon emissions have been rising over 1970-2010. The energy efficiency gains are partly due to autonomous change through increased efficiency of products or changes in the economic structure. Also, climate and energy policies play a role in stimulating energy efficiency.

Changes in the fuel mix of the energy sector avoided emissions

The energy sector is the largest emitter of CO_2 in Germany (currently about 45% of total CO_2 emissions in Germany). Until the 1980s, the CO_2 emissions from the energy sector rose due to increased electricity use of the economy. From the late 1980s, emissions started to decrease.

The government has actively developed environmental and energy policies to stimulate changes in the fuel mix of the energy sector and end-user energy efficiency, which have contributed to the current state of decarbonisation in Germany.

In this country case study, we focus on electricity and heat production, and end-user efficiency connected to electricity and heat demand, as drivers of carbon emission reduction. The share of heat and electricity in final energy consumption is 50% and 30% respectively of total energy use in Germany.

We will start this case study with describing the energy policies that have lead to decarbonisation in section 2, after which we will analyse the impact on the economy in section 3.

Energy and Climate Policies

Guide to next section:

1 *FUEL MIX*
- Electricity
- Heat

2 *ENERGY EFFICIENCY*
- Energy sector
- Households, services
- Industry

Political vision – Germany's energy policy has historically been concerned with increasing security of supply. Throughout the last two decades, the policies have shifted to decarbonisation and stimulating industrial opportunities. But now Germany faces the challenge as the affordability of energy is posing a problem for households.

Evolution of the focus of energy policies in Germany

International events

- 1973 – First oil crisis
- 1979 – Second oil crisis, Nuclear accident in U.S.
- 1986 – Chernobyl nuclear disaster
- 1990
- 1996 – First EU electricity and gas liberalisation directive
- 1997 – Kyoto protocol, adopted in 1997, enforced in 2005
- 2000
- 2005 – Introduction of the EU ETS
- 2007 – EU Council adopts 20-20-20 goals
- 2008 – Global financial crisis
- 2011 – Nuclear disaster in Fukushima
- 2012

Phase

1. *Guaranteeing the security of energy supply*
2. *Support for renewable energy*
3. *Energiewende*

Policy focus

1973-1990: Security of supply

As a response to the first oil crisis in 1973, Germany increased its gas import from the Soviet Union. Germany also tried to diversify energy supply by shifting its focus to domestic coal and nuclear energy, which were stimulated politically and economically. But the anti-nuclear movement in the 1970s and the environmental movement in the 1980s created a mindset in favour of renewables and climate-friendly policy. In the late 1980s, several measures were initiated to create a market for renewable technology and gain experience with renewable technologies, which can be seen as a formative phase that contributed to the later success of renewables in Germany.

1990's: Decarbonisation

The reunification of East and West Germany in 1990 accelerated the decrease in carbon emissions during 1990-1995 due to structural economic changes, as well as a strong decrease in the use of coal. Given the increased awareness on climate change the energy policies' focus shifted to decarbonisation. The National Climate Protection Programme was initiated. In 1991, Germany implemented a feed-in tariff system for power from renewable energy, which created investment incentives and the foundation for later — more successful — feed-in schemes.

2000-now: Decarbonisation & industrial opportunities

Energy policies from 2000 have been focusing on increasing efficiency in energy use (and the eco tax reform) and the use of renewable energy (Renewable Energy Act). The implemented feed-in tariffs resulted in strong financial incentives for renewables. In 2011 20% of electricity demand was supplied through renewables. The Atomic Energy Act amendment of 2002 (again amended in 2011 after the Fukushima incident) requires the phase-out of nuclear energy and has stimulated the switch to renewable energy, as alternatives to decarbonise are limited. The Energiewende, as the transition is called in Germany, is providing opportunities for new economic activities, which are actively stimulated by the government. But now the transition imposes challenges on the affordability of electricity for households, which leads to political debate on the future of the feed-in tariff.

Political context

1969-1990: Long-term coalitions focus on coal and nuclear

The coalition of Social Democrats and the Liberal party (1969-1982) strongly supported energy generation from nuclear and coal, driven by the oil crises. Domestic coal was subsidised and nuclear was stimulated through R&D. But the nuclear accidents in Chernobyl in 1986 turned the divided public opinion towards strong opposition against nuclear. The Social Democrats and Green party, which were at that time in the opposition (coalition of the Conservatives and Liberals – 1982-1990), turned against nuclear.

1990-1998: First political support through financial incentives

Under the government of the Conservatives and Liberals (1990-1998), an electricity feed-in law was initiated by conservative members of the Parliament, who were influenced by the lobby of several associations for renewable energy. The private ownership of renewable energy proved to be important at an early stage in the development of renewable energy in Germany to generate political support.

1998-2005: A changed political context

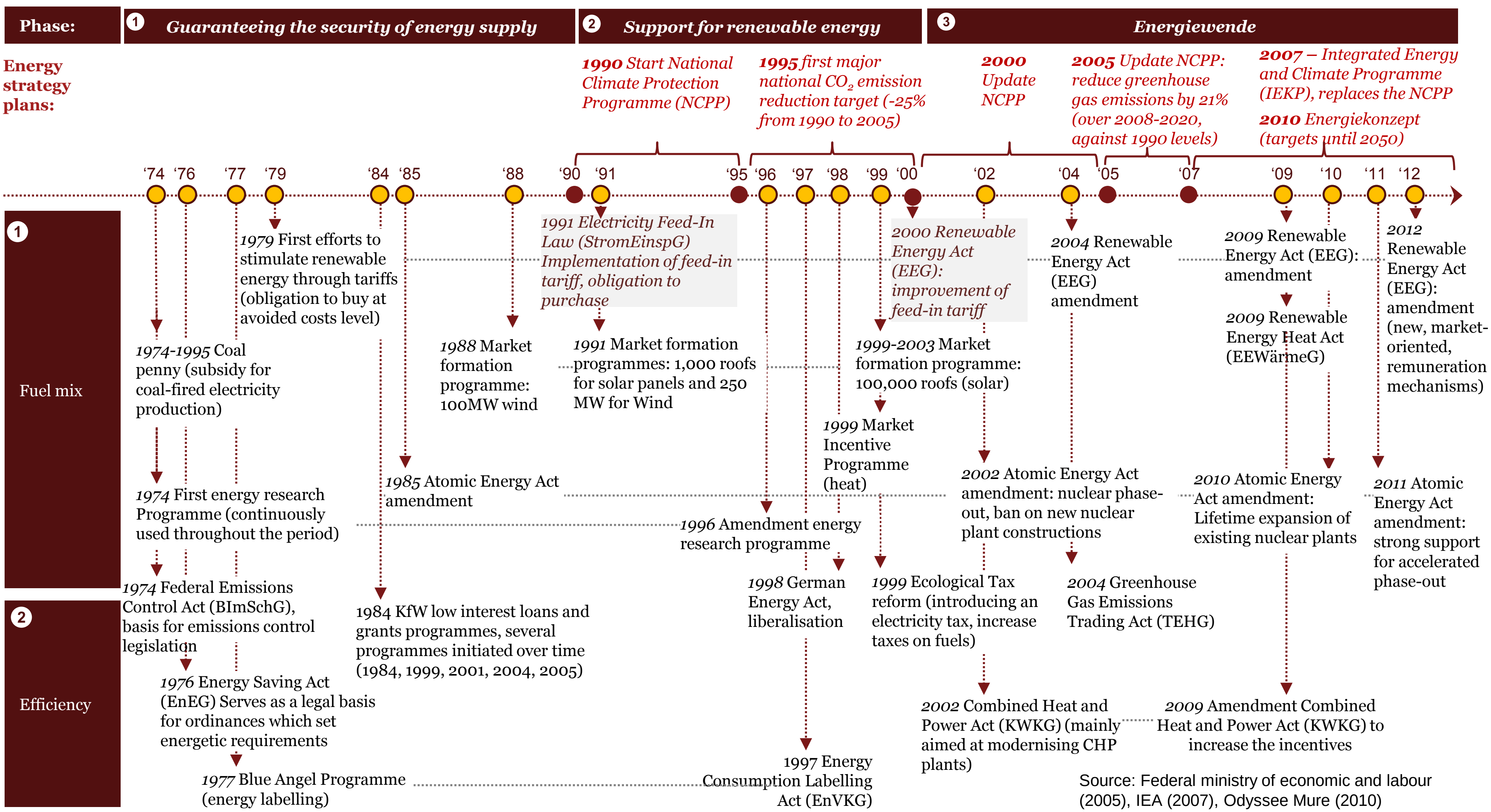
The red /green coalition (1998-2005) committed strongly to mitigating climate change through renewable energy and energy efficiency. They furthermore initiated a phase-out of nuclear power.

2005-2012: Broad political support

Private individual ownership of renewable energy and the stimulation of economic growth led to broad political support for renewable energy and the feed-in scheme, although debates intensify on increasing energy prices.

Sources: Eichhammer, W. et al (2001), Lauber, V. And Mez, L. (2004a), IEA (2007), Stern, J. (2005)

Implemented policy instruments –Germany used long-term energy policy instruments, which were continuously improved. The most distinctive measures used to realise the energy and decarbonisation goals include the renewable energy feed-in tariffs.



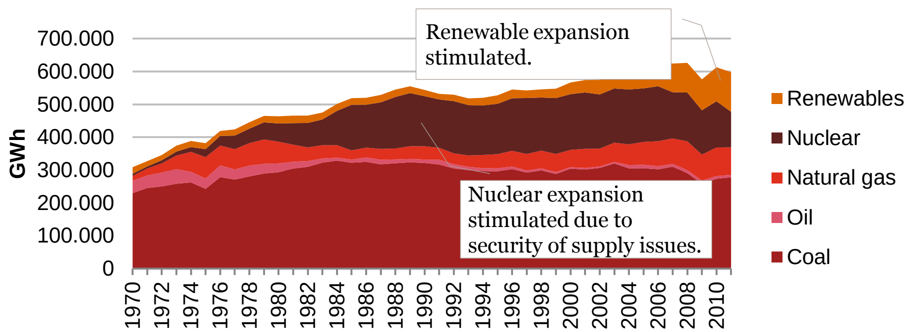
Source: Federal ministry of economic and labour (2005), IEA (2007), Odyssee Mure (2010)

FUEL MIX

1 Concerns regarding security of supply and dependence on foreign countries have stimulated Germany's shift to nuclear energy. Anti-nuclear movements in the 1970s and strong environmental movements in the 1980s changed the public opinion on nuclear power. The focus changed towards stimulating renewable energy.

Electricity | Heat

Electricity production by fuel, 1970-2011



Source: The World Bank

The first oil crisis in 1973 impacted the German economy due to its dependency on oil imports. Fuel prices increased, resulting in a stagnation of economic growth, followed by an economic downturn. Unemployment increased from 273,000 in 1973 to more than a million in 1975. In order to secure energy supply, Germany increased its gas imports from the Soviet Union, supported domestic coal and stimulated nuclear power.

The *coal penny* was used to stimulate domestic production

In 1974, the coal penny was introduced after an agreement between the German coal-mining industry and the Federation of German Power Plants. Electricity generators made a long-term agreement to use German coal in their plants instead of cheap imports. To compensate the higher costs incurred, the power suppliers were entitled to charge consumers an extra "Kohlepfennig" – a coal penny on the electricity bill. This subsidy was intended to save 100,000 jobs in the mining industry. Incentives were paid out of a government fund financed by a surcharge on final customers electricity prices. This surcharge varied from 3.24% in 1976 and 8.5% in 1995. In 1995, the German Federal Constitutional Court declared the coal penny as unconstitutional and was subsequently abolished.

Thereafter, other instruments, like financial grants as well as favourable tax treatments were granted as subsidies for the coal mining industry.

Nuclear was a publically controversial solution to the oil crisis

Publicly funded R&D activities were one of the drivers behind the establishment of the German nuclear industry. Although nuclear power experienced rapid expansion as a response to the oil crisis, it quickly became controversial within the public between 1976 and 1985. After the nuclear accidents in Three Mile in the US (1979) and in Chernobyl (1986), opposition to nuclear power and anti-nuclear movements in Germany increased significantly (from 10% to 70% of the people opposing) within two years after the Chernobyl accident (Jahn, 1992).

Under the Social Democrats/Greens coalition in 1998, the decision was made to phase out nuclear and impose a ban on building new plants, implemented through an agreement with the power sector in 2001 and an amendment of the Atomic Energy Act in 2002. Nuclear power plants were assigned a maximum lifetime based on a defined output, which resulted in a requirement for all nuclear plants to be closed by 2020. The Conservatives/ Liberals coalition lead by Merkel in 2010 decided to extend the lifetime of the plants, but after the Fukushima nuclear disaster this decision was reversed and an immediate shutdown of the eight oldest nuclear power plants in Germany was implemented.

Support for renewable energy increased due to climate change awareness

Increased awareness on the need to decarbonise in the late 1980s provided incentives to step up efforts to stimulate renewable energy. The decision to phase out nuclear imposed questions on how to continuously maintain or increase the decarbonisation rate. This created a strong incentive for increasing the use of renewable energy in Germany.

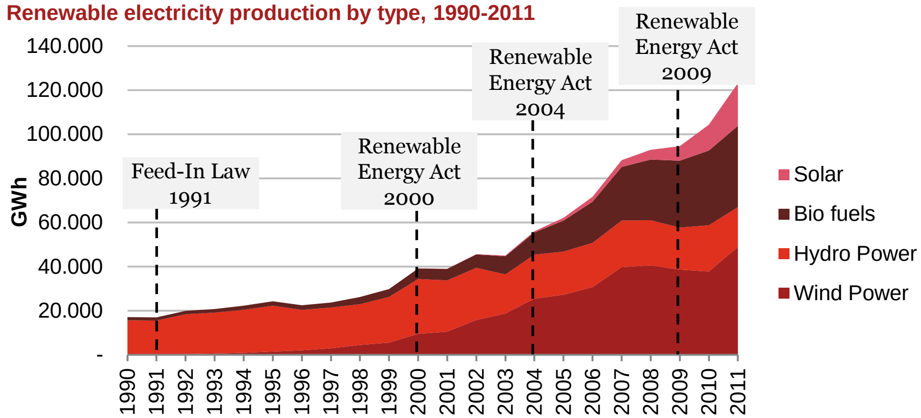
Sources: Lauber V. Jacobsson, S. (2004b), IEA (2007), Stern, J. (2005)

FUEL MIX

1 The 1970s and 1980s were characterised as a formative phase for renewable energy, dominated by subsidies and R&D activities. As of 1991, renewable energy has been supported by the Feed-In Law. But the incentives provided by the feed-in tariff were still rather limited.

Electricity | Heat

Renewable electricity production by type, 1990-2011



Source: BMWi- Energiedaten

Formative phase for renewables in the 1970-1980s

The formative phase for the deployment of renewable energy, from the mid 1970s till the late 1980s, was characterised by generous R&D and investment subsidies.

In this period, several environmental organisations, such as the Institute of Ecology or German Solar Energy Industries Association, were set up that contributed to the renewable energy market in Germany.

By the end of the 1980s, concerns over climate change led to the first National Climate Protection Programme (NCPP) in Germany, which serves as a strategic plan for reducing emissions.

Government funded R&D programmes to stimulate technology development

Although R&D funding in the energy sector was strongly dedicated to nuclear power and fossil fuels, R&D spending for renewable energy sources increased from 1974 to 1982 by more than 15 times. Between 1977-1989 industrial firms and academic institutions were granted funding to explore the development of turbines. The major part of research funding for solar was focused at cell and module development.

Investment subsidies for practical experience

In addition to investing in research and development, the government has provided investment subsidies for wind and solar (e.g. 70% of the initial investment costs in the 1,000-roof programme for solar were covered). This has stimulated commercial deployment of technologies that were developed.

Stimulating renewables though tariff incentives

In 1979, a renewable energy tariff was introduced to stimulate demand for renewable electricity. Electricity distribution companies were obliged to purchase renewable energy produced in their supply area, and remunerate the producer based on avoided costs (the costs of producing electricity themselves). Utilities interpreted these avoided costs as avoided fuel costs, which limited the effectiveness of this policy measure.

Little effect from improved tariff incentives in the early 1990s

The electricity Feed-in law (1991) was initiated under the ruling of the Conservatives and Liberals. The law strengthened the production of energy from renewable sources. Utilities were obliged to grant renewable energy generators access to the grid and to buy electricity at premium prices (feed-in tariffs).Remuneration of renewable energy generators was based on 65% to 90% of average consumer price per kWh of the penultimate year, depending on the type of renewable energy.

But the Feed-In Law provided limited incentives. As the feed-in tariff was based on the market price, renewable energy producers faced decreasing levels of compensation due to declining market prices after the liberalisation of the energy market in 1999. Also, the burden was spread over regional utilities unevenly, since some utilities experienced a higher share of renewable energy being produced in their area than others. This resulted in a call for reform of the Feed-in law.

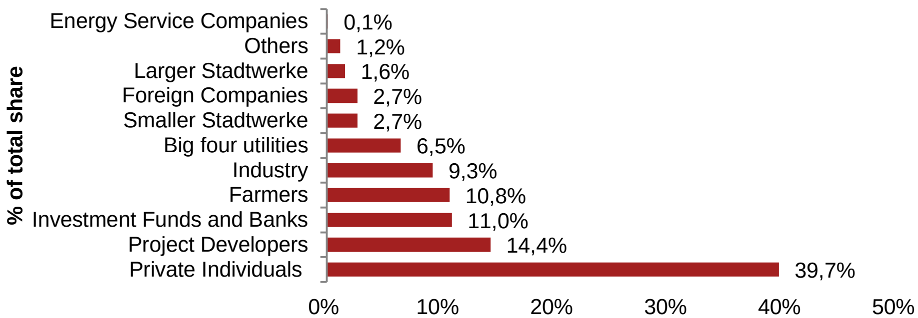
Sources: Lauber V. Jacobsson, S. (2004b), Lauber, V. and Mez, L. (2004a), IEA (2007). Lipp, J. (2007)

FUEL MIX

Electricity | Heat

1 In 2000, the Renewable Energy Act (EEG) replaced the Feed-In Law. It provides stronger incentives for particularly PV, wind and biomass use. Strong reliance on individual ownership was a key to secure the continuity of the policy. Continuous R&D investments resulted in new industrial activity.

Ownership structure of renewable energy in 2010



Source: trend:research and Klaus Novy Institut,

A pro-renewable age in politics

In 1998, the Social Democrats/Greens coalition replaced the Conservative/Liberal government. The coalition agreement consisted of commitments towards an eco tax reform *(please refer to page 79),* a legislation improvement of the Feed-in Law and a phase-out of nuclear power. The combination of these measures proved to give a strong incentive for the use of renewable energy in Germany.

Long-term investment incentives for renewable energy

The Renewable Energy Act (EEG) replaced the Feed-in law to improve the effectiveness of the law. As with the Feed-In Law, the premise of the EEG was built around its initial features, namely the feed-in tariffs as well as granting access to the public grid. Firstly, the EEG provided a guaranteed tariff for electricity production for a period of 20 years, which is decreased over this period (regressive scheme). Secondly, it introduced stronger tariff differentiation between technologies to created a level playing field for various technologies. This increased the demand for higher-cost technologies which incentivised technology development. Thirdly, under the EEG, a nationwide settlement system for costs incurred by utilities was introduced.

The costs of renewable energy compensation were distributed over all consumers across all power grid operators through a general mark-up on the electricity bill (EEG Umlage).

In the last decade, the targets regarding the share of renewables in total electricity supply were adjusted upwards. Several changes have been made in the Renewable Energy Act. Most important modifications address the change in feed-in rates.

Although the Act was initiated by the Social Democrats/Greens, the Conservative/Liberal coalition that came to power from 2005 continued supporting the Act. This can be largely explained by the broad public support for renewables, which is driven by the local ownership structure of renewables in Germany. 50% of the installed renewable energy capacity is currently owned by private citizens and farmers, mainly through energy cooperative (Energiegenossenschaft) *(please refer to the adjacent chart)*. The combination of low interest loans from the KfW Bank as well as the feed-in tariff offered individuals in Germany an attractive investment option.

Strong improvements in incentives for renewable energy were experienced by solar cells. Due to the feed-in tariff and the 100,000 roofs programme, solar technology became an interesting investment option. Under the 100,000 roofs programme (1999-2003), favourable debt financing was provided for solar energy.

Production incentives combined with R&D to stimulate the domestic industry

Germany has continued its efforts regarding R&D activities for renewables to develop the technology and decrease its costs while building up a domestic renewable energy technology industry *(please refer to page 85 for the R&D budgets).*

Sources: Lauber V. Jacobsson, S. (2004b), Lauber, V. and Mez, L. (2004a), IEA (2007); German Federal Ministry of Economics and Technology

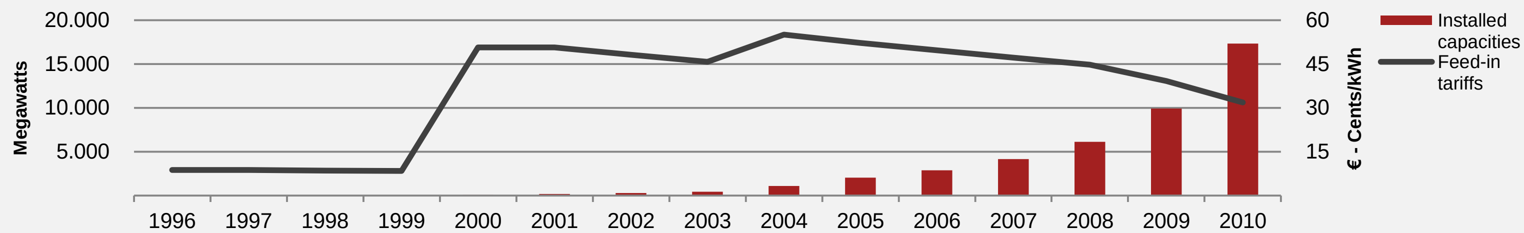
FUEL MIX

1

Solar case study –The German photovoltaic industry was stimulated through the use of market formation programmes and the feed-in tariffs. German R&D investments as well as the competition from other (low-cost) countries have led to a substantial decrease in technology costs for solar.

Domestic capacity commissione d was strongly impacted by subsidy schemes

Cumulative installed photovoltaic power and feed-in tariffs in Germany, 1996-2010



Industrial development: was a key element in German energy policy

Demonstration programmes as part of R&D policy for early market development

The 1,000 roofs programme of 1990 was designed to promote the purchase and installation of 2,250 grid-connected rooftop PV systems. Investments in the solar industry were stimulated however the programme was still relatively small to. From 1999 to 2003 the 100,000 roof programme was launched as the successor to further stimulate market formation through loans issued by the KfW Bank. The Eastern Germany was chosen as a hub for the development of solar technology due to lower labour costs and the need to revive the region.

Exports and market expansion lead to solar industry growth

Due to the structural market formation programmes and the interest of foreign countries in solar energy industry could further grow. With an installed capacity of 17k Megawatts (2010), Germany is considered to be the worldwide largest installer of photovoltaic capacity.

Stagnating growth due to increased competition

By 2010 the German solar industry employed c. 130,000 workers and generated a GVA of €10bn Euros with an export ratio of 50%, which means that half of the PV technology produced in Germany is exported to other countries (Fraunhofer, 2012). Other countries (e.g. China) are rapidly developing their solar industry and produce at lower costs than Germany, which stimulate further price declines.

Financial incentives to stimulate a domestic market

Investment incentives and feed-in subsidies

The 1,000 roof programme was incentivized by a 70% subsidy (50% federal subsidy, 20% state subsidy). The Feed-in Law required utilities to buy the electricity at a rate which for solar amounted to 90% of the average tariff for final customers.

Renewable Energy Act turned solar into an interesting investment option

Under the EEG (as of 2000) feed-in tariffs for solar increased significantly from 8€cents to c. 50€cents. In combination with the 100.000 roofs programme, this revised Feed-in Law meant that solar cells became an interesting investment option. The certainty of the scheme provide credible investments environment.

Ownership has played a vital role in Germany

New ownership structures emerge d in Germany

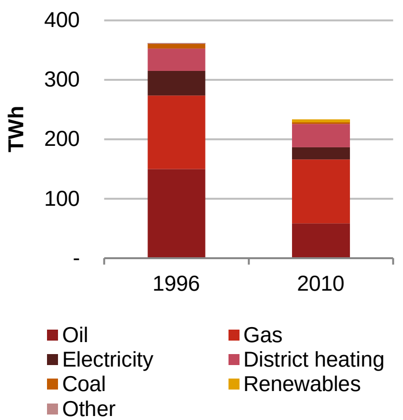
The expansion of solar PV brings along a shift in the ownership structure of electricity production. Private citizens and farmers were able to generate their own electricity. The feed in tariffs were changed over time to reflect the development of technology costs, driven by innovation in the industry and scale effects. However the rapid decrease in technology costs could not keep up with technology costs reduction, which lead to a favourable business case for solar PV. Currently, more than half of all renewable energy capacity installed in Germany is owned by private citizens (including other renewable technologies. This results in broad support of the population for renewable energy in Germany, which is reflected in politics.

FUEL MIX

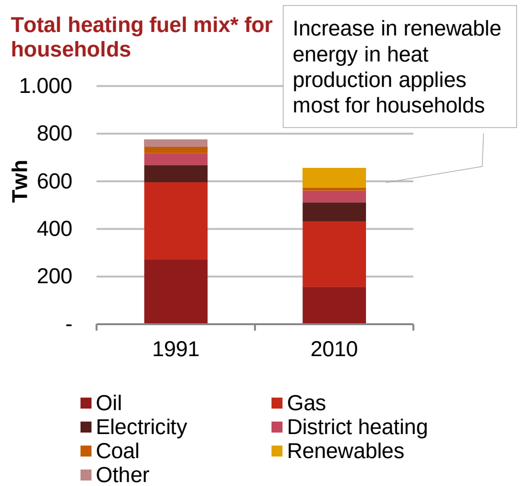
Electricity | Heat

1 Like for electricity production, Germany aims to increase the use of renewable energy sources in heat production. From the late 1990s, Germany started to stimulate this development through investment grants, loans and, more recently, an obligation to use renewable energy for new buildings.

Total heating fuel mix* for trade, commerce and service

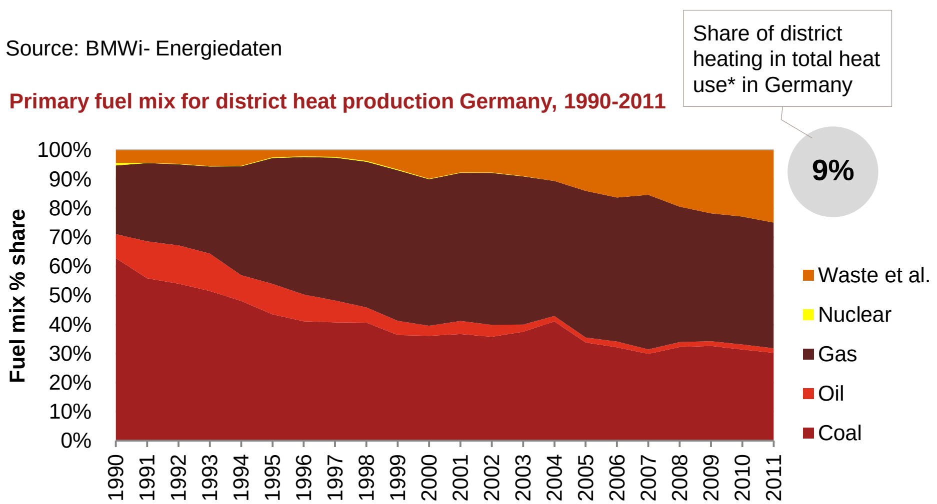


Total heating fuel mix* for households



Source: BMWi- Energiedaten

Primary fuel mix for district heat production Germany, 1990-2011



* Incl. space heating, water heating, other heating processes

Source: BMWi- Energiedaten

Aiming for a greener heat fuel mix in Germany

As for the fuel mix for electricity production, the fuel mix for heating was diversified with renewable energy and natural gas, which mainly replaced the use of oil. District heating is still relatively small in Germany (9% of total heat use* in Germany) compared to countries like Sweden and Denmark.

... through investment grants and low interest loans...

The market incentive programme (MAP, started in 1999, amended several times over the years) refers to an instrument of the German government, which aimed to increase the use of biomass, solar energy and geothermal energy in heat generation. Eco tax revenues from renewable energy plants are used to fund this development programme for renewable energy.

The MAP programme comprises two support mechanisms depending on the investment project. Smaller systems designed for single and two-family homes are supported with grants from the Federal Office of Economics and Export Control (BAFA), whereas larger systems can apply for low interest loans and partial debt acquittal at the KfW Bank.

... and an obligation of using renewable energy for new buildings

As part of the Integrated Energy and Climate Protection Programme (IECP), which replaced the National Climate Protection Programme, the Renewable Energy Heat Act (EEWärmeG) was introduced in 2009. Similar to the EEG, which focuses on the electricity fuel mix, the EEWärmeG obliges the deployment of renewable energy in the heating and cooling system of new buildings. The aim is to achieve a 14% share in the use of renewable energy for heating and cooling by 2020. New constructions under the MAP during 2009-2011 resulted in annual CO_2 savings of 1.9 Mt CO_2 equivalent.

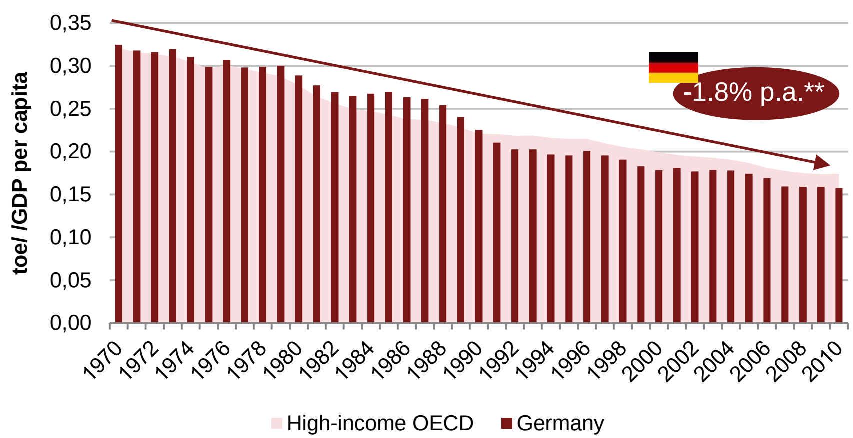
Recent reviews show that at least half of the newly constructed buildings during 2009-2011 deployed renewable energy for their heat production. The share of renewables in heat production increased from 8.9% in 2008 to 11% in 2011.

Source: IEA (2007), Odyssee Mure (2010), Federal ministry of economics and labour (2005)

ENERGY EFFICIENCY

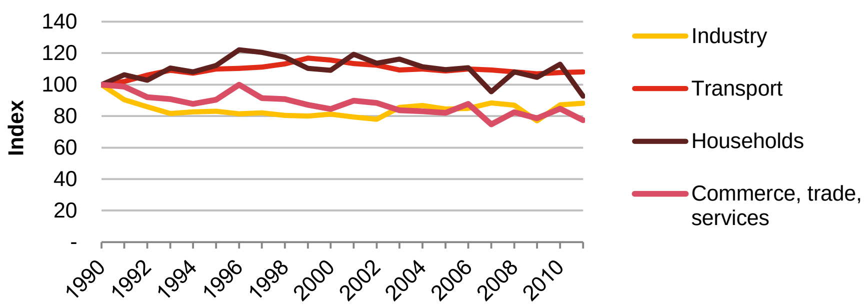
2 The oil crises in the 1970s stimulated Germany to step up energy efficiency policy measures. Energy conservation in Germany started to outperform high-income OECD countries from the 1990s, stimulated by structural changes in the economy as well as improvements in end-user sectors.

Energy intensity (toe/GDP thousand USD)*, 1970-2010



Source: The World Bank

Energy consumption per sector****



Source: BMWi

*The energy intensity includes the transport sector
**Change in primary energy intensity; Final energy use intensity decreased by - 3,1% annually (1990-2011)
*** Transport sector is excluded form the scope of this study
**** Due to the reunification, sector data is only available from 1990

The improvement of energy intensity in Germany has accelerated

The first oil crisis stimulated the German government to initiate policies aimed at reducing the dependency on imported fuels. Increasing energy efficiency became an important strategic goal of the government. Germany was one of the first countries implementing energy labels to stimulate awareness among consumers about how energy efficient purchased appliances are. Normally, a part of energy efficiency improvements are offset by a so-called rebound effect as decreased costs enable increased household consumption of energy or other goods and services. But energy intensity of Germany decreased and is currently lower than the energy intensity of high-income OECD countries. This is considered to be partially driven by the reunification of East and West Germany in 1990. Autonomous growth (new products, changing consumer demands and behaviour) is secondly known to have a large impact on energy efficiency developments. Thirdly, energy policies have influenced the development of energy intensity *(please refer to the following pages)*.

Energy intensity depends on the development of

1. efficiency in the energy sector and
2. efficiency of the end users of energy (households, services and industry***).

In Germany, most of the improvements have been made in energy efficiency of end-users. The energy use in the industry and service sectors has decreased from 1990 onwards by -0.1% and -1.2% p.a., while their gross value added (GVA) developed by 0.1% and 1.7% p.a., respectively.

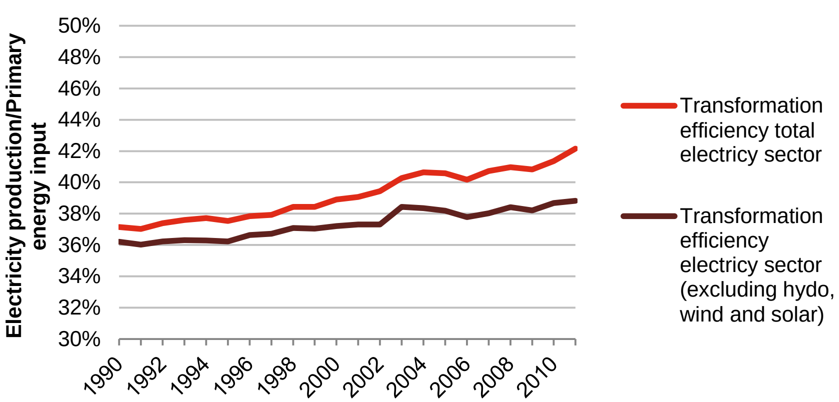
Efficiency in heat and electricity production, that is, in the energy sector, was relatively stable, reflecting the low change in the use of combined heat and power (CHP) in Germany. Underlying strategies and policy choices will be discussed in the next three pages for the energy sector, households and services and the industry:

Energy sector + Households, services + Industry

ENERGY EFFICIENCY

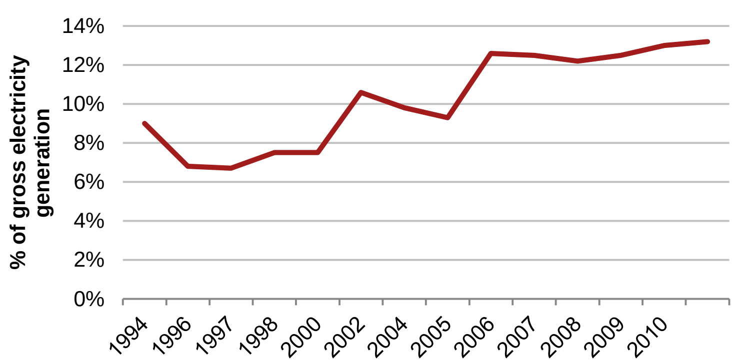
2 Efficiency in the energy sector was limited in Germany due to the low utilisation of CHP. Germany has focused on increasing the use of CHP from 2002. Electricity generated in CHP plants is entitled to feed-in tariffs and gets priority access to the grid.

Efficiency for electricity production, 1990-2011



Source: Energiedaten (BMWi)

CHP electricity generation, 1994-2010



Source: Eurostat

Efficiency in the energy sector has improved

The increase in energy efficiency in the electricity sector was increased due to the reunification effects (BMWi, 2010). From the late 1990s, increased use of renewables contributed to efficiency increase, as renewables, solar and wind power have a 100% efficiency.

The role of combined heat and power is still limited

Although the use of CHP has increased over time, it is still rather limited compared to countries like Denmark (where 66% of power generation comes from CHP plants).

Germany has focused on increasing the use of CHP by the means of the CHP Act of 2002. The Act aims at accelerating the modernisation of CHP plants. Under this law, network operators are obliged to connect CHP plants to their grid system and to buy their electricity. Also, electricity generated from CHP plants is entitled to premium payments. The German government has introduced various incentive schemes to support CHP production, which have changed over time:

- Biogas CHP receives favourable feed-in tariffs under the Renewable Energy Act
- Natural gas and heating oil, used for CHP are partially exempted from Eco tax.
- CHP plants are exempted from the tax on fossil fuels if their efficiency is over 70%.

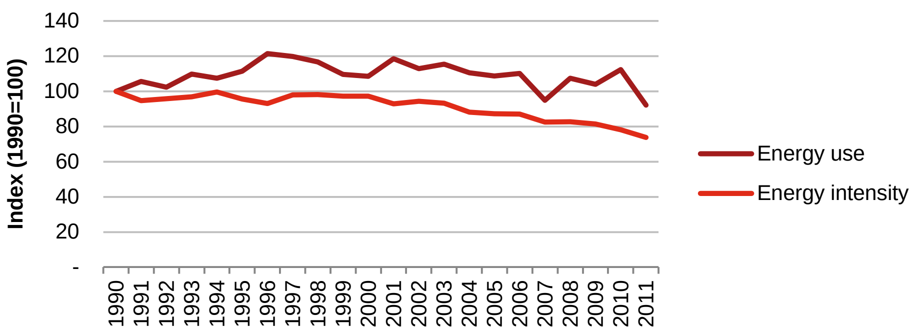
The 2009 amendment of the CHP law aims at stimulating new construction of CHP plants, without a size limit. Also, the government aims to achieve a share of 25% of total electricity production from CHP plants by 2020. Bonus payments are provided for the entire electricity production, rather than solely for electricity fed into the grid.

Sources: BMWI (2010)

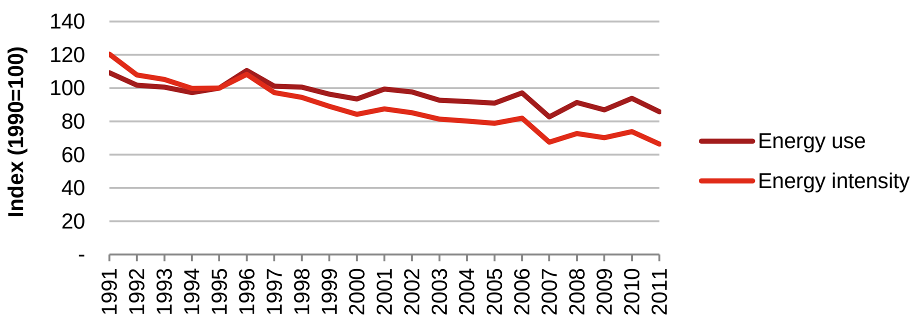
ENERGY EFFICIENCY

2 From the early 1990s, energy intensity has been decreasing both in the service sector, and, more recently, in households. The German government used energy standards and labelling, taxes, and initiated several financial programmes through KfW Bank to stimulate this development.

Energy intensity (End-energy use/living area in m²) and energy use for households, Indexed 1990-2011



Energy intensity (End-energy use/GVA) and energy use for commerce, trade and services, 1991-2011



Source: Energiedaten (BMWi)

*German carbon emissions from the existing building stock are assessed to have been reduced from 1990 to 2006 by 24%, largely achieved through KfW's programme for the renovation of existing buildings (Kleemann and Richter, 2008).
Sources: Odyssee Mure 2010,
http://www.bbsr.bund.de/cln_032/nn_1029270/EnEVPortal/EN/Archive/EnEV/enev.html

Energy efficiency gains both in the service sector and in households contributed to the overall decrease in energy intensity in Germany. The following energy efficiency policies contributed to this development.

Energy performance standards and labelling

The Energy Saving Act (Energieeinsparungsgesetz [EnEG]), issued in 1976, aimed at reducing the dependency on imported fuels. Based on this law, several ordinances were issued over time, influencing the energy requirements of buildings and their appliances. Currently, the Energy Saving Ordinance of 2001 (which replaced the Thermal Insulation Ordinance of 1995 and the Heating Appliance Ordinance of 1998) has been amended several times, driven by national targets as well as EU legislation.

Complementary instruments are energy labels, to guide consumers in recognising the most energy-efficient products and buildings. Germany was one of the first countries to initiate energy labelling (German Blue Angel Programme, 1977). Energy labels of appliances have been extended to energy-related products (amendment of the Energy Consumption Labelling Act (*Energieverbrauchskennzeichnungsgesetz* EnVKG, originating from 1997).

KfW Bank provides financial instruments

KFW Bank's programmes are the central financing instruments of German energy policies. KfW Bank promotes the construction of new energy-efficient homes and the energy-efficient refurbishment of older residential buildings with grants or loans at favourable conditions. Over the years, several programmes were initiated through KfW Bank, like the CO_2 building rehabilitation, housing modernisation and ecological construction programmes. The impact of the programmes is considered to be high*.

Ecological tax reform

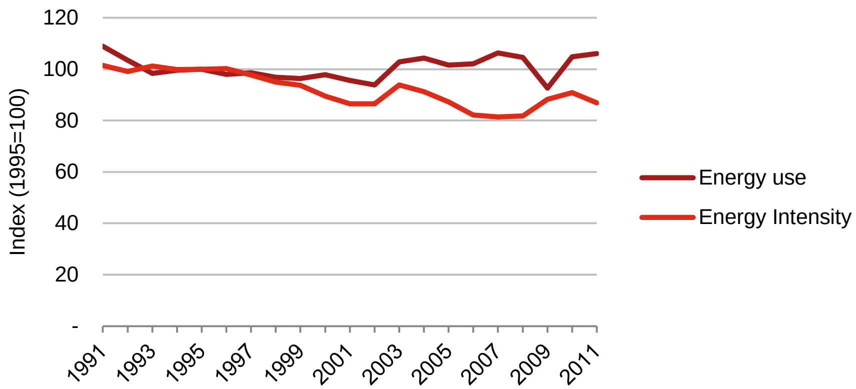
The taxation system was reformed from 1999 onwards to provide stronger incentives to decrease energy use *(please refer to page 79)*.

ENERGY EFFICIENCY

Energy sector | Households, services | Industry

2 Energy efficiency in the industry increased over the last 20 years, driven by structural economic changes (due to the reunification) and the government's energy efficiency policies.

Energy intensity (End-energy use /GVA) and energy use for the industry



Source: Energiedaten (BMWi)

Since the reunification, energy consumption of the industry has decreased by 2,5% while value added grew about 30%

The decrease in the energy intensity of the industry in the early 1990s could be partially explained by the reunification of Germany and structural economic change. Several energy efficiency policies have also played a role in the decrease of energy use.

Voluntary agreements

Prevalent commitments of the industry towards CO_2 reduction and energy efficiency were chiefly dominated by voluntary agreements, such as the Declaration of German Industry on Global Warming Prevention (DGWP). Agreements to reduce CO_2 emissions were updated several times in 1995, 1996, 2000 and 2002. These amendments incorporate measures to increase energy efficiency at onsite production facilities. Voluntary agreements of the industry are responsible for significantly more than half of the identified energy savings (BMWi, 2001).

KfW grants and loans

Low-interest loans and grants of different KfW Bank programmes (since 1984) stimulate an increase in energy efficiency in the industry. An example of these programmes is the energy efficiency programme for SMEs (since 2008). Given the resource scarcity of smaller enterprises, KfW Bank offers special support to SMEs through low interest rates for loans and grants for energy efficiency and corporate environmental protection. Investments can be made in and outside Germany and the main criterion for these investments is that they substantially contribute to improving the environment.

Ecological tax reform

The tax system was reformed starting from 1999, whereby a tax on electricity was introduced (*please refer to page 79)*. Taxes on fuel use and electricity are used to improve energy efficiency in the industry, but there are exemptions present which reduce the tax burden for the energy-intensive industry.

EU ETS directs the industry toward climate change

More recently, the EU Emission Trading System (EU ETS), launched in 2005, is used to influence CO_2 emissions and, so, energy efficiency. But at present, the incentive of the EU ETS to reduce emission is limited, due to low market prices for emissions certificates of the system and overcapacity of allowances. Changes are being considered to improve the incentive of the ETS.

Source: Odyssee Mure (2010), Beuermann and Sanatarius (2006).

FUEL MIX & ENERGY EFFICIENCY

1 & 2 Eco tax case study – The Social Democrats/Green coalition started an eco-tax reform in 1999. This reform introduced the electricity tax (StromStG) as well as an increase in taxes on several other energy carriers or goals of energy usage.

Current energy and electricity tax rates exemption (excl. fuel usage in the transportation sector) in Germany, 2012

	Fuel use	Coal per GJ	Natural gas per MWh	Heating Oil per 1,000l	LPG per tonne
	Standard rate for heating purpose or usage in favourable assets	€0.33	€5.50	€61.35	€60.60
	Tax exemptions				
Heat	**For industrial users if used in eligible plants**	N/A	€1.38	€15.34	€15.15
Heat	**For eligible CHP < 2 MW**	€0.00 – 0.33	€4.42 – 5.50	€40.35 – 61.35	N/A
Electricity	**For eligible plants (incl. CHP) > 2 MW**	Complete exemption			
Electricity	**For eligible CHP < 2 MW**	€0.00 – 0.33	€4.42 – 5.50	€40.35 – 61.35	N/A

Electricity consumption	€ per MWh
Standard rate	€20.5/MWh
Reduced rate (public train transport)	€11.42/MWh

Ecological tax reform

In 1999, the ecological tax reform was implemented (*Gesetz zum Einstieg in die ökologische Steuerreform, enacted on 24 March 1999)*, which aimed to address unemployment, environmental damage and the social security system at the same time. Taxes on road and heating fuels increased and a tax on electricity was introduced. Tax revenues were intended to be used in line with the double-dividend principle, that is, it is used for a gradual reduction in statutory pension contributions to reduce labour cost and increase employment. The ecological tax reform furthermore was designed to promote renewable energy projects, that is, tax revenues generated from the ecological tax reform are spent on programmes promoting renewable energy (e.g. MAP).

The eco tax is not a tax in itself but a tax reform. This means that the rates of existing energy taxes such as in the mineral oil tax act (MinöStG), which has been replaced by the Energy Tax Act (EnergieStG) in 2006, were simply increased and the a new tax was introduced, being the electricity tax (StromStG). The Energy Tax Act regulates the taxation of all fossil energy carriers and bio fuels.

Exemptions to nurture competitiveness and stimulate clean sources/technologies

To maintain competitiveness, exemptions were made for the energy-intensive businesses in the producing industries, such as manufacturing, agriculture, fishery and forestry businesses. Also, exemptions are made for combined heat and power plants and for bio fuels used for heating purposes.

The complete exemption from the electricity tax includes e.g. the electricity usage taken from a grid exclusively fed by "green" sources, for electricity generation purpose, and from small plants (< 2 MW) for near-by consumption.

Sources: EnergieStG, StromStG, Beuermann, C. and Santarius, T., (2006)

Economic Impact of the Energy and Climate Policies

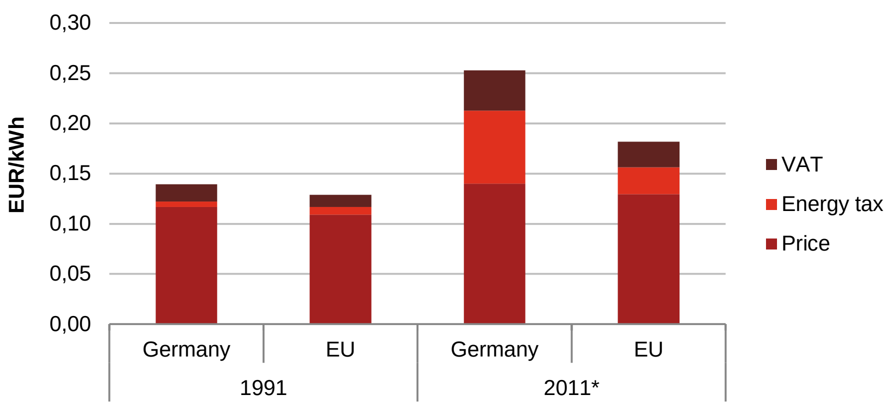
Guide to next section:

- Competitiveness
- Growth (new industries)
- Climate
- Security of supply

Introducing feed-in tariffs to promote renewables have increased the tax component in electricity prices for domestic consumers in Germany. Prises have risen significantly but this was partially driven by external factors, such as increasing global fuel prices.

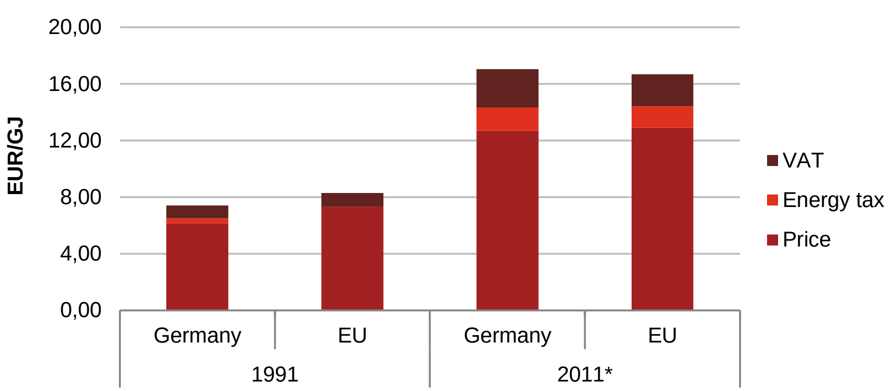
Competitiveness | Growth | Climate | Security of supply

Electricity prices for domestic consumers in 1991 and 2011



Source: Eurostat

Gas prices for domestic consumers in 1991 and 2011



Source: Eurostat

* New methodology was adopted in 2007. So values before 2007 are not comparable with 2011 numbers. EU data includes 27 Member States, whereas 1991 includes EU-15

Consumers are paying higher energy bills

As we have seen earlier, the average electricity consumption per household barely changed in 1991-2010, while electricity prices have increased significantly. So the average electricity bill per household has increased substantially. Energy efficiency gains are not expected to have offset the increase in electricity prices.

The increase in electricity prices has been mainly caused by an increased taxes component. The tax component includes the mark-up paid to finance the feed-in tariffs *(please refer to page 83 for the increase in the mark-up per kWh)*. Compared to the average electricity prices in the EU-27 in 2011, German consumers pay ca. 40% more, mainly because of significantly higher energy taxes. But at the same time a large component of prices is normally wholesale prices and distributions costs, which also depend on factors other than renewable energy policies (e.g. international fuel prices or transmissions infrastructure development).

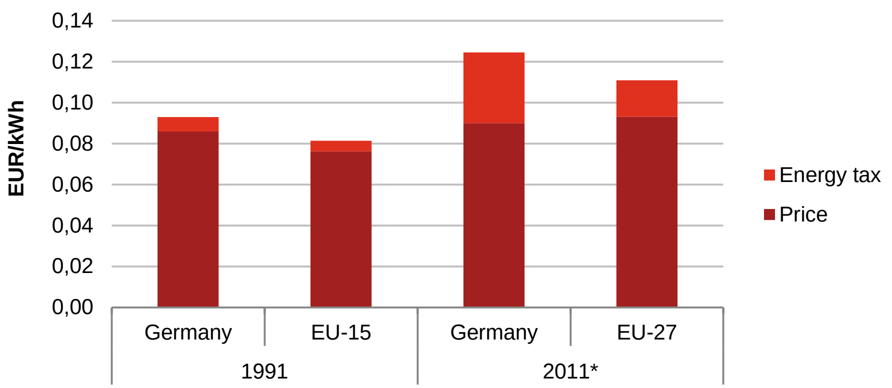
Gas is another important energy source for household use (more than 40% of total space heating is fuelled by natural gas). Its price in Germany is currently comparable to the European average.

A net effect of energy and climate changes policies on consumer welfare is difficult to assess, as it is a result of the interaction between many factors such as wholesale prices driven by trends in global markets, the development of consumer purchasing power, returns from locally owned renewable energy sources.

Industrial electricity and gas prices exceed the European average. But, as a common practice, energy-intensive businesses are exempted from a part of the taxes to sustain their competitiveness.

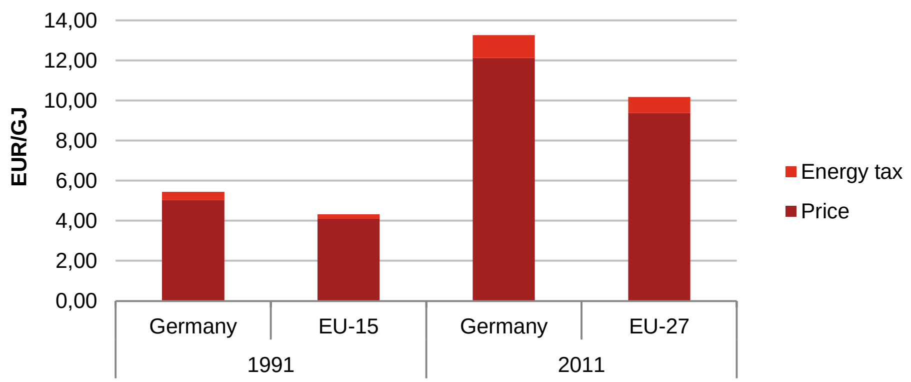
Competitiveness | Growth | Climate | Security of supply

Electricity prices for industrial consumers in 1991 and 2011



Source: Eurostat

Gas prices for industrial consumers in 1991 and 2011



Source: Eurostat

* New methodology was adopted in 2007. So values before 2007 are not comparable with 2011 numbers. EU data includes 27 Member States, whereas 1991 includes EU-15

Exemptions from payments to cover the feed-in tariffs sustains the companies' competitiveness

Electricity prices for industrial consumers have increased over the last two decades. In 2011, the German price was 12% higher than the European average. The difference was again caused by a heavier tax burden in Germany, driven by the mark-up paid to finance the feed-in tariffs. The price difference with the European average is, however, smaller than for domestic consumers *(please refer to the previous page).*

Generally, the German industrial policy protects the competitiveness of the energy-intensive industry. The energy-intensive industry pays significantly reduced rates. Yet in practice, the design of the system has allowed other companies to qualify for exemptions. This decrease in the number of companies obliged to pay the mark-up results in an increase in the burden for domestic consumers, as the total feed-in obligation must be financed through payments by the end users.

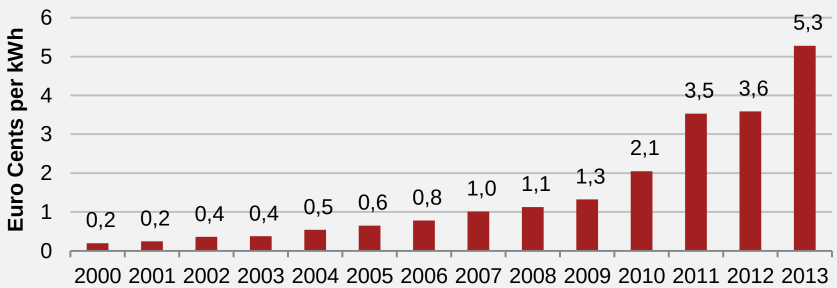
Gas prices are historically higher in Germany compared to the European average

For gas use, the German industrial consumers pay about 30% more than the European average. But here the difference is mainly caused by the actual price difference of gas rather than different taxation schemes.

Case study Renewables challenge – Recently, the support for the EEG has been challenged due to concerns about rising energy prices, insufficient reliable capacity and a lack of transmission grids to connect renewable supply with demand. New market mechanisms have to be designed.

Competitiveness | Growth | Climate | Security of supply

Evolution of the EEG feed-in mark-up (EEG Umlage), 2000-2013



Source: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

The EEG is in the centre of political debate in 2013

Energy prices for private households continuously increased from €0.15 in 2000 to €0.25 per kWh in 2012 for a large part caused by an increase in the mark-up imposed by the EEG feed-in tariff. The EEG feed-in incentive scheme was well accepted given the guarantees it gave to investors combined with a good business case, due to above expected decrease in technology costs (for PV). So the mark-up has been rising rapidly to cover for the costs of the feed-in scheme.

The exemption of energy-intensive industries from the feed-in charges (EEG Umlage), are considered to be the reason for the increasing consumer energy prices. Due to competitiveness reasons, energy-intensive industries are subject to significantly lower mark-up charges or they are exempted.* Although the law claims that only energy- intensive industries should be exempted, now a large number of non-energy-intensive companies qualify for it too. So the cost burden is forwarded to the final consumer's electricity bill. This particularly affects low-income households. The German Consumer Association suggests that if energy-intensive industries were included in the feed-in scheme, this would result in lower actual feed-in mark-up.

Sources: BMU- Zeitreihen zur Entwicklung der erneurbaren Energien in Deutschland (2012)

Constant dialogues at a federal level between the Ministry of Economics and the Ministry of Environment strive to determine a solution on the prospects of the feed-in tariffs.

Additional remuneration schemes reflecting the market dynamics

As a response to rising feed-in charges, new market stimulation mechanisms have been introduced in 2012. Direct marketing mechanisms, namely the "market bonus scheme" and "green electricity privilege" for energy generated from renewable energy facilities, were implemented.

The objective is to get renewable energy plant operators to produce electricity in a market-oriented manner (in accordance to energy demand) rather than opt for a continuous production. First, under the market bonus scheme, renewable energy plant operators can sell their electricity directly to the energy traders and in this way bypass the local grid operator. Plant operators will be better or worse off depending on the wholesale market price for electricity. Additionally, costs incurred due to the market bonus scheme (admission to energy exchange, IT infrastructure, personnel, etc.) are reimbursed through a management premium. Second, green electricity privilege can exempt electric utilities from payment of the feed-in charges if 50% of their electricity is generated from diverse renewable energy sources.

Multiple challenges for carbon-free energy system in Germany

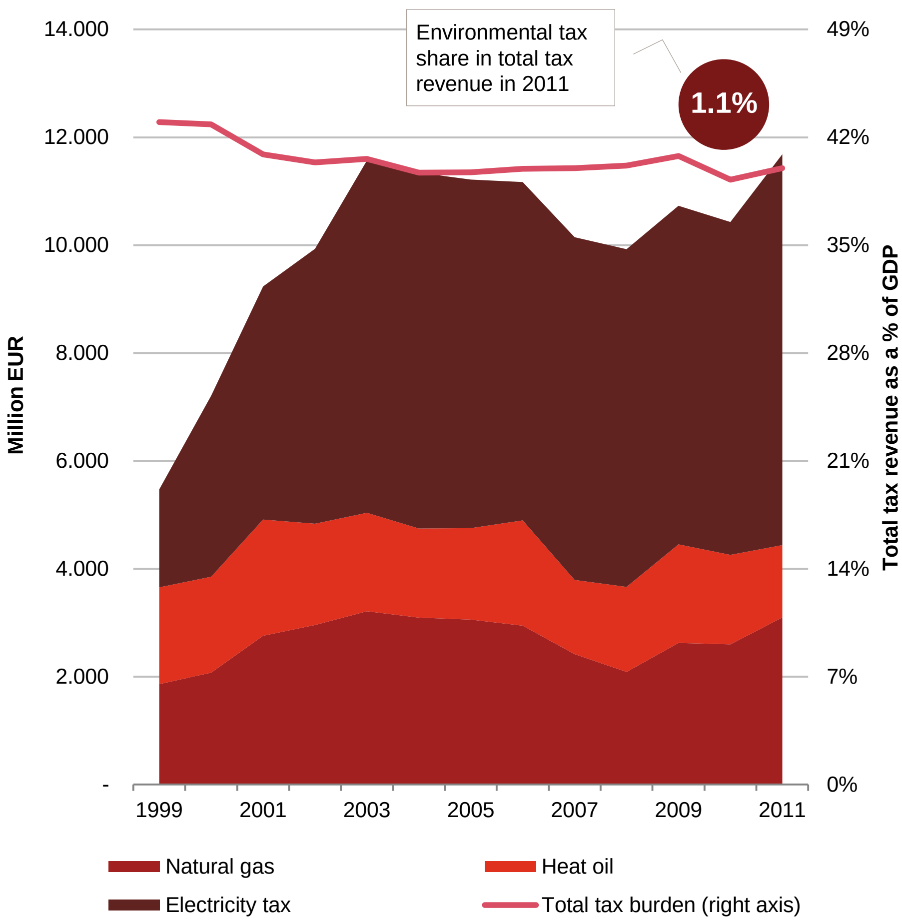
While the government is still committed to continue supporting renewables, the increasing share of renewables also imposes other challenges. The production of renewable energy is located in different areas than the consumer, which means that transmission grids have to be expanded. Secondly, renewable power production is intermittent. If there is inadequate reserve capacity in the market, the system would be subject to frequent black-outs, which can lead to economic and security of supply-related harm to the country. The government needs to find solutions to incentivise the availability of sufficient back-up capacity.

*Exemption depends on (1) electricity consumption and (2) electricity cost/GVA ratio of the companies have to bear and results in 10% per cent of the feed-in charge or at least 0.05 cents/kWh.

The tax reform in 1999 increased the environmental tax burden at a macro level. The introduction of higher environmental taxes replaced other taxation, resulting in a stable tax burden (as a percentage of GDP) over the last decade.

Competitiveness | Growth | Climate | Security of supply

Environmental taxes (excl. transport fuels), 1999-2011



Source: German Federal Environment Agency, Federal Ministry of Finance

Total tax burden after the introduction of "eco-tax" remained stable

After the tax reform in 1999, the environmental tax revenue increased substantially. In 1999, the share of the selected tax revenue (excluding transport fuel and automobiles) of the total tax revenue was 0.6%, which increased to 1.1% in 2011.

The total tax burden has not increased (in 1999, total taxes accounted for 43% of GDP; in 2011, the share decreased to 40%). This suggests that increased environmental taxation presumably on a macro level did not result in reduced welfare. In line with the goals of the tax reform, it shifted the tax burden from direct to indirect taxation. But, on a micro level companies and sectors still faced increase increased tax burden, depending on the mix of production factors used (e.g. labour, capital, natural resources). Competitiveness of energy intense industries was addressed by implementing tax exemptions for industrial users *(please refer to page 79)*.

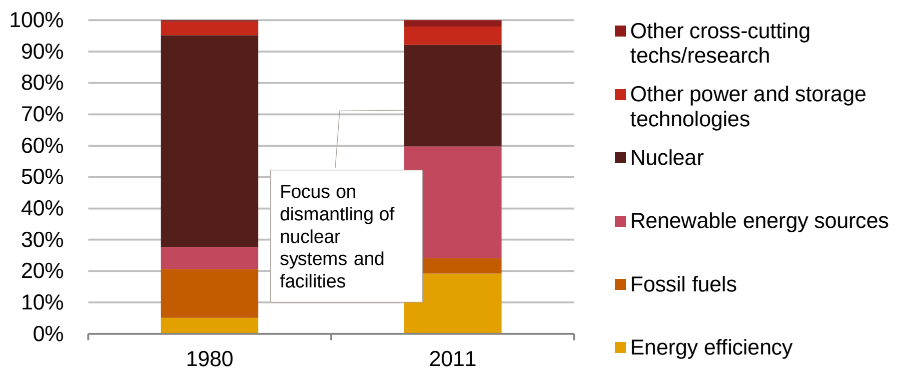
Tax revenue is serves various goals

Eco tax reform is known to serve various goals. Social security payments and labour taxes have been reduced to stimulate employment. At the same time, it encourages energy efficiency, which leads to less CO_2 emissions. The revenue is used to finance the market incentive programme (MAP) as discussed earlier. The goal of the programme is to stimulate renewable capacity expansion, modernisation of buildings, and other energy efficiency measures.

From the 1970s Germany has actively combined its energy polices with industrial politics. Through creating a domestic market for renewable energy and regulatory continuity the development of new domestic manufacturing industries were stimulated.

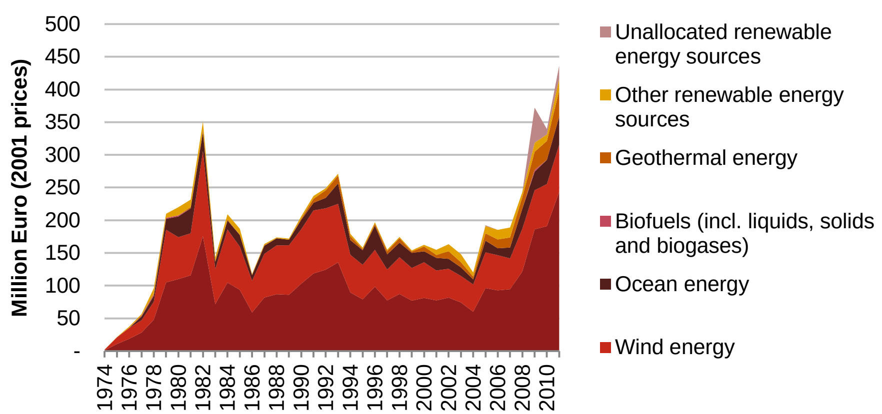
Competitiveness | Growth | Climate | Security of supply

R&D government investments in R&D in Germany



Source: IEA (R&D database), , Weis et al. (2011)

R&D Budgets for renewable energy in Germany, 1974-2011



Source: IEA (R&D database)

Decarbonisation goals in Germany were combined with industrial politics to stimulate the development of new manufacturing industries. One of the main ways to stimulate these industries was to create a domestic market.

Creating a domestic market…

During the formative phase of renewable energy (1970s-1980s), demonstration projects and R&D investments were used to create a niche market for renewable energy. The formative phase initiated learning networks, and stimulated the first firms to enter this niche market. The initiation of feed-in tariffs in the beginning of the 1990s further strengthened this niche market, which stimulated (new) companies to enter the market. The wind turbine industry grew to be the second largest in the world in that period.

…to stimulate industrial development

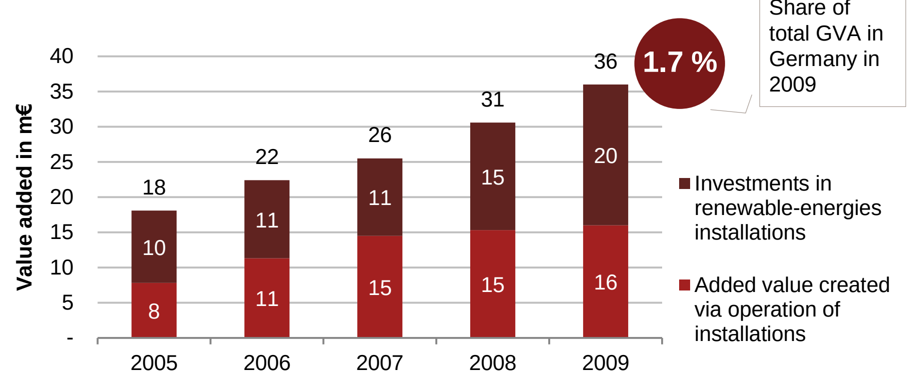
For the Social Democrats (as a part of the coalition of the late 1990s, which had implemented important decarbonisation policies), the argument of stimulating the domestic industry played a central role in strengthening the feed-in law. Due to the liberalisation of the energy market, electricity prices dropped and the wind-turbine industry was suffering as a result of the decreased remuneration for wind turbine owners. Strengthening the support for renewable energy could make the industrial activity and the correlating employment more sustainable (Lauber, 2004a).

The continuity of supply-stimulating policies, from the late 1980s, played an important role in Germany in helping the development of new renewable industries. The broad public support for renewables played an important role in assuring the continuity of supply-stimulating policies. This support was shaped through an interactive process of institutional change (R&D policies, feed-in tariffs), market formation for technologies, entry of firms and organisations in the field of technology development and the strengthening of coalitions lobbying in favour of renewable technology (Lauber et al. 2004b).

The industrial and energy policies deployed by the government have led to new emerging industries. As technology developed and global markets grew, other (low labour cost) countries have caught up and are competing with Germany on the domestic as well as global markets.

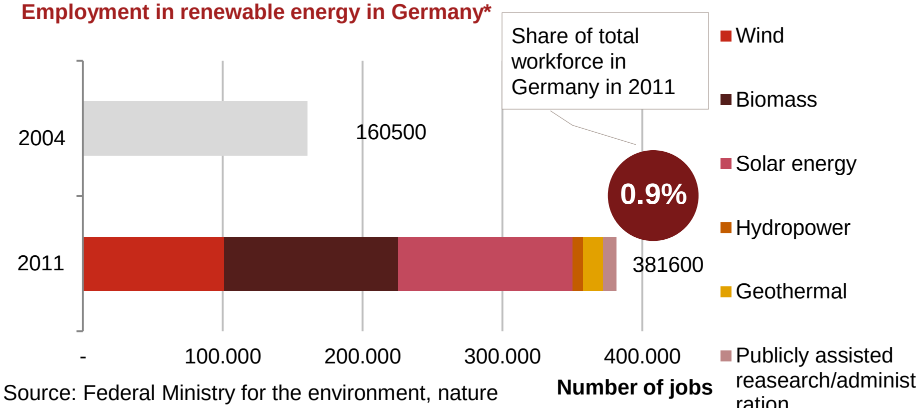
Competitiveness | **Growth** | Climate | Security of supply

Development of the value added of renewable energy in Germany



Source: Federal Ministry for the environment, nature conservation and nuclear safety (2010)

Employment in renewable energy in Germany*



Source: Federal Ministry for the environment, nature conservation and nuclear safety (2012)

* Includes jobs resulting from investments in renewable installations, operation of these installations, exports and imports, services (such as provision of required biomass and services by other industrial sectors) and work funded by the public and non-profit sectors to promote renewables

The industrial and energy policies deployed by the government have led to the creation of new industries. The success of these new industries largely depends on whether the industry is also able to expand their domestic business into an export business to serve customers on a global scale.

The renewable energy sector is contributing 1.7% to GVA

In 2009, the renewable energy industry (technology, development and operation of installations) contributes 1.7% to total GVA of Germany. Added value is generated through the actual operation of renewable energy plants as well as the construction of new installations.

Biomass, wind and solar energy sectors are the largest source of employment

The employment resulting from renewables is currently estimated at 0,9% of total employment in Germany. 68% of renewable energy jobs (in 2009) were estimated to be generated by the Renewable Energy Act (Federal Ministry for the environment, nature conservation and nuclear safety, 2010). But employment effects do not necessarily lead to a welfare effect, as a crowding out of jobs in other industries might take place: people will switch from other jobs in other industries. So the actual welfare gain might be limited. Studies show that the net employment balance is zero or even negative due to job losses in conventional energy generation (Frondel et al.,2009).

The challenge of maintaining competitive advantage

The competitive position of the German wind, biomass and, in particular, of the solar industry is increasingly threatened by the technology catch-up of low labour-cost countries like China (*please refer to the case study on solar energy on page 73)*. The industry faces competition within its domestic market, leading to defaults of companies and economic effects “leaking” to other countries. Continued innovation is considered important to maintain the competitive advantage in a high labour-cost country.

Energy and climate change policies contributed to large amounts of CO_2 emissions being avoided after 1990. Efficiency gains, which are partly driven by autonomous change, have contributed the most.

Competitiveness | Growth | **Climate** | Security of supply

Avoided CO_2 emissions as an important economic benefit

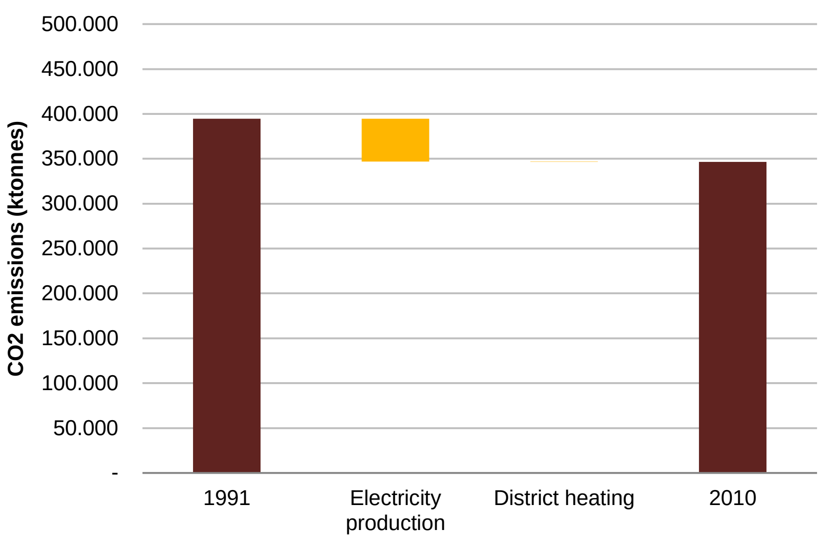
After an increase in CO_2 emissions until the 1980s, due to increased use of coal in electricity production, the CO_2 emissions in the energy sector started to decrease. Since 1991 emissions of the power sector were reduced by 12% *(please refer to the graph below).*

If the sector would have continued production with the fuel mix and energy efficiency level from 1990, given the GDP growth, the CO_2 emissions would have increased by about 28% towards 2011 compared to 1990 (*please refer to figure below*).Through energy efficiency gains and fuel mix changes about 90 Mtonnes of CO_2 emission was avoided.

After the first oil crisis, a large amount of CO_2 emissions has been avoided by implementing various climate change and energy policies. The increase in electricity demand has mainly been met by using low-carbon sources like nuclear (for security of supply reasons) and renewables (for primarily decarbonisation reasons). Decarbonisation after 1991 was driven by growth in renewables as Germany stopped building new nuclear power reactors.

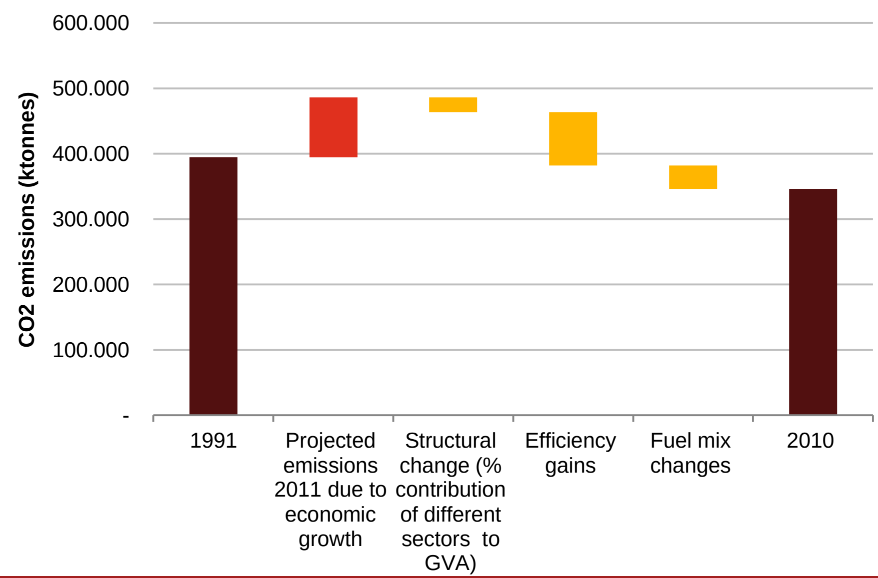
The German federal ministry for Environment, Nature Conservation and Nuclear Safety (2010) has estimated that in 2009 the use of renewable energy in the electricity and heat sectors prevented about €7.4 - €7.8 billion of environmental damage.

Change in observed CO_2 emissions in the energy sector, 1991-2010



Source: Energiedaten BMWi, PwC analysis

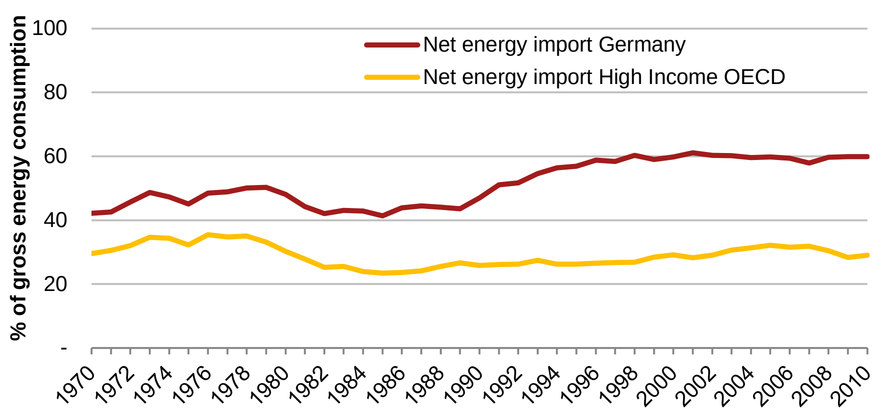
Avoided CO_2 emissions for the energy sector projected from 1991 to 2011, and factors mitigating these CO_2 emissions



Decarbonisation policies in Germany have not resulted in decreased energy imports. It still accounts for about 60% of the energy consumption. Security of supply is improved by diversifying its imports among new trade partners.

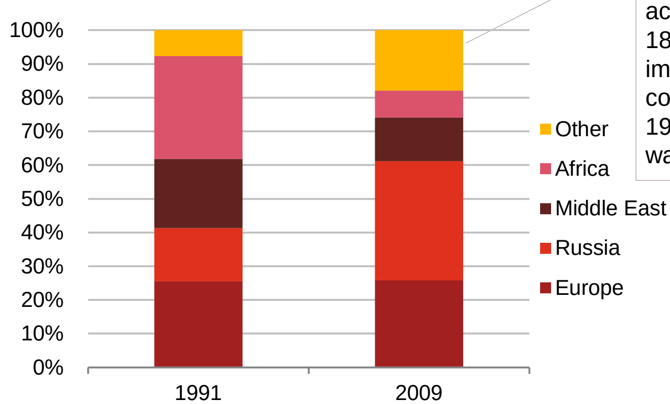
Competitiveness | Growth | Climate | **Security of supply**

Net energy imports in Germany and high-income OECD, 1970-2010*



Source: The World Bank

Crude oil imports by country of origin, 1991 and 2009*



Oil imports from other countries accounted for c. 18% of total oil imports in 2009. In comparison, in 1991 this share was c. 8%

Source: Energie in Deutschland 2010

* Includes energy used for transport purposes

Germany still depends on energy imports

Germany still largely depends on energy imports. Net imports increased during 1970-2010 and accounts for around 60% of gross energy consumption. Compared to high-income OECD countries, security of supply is relatively low in Germany.

But this can mainly be explained by the composition of the German fuel mix. Germany still depends on fossil fuel and the only abundant domestic resource is coal. Other fuels, such as natural gas and oil, are largely imported from other countries.

The expansion of renewables (wind and solar) have positively improved security of supply. But renewables sources are mainly used to replace coal-fired plants, which is a domestic energy source. So the impact on the energy trade balance is rather limited as the demand for conventional energy is still high.

Germany currently however is a net exporter for electricity.

Diversification of imports

To reduce risks associated with a high dependency on energy imports, Germany is aiming to diversify its imports. An increasingly larger share of fossil and nuclear fuels is imported from several countries instead of sourcing all from a single country. All the same, Germany still remains very dependent on energy imports from Russia – c. 35% of imported crude oil and c. 37% of natural gas originate from Russia.

Source: Federal Ministry of Environment

Case Study UK

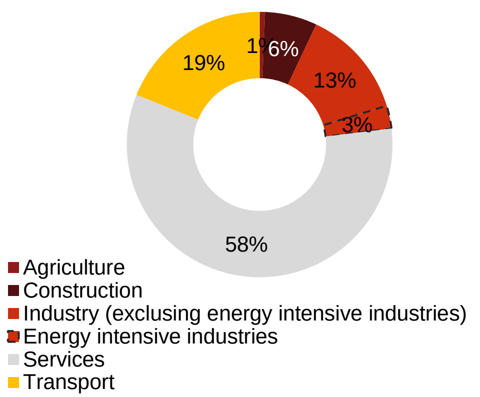
***Decarbonisation in the UK**: During 1970-2012, the UK's decarbonisation was characterised by natural gas replacing (more carbon-intense) coal and structural changes in the economy driving energy efficiency. For a long time, a free market approach was dominating the UK energy policy, which resulted in a lack of long-term policies to stimulate decarbonisation. Recently, broad political support for government intervention was realised by means of Climate Change Act (2008), which sets a clear but challenging decarbonisation path for the country. Since nuclear energy is not likely to increase and natural gas use has already replaced carbon intensive fossil fuels, the challenge is to significantly increase the use of renewables and stimulate energy efficiency. A variety of measures was recently implemented to meet this challenge.*

***The economic impact of decarbonisation:** The UK's energy prices, which are still below the European average, follow a global trend upward. Energy-intensive industry and households bear a lower tax burden as the government aims to protect competitiveness and reduce fuel poverty.*

Decarbonisation has led to additional economic activities. Although the UK is not known for green technology industry, renewable energy, nuclear and energy efficiency sectors generate about 1% of jobs in the UK.

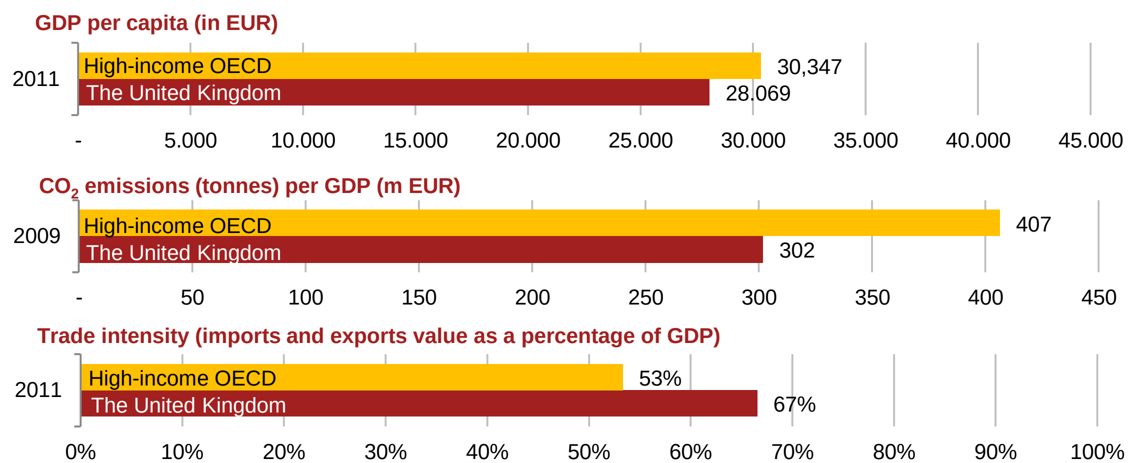
Security of supply was negatively affected by depleting natural gas resources, which made the UK a net energy importing country again in the last decade. Fuel diversification was mainly achieved towards fossil fuels, leaving room for improvement through renewable energy use.

Gross Value added (GVA) by sector in the UK (2010)



Source: Eurostat, Office for National Statistics UK
Energy-intensive industries include manufacturing of paper, products, chemicals, (basic) metals and coke/refined petroleum products

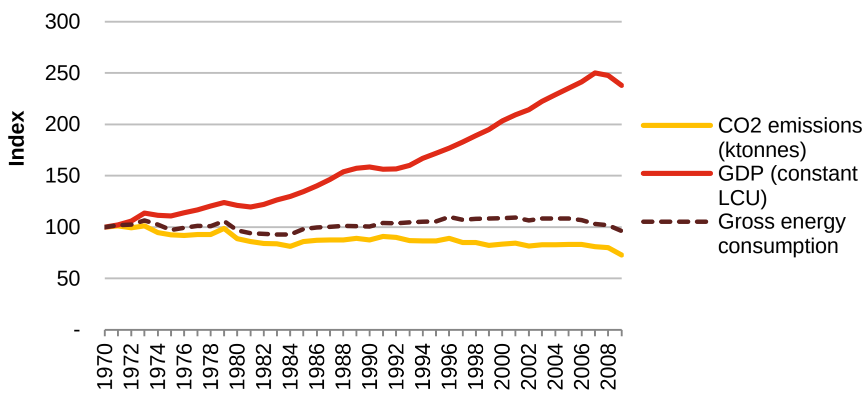
GDP 2011: €1,747bn| Population: 62.6m



Source: Eurostat; The World Bank

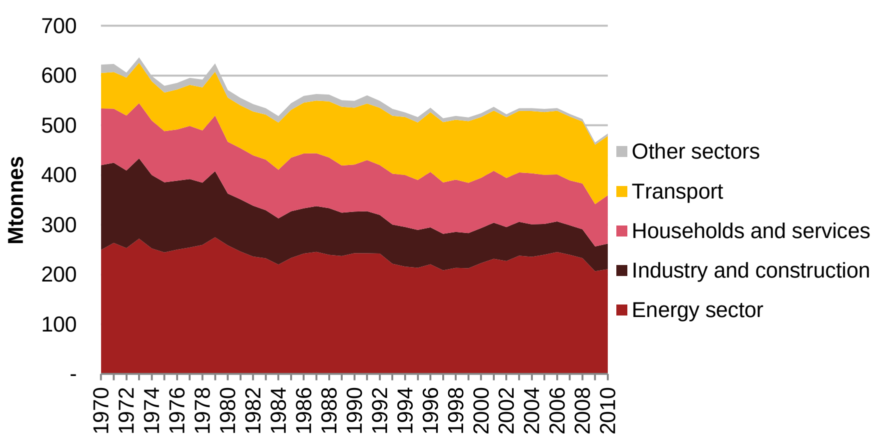
The UK has achieved economic growth decoupled from energy use and CO_2 emissions during 1970-2009. Carbon emissions dropped in the energy end-user sectors, i.e. households, services and industry, while emissions of the energy sector remained constant.

GDP and CO_2 emissions in the UK, 1970-2009



Source: The World Bank

CO_2 emissions per sector, 1970-2010



Source: The World Bank

Decoupled economic growth

The UK's economic growth started to decouple from energy use and carbon emissions in the 1970s. Our high-level analysis of the period between 1970 and 2009 showed that decoupling of economic growth from energy use was relative (an increase of 1% in GDP led to a 0.6% increase in total energy use). Economic growth was also decoupled from CO_2 in absolute terms (an increase of 1% in GDP coincided with a 0.7% reduction in total carbon emissions). This indicates that both fuel mix and energy efficiency changes were contributing factors to the decline in emissions.

Several reasons led to this decoupling in the UK. Firstly, the economy has witnessed structural changes. De-industrialisation started in the 1960s. In the late 1960s, more than 50% of the workforce was employed in services and the share has continued to grow, as has the relative share of the UK's gross value added (GVA). Restructuring of the economy and globalisation have led to industrial production being moved offshore. Last but not least, the government implemented multiple energy policy measures since the 1970s, which led to fuel mix changes and energy efficiency improvements.

Energy sector responsible for 44% of carbon emissions

Industry showed the largest changes in carbon emissions, followed by households and services, whereas total emission in the energy sector remained rather stable (*please refer to the second adjacent graph*). In 2010, the energy sector emitted 44% of total CO_2 emissions in the UK.

In the rest of the country case study, we are going to focus on electricity and heat production and end-user efficiency connected to electricity and heat demand as drivers of carbon emissions reduction. The transport sector is excluded from our analysis. The sectors in scope represent c. 60% of total energy demand and around 75% of total CO_2 emissions.

Sources: Crafts, N. Britain's Relative Economic Performance, 1870-1999; PwC analysis

Energy and Climate Policies

Guide to next section:

1 *FUEL MIX*	2 *ENERGY EFFICIENCY*
Electricity	Energy sector
Heat	Households
	Industry and Services

Political vision – A discovery of large gas resources resulted in a stable share of fossil fuel use in the UK. The government focused on energy efficiency instead as a means to reduce emissions and fight fuel poverty. But this did not result in substantial carbon savings. A more stringent approach came with Climate Change Act (2008).

Evolution of the focus on energy policies in the UK

International events

- '73 – First oil crisis
- '79 – Second oil crisis, nuclear accident in the US
- '86 – Chernobyl disaster in Ukraine
- '90
- 96 – First EU electricity and gas liberalisation directive
- '97 – Kyoto Protocol, adopted in 1997, enforced in 2005
- '05 – Introduction of the EU ETS
- '07 – EU Council adopts 20-20-20 goals
- '08 – Global financial crisis

Phase

1 Security of supply

Policy focus

Improving energy efficiency and affordability

The first oil crisis imposed a risk on security of energy supply. The UK government chose to boost exploitation of own resources and increase energy efficiency. The discovery of oil and gas reserves in the North Sea in 1960s-1970s made the UK an energy exporting country from 1980. As nuclear energy lacked public support and proved to have underestimated lifetime costs, fossil fuels remained the main source for heat and power production. The government promoted energy efficiency as a way to protect energy security.

During this period, the government started preparing for privatisation and liberalisation of the energy market. The mining industry began to lose its monopoly. British coal was more expensive than imported coal. The government announced intentions to close down pits and to limit working hours. This resulted in the miners' strike (1984-1985). Shortly afterwards, in 1986, the gas market was privatised (oil had been privatised already in the mid 1970s) and was planned to be liberalised in the 1990s to introduce more competition in the energy market.

2 The Dash for gas

The opening of the market

1990-1997 marks a strong focus on electricity market privatisation and liberalisation. The intention was to reduce power prices for consumers and address a fuel poverty issue in the UK. Little policy interventions were made in the fuel mix and energy efficiency.

After the gas market and electricity market reforms (in 1986 and 1990 respectively), natural gas started gaining market share in power production. Gas was now allowed to be used as a fuel for power generation (earlier restricted by an EU directive implemented in 1976). At that time, gas was cheaper than coal and Combined Cycle Gas Turbines were more efficient and less CO_2-intensive than coal-fired plants. Besides, gas became directly accessible to third parties (large consumers could purchase directly from the producers).

3 Ambitious decarbonisation targets

Energy security and climate objectives combined

In the 1980s-1990s, the UK was considered the 'Dirty Man of Europe' as it often resisted European emissions control legislation. But the UK's energy policy increasingly took into account climate objectives driven by Kyoto Protocol goals and the ambition to reach the announced goals for 2010 and 2020. The set targets for 2010 were at risk of not being met as the progress was too slow. The UK's general strategy towards climate change and decarbonisation was outlined in the Climate Change Programme in 2000.

A series of acts and policies were introduced: broader energy taxation, renewable obligations and eventually, Climate Change Act in 2008. The act sets emission budgets for periods of five years and in this way provides a long-term vision on decarbonisation trajectory. The UK faces the challenge of how to achieve the ambitious goals given the discovery of shale gas in the US or the resistance to close down coal plants. Carbon capture and storage technology is considered a promising solution in the UK, but its commercial application is likely to be delayed.

In addition, after 25 years of being a net exporter of energy, the country became a net importer again in 2004. This brought the energy security question back to the political agenda.

Political context

1979-1997: free market approach

In 1979, the Labour Party lost the elections to the Conservatives, who stayed in power until 1997. The Cabinet of 1979-1983 was committed to reduce state interference in the market and let the market define the optimal energy demand. So the Cabinet planned for privatisation and liberalisation of the energy market (coal, gas and electricity). The Conservative government generally agreed on the importance of reducing CO_2. But few long-term policies to reduce energy demand or to increase the use of renewables were introduced in this period. The theme of free market and limited government intervention played a vital role at that time.

1997- now: more interventions from the government

In 1997, the Labour Party returned to power, and started regulating the energy market by combining obligations and taxation. In 2010, the new Cabinet of Conservatives, together with Liberal Democrats, preserved the priorities in the energy market (energy security and environmental goals).

Overall, British political parties were consistent in supporting climate change mitigation, which became particularly strong after 2005-2006 when David Cameron took over the leadership of the Conservatives.

Implemented policy instruments – The UK experimented with a broad range of financial and regulatory instruments in the energy efficiency area in the entire period after 1973, whereas fuel mix changes, until a few years ago, were mainly left to the liberalised market and fossil fuel taxation.

Phase: 1 Security of supply | 2 The Dash for gas | 3 Ambitious decarbonisation targets

Strategy: Climate Change Programme 2000

Timeline: ’74 ’75 ’76 ’77 ’78 ’86 ’90 ’93 ’94 ’00 ’01 ’02 ’07 ’08 ’10 ’11 ’13

1 Fuel mix

Oil Taxation Act 1975: oil companies to pay petroleum revenue tax, gas companies excluded

Energy Act 1976: restriction on natural gas burning for electricity generation

Gas Act 1986: privatisation of British Gas

Non-fossil fuel obligation: distribution companies required to purchase nuclear and renewable electricity → Market-based **renewables obligation** (RO)

Electricity market liberalised **(Electricity Act 1989):** gas allowed for power production

Fossil Fuel Levy: levy paid by suppliers of electricity from non-renewable sources → **Climate Change Levy** (CCL): energy tax for energy supply to industry and services

UK CCS competition for the first full-scale **CCS demonstration project**

Feed-in Tariffs for small-scale renewables

Climate Change Act 2008: five-year emission budgets

Capacity market for power production

Contracts for Difference (renewables and nuclear)

Emission Performance standards (power plants)

Renewable Heat Incentive

The Green Deal: upfront loans for low-carbon solutions

2 Efficiency

Carbon Trust: to advise, fund and support the deployment of low-carbon solutions

UK ETS: carbon emission allowances → **EU ETS:** carbon emission allowances

Carbon Reduction Commitment (CRC): emission allowances for non-EU ETS large non-energy-intensive businesses

Carbon Price Floor: introduction for EU ETS power sector

Energy efficiency programme: standards and financial support, campaigns → **Four-year energy efficiency programme**: funding and campaigns

The Energy Efficiency Demonstration Scheme (1978-1989): Provided companies with 25% of capital cost for emerging technologies in energy efficiency

Energy Savings Trust: Financial and information support for energy efficiency measures

Energy Savings Obligations: obligation for suppliers to achieve energy savings at the customers’ end → **Energy Efficiency Commitment** by suppliers → **Carbon Reduction Emissions Target** at the customers’ end → **Energy Company Obligations** to save energy at the customers’ end

VAT on domestic power and fuel consumption

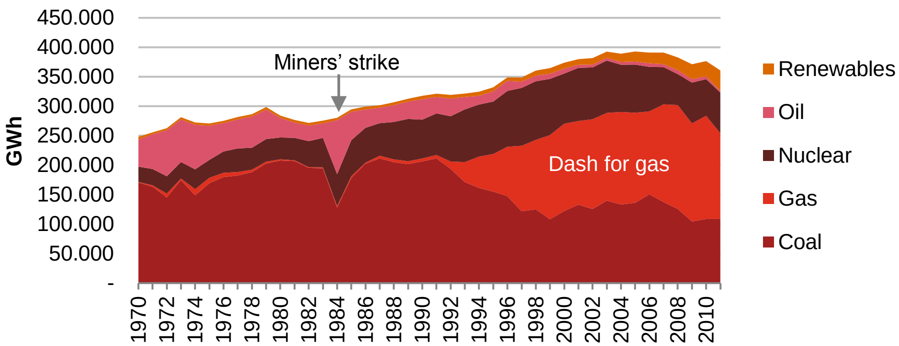
Climate Change Agreements: CCL exemptions for energy-intensive industry

FUEL MIX

Electricity | Heat

1 **The UK started focusing on energy security after the oil crisis in 1973 by increasing domestic production of gas. After the energy market was liberalised, gas replaced coal and oil in power production. The slow start of renewables can be attributed to the lack of domestic market demand stimulation.**

Electricity production by fuel, 1970-2011



Source: The World Bank

Increasing security of supply after the oil crisis in 1973

The UK experienced rapidly increasing oil prices during the Arab war in 1973. The oil crisis did not lead to an immediate change in the energy policy relating to the country's fuel mix. The government focused on replacing imports with domestic production and promoting energy efficiency to reduce the demand altogether. It also started taxing revenue from oil extraction (*The Oil Taxation Act 1975*) to discourage oil production. *The Energy Act 1976* implemented an EC Directive with restrictions on burning natural gas for generating electricity.

Decreasing use of coal in favour of the Dash for gas

After the Conservatives won the election in 1979, the focus of the government shifted towards less state interference in markets. Liberalisation and privatisation in the energy market caused the coal mining sector to decline. British coal was more expensive than imported coal. Announced pit closures, which would result in up to 20,000 lay-offs, led to a miners' strikes in 1984-1985. This had a temporary impact on the country's fuel mix for power production, as oil replaced the coal shortage. But the government pursued the planned closures and over the years, the role of coal in power production decreased and was replaced by increased use of natural gas.

In 1988, the government approved natural gas-burning plants, as CCGT was more efficient than coal-fired plants. This resulted in the so-called Dash for gas. When the electricity market was liberalised in the 1990s, natural gas became a preferred fuel for power generation.

Nuclear issues

When the government privatised and liberalised the electricity industry, it faced an issue with nuclear power plants. Private investors were difficult to attract to buy nuclear power plants as large funds were needed for inevitable decommissioning and waste management. Privatisation of nuclear power plants was delayed.

In 1990, the government introduced a *Non-Fossil Fuel Obligation (NFFO)* to make electricity suppliers purchase electricity from nuclear power plants and renewable power producers (subsidies only for nuclear power would not have been approved by the EU). The government placed orders for long-term contracts for electricity suppliers to accept electricity to their grid at an agreed price. The contracts were granted for lowest-price bidders (power producers) in a technology group and financed by the *Fossil Fuel Levy*, paid by suppliers of electricity. But subsidies were phased out (contracts were granted until 1998), and the share of nuclear power has declined since then.

Renewables on the way

Until the 2000s, renewable energy sources only marginally contributed to the UK's energy mix. The UK's policy to stimulate renewable energy production before 1990 was based on *R&D programmes* and technology demonstration projects. But there was little emphasis and funding for domestic market formation. The *NFFO* mentioned earlier was initially designed to support nuclear energy, so the majority of subsidies were used for nuclear energy. The policy contributed modestly to the expansion of renewable energy sources. After signing the Kyoto Protocol in 1997, it became clear that additional action had to be taken to increase renewable power generation. *(For more information on policy measures, please refer to the next page.)*

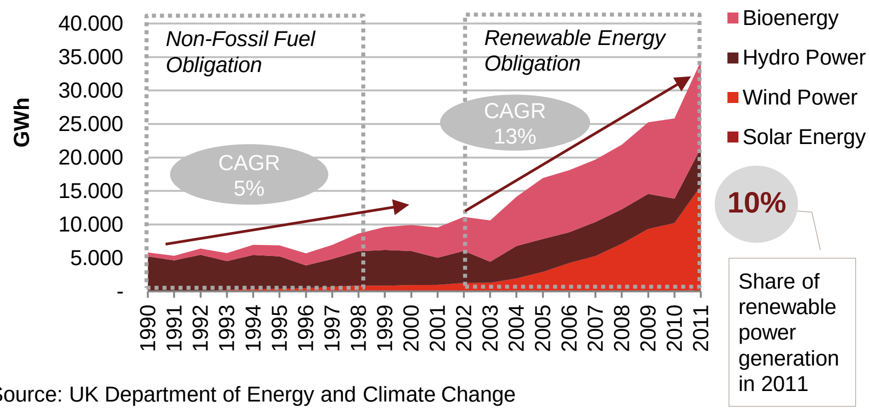
Source: Pearson, P., Watson, J. (2012); Winskel, N. (2002)

FUEL MIX

1 To catch up with the emission reduction targets, the government introduced renewable demand-stimulating measures (obligations and Feed-in Tariffs) in the 2000s. Bio energy and offshore wind became the leading technologies.

Electricity | Heat

Renewable electricity production by type, 1990-2011



Source: UK Department of Energy and Climate Change

From market to interventionist approach for renewables

The Labour Party that came to power in 1997, the year of the Kyoto Protocol, declared the need for increased government intervention. Evaluation of the free market approach to stimulate renewables and increase energy efficiency revealed incentives were lacking in the market. In the 2000s, the government took a more proactive approach towards decarbonising the power sector. In 2011, renewables constituted c. 10% of the fuel for electricity production in the UK. Most of the growth since the 2000s came from wind power (particularly offshore) and expansion of bio energy (mostly landfill gas, co-fired with fossil fuels and waste).

A new wave of renewable energy policies since 2000

The government founded *The Carbon Trust* in 2001, which played an important role in providing financial support (loans or capital) and expertise for renewable energy projects in the UK. Funding for the Carbon Trust reduced as government allowed the Trust to seek a greater share of private funding.

In 2001, Fossil Fuel Levy was replaced with the *Climate Change Levy* *(please refer to page 104 for more information on the levy)*. The levy was imposed on the supplied energy (heat and power) to industry and services, unless it was sourced from renewables.

The government decided to redesign the renewable support scheme. *The Renewable Obligation (RO)* for electricity suppliers was launched in 2002 and requires them to supply an increasing share of renewable electricity. Initially, the obligation was set at 3% of electricity generated from renewables. In 2011, the required share was raised to 11.1%. Suppliers have to obtain a certificate for every purchased megawatt of renewable power (1MWh = 1 certificate). Besides, the suppliers can 'buy out' the obligation if they do not want to participate by paying a fixed price for every unit of renewable electricity not purchased. This 'buy-out' revenue is then redistributed among the participating suppliers, increasing the attractiveness of participation. Costs of certificates are passed on to consumers via their energy bills.

Listed policy measures contributed to the faster move of renewables. Wind power, offshore wind in particular, significantly expanded its capacity with another 12 MW in construction or with planning approvals.

The Climate Change Act in 2008 sets the ambitions to decarbonise even further. This will definitely require an even faster expansion of renewables. The implications of the Act are outlined in the next page.

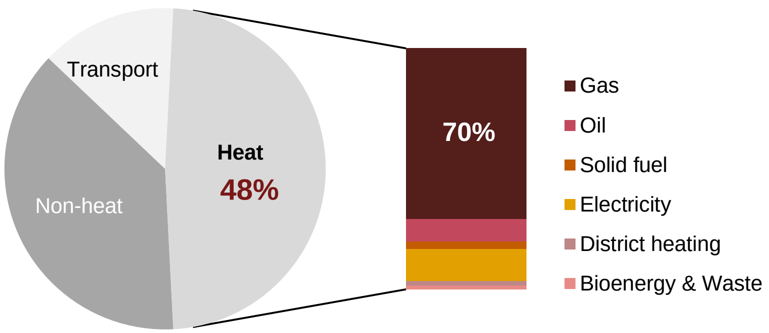
Source: Feed-In Tariffs Ltd; HM Revenue & Costums

FUEL MIX

Electricity | Heat

1 The fuel mix for heat was largely determined in the 1960s-1970s, when gas was chosen as a leading fuel. This reduced heat-related emissions substantially. Until 2012, policy measures affecting fuel mix for heat were rather scarce.

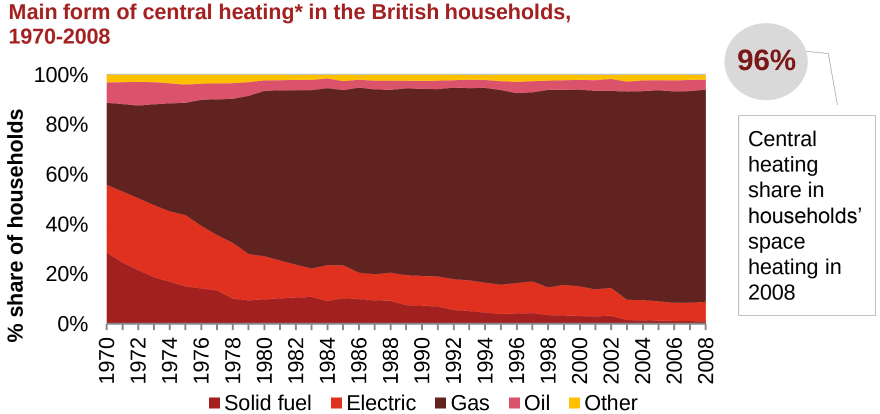
Total energy consumption by purpose and primary fuel mix for heat*, 2010



*Heat includes space heating, water heating, cooking, process use and drying/separation. Non-heat use includes computing, cooling and ventilation, lighting, appliances, motors, compressed air and refrigeration.

Source: Energy Consumption in the UK, DECC (2012)

Main form of central heating* in the British households, 1970-2008



*Central heating is a system of warming up a building by heating water or air in a single location and circulating it through pipes and radiators or vents.

Source: United Kingdom's housing energy fact file, DECC (2012)

Natural gas for heating

In 2010, almost half of the total overall energy consumption in the UK was heat consumption. The main fuel for heat production in the UK is natural gas (*please refer to the first adjacent graph)*. Natural gas was discovered in the North Sea in 1965 and the national gas pipeline infrastructure was constructed in 1967, so that natural gas could be used for heating purposes in homes. Since 1970, the share of homes using gas for heating purposes in the UK has more than doubled, replacing coal and electrical heating. In 2008, about 93% of homes used gas for heating purposes. A switch from coal to natural gas has reduced carbon emissions from heating substantially.

Stimulating renewable heat demand

Apart from general emission reduction policies, very few targeted policies stimulated the introduction of low-carbon heating solutions, such as renewable energy conversion to heat. Only c. 2% of heat in households is derived from renewable sources and district heating *('other sources' in the second adjacent graph*). In 2012, the government introduced *The Renewable Heat Incentive (RHI)*, financed through Feed-in Tariffs. It is a long-term financial support scheme aimed at promote renewable heat installations in industry and services. A proposal to introduce an RHI for households is in progress.

Sources: DECC; Winskel, N. (2002)

FUEL MIX & ENERGY EFFICIENCY

1 & 2 *Case study Climate Change Act* – Renewable obligation and steps on energy efficiency appeared to be insufficient to guarantee that emission targets would be achieved. The government agreed on Climate Change Act 2008, which sets carbon budgets in law and is expected to provide the necessary security for investments in renewables and CCS.

What does the Climate Change Act (2008) do?

The Climate Change Act, the first of its kind in the world, sets a legally binding target for the UK to cut its greenhouse gas emissions by at least 80% below 1990 levels by 2050. The act passed with the support of all political parties. It introduced a system of binding five-year carbon budgets, to be set at least 15 years in advance, aimed at providing certainty to investors and decision-makers about the commitment to transition to a low-carbon economy.

An independent body, the Committee on Climate Change, is mandated to recommend future carbon budgets and to regularly check the government's progress against them.

Progress up to date

According to the government, existing policies put the UK on track to cut emissions by over a third, based on 1990 levels, by 2020. Emissions are already down by a quarter from 1990 levels (in 2012). Much of the reduction resulted from the switch from high CO_2 coal to low CO_2 natural gas and a decline in heavy industry, the majority of which moved abroad. In 2010, the government introduced *the Feed-in Tariff (FIT)* intending to support the low-carbon electricity generation through small-scale system (so far, it boosted the small-scale PV sector in particular). But achieving carbon budgets will require additional policy measures, financial resources and political commitment.

The first carbon budgets in the UK, 2008-2027

	1st carbon budget	2nd carbon budget	3rd carbon budget	4th carbon budget
Years:	2008-12	2013-17	2018-22	2023-27
$MtCO_2e$:	3,018	2,782	2,544	1,950
% reduction below base year level	23%	29%	35%	50%

Sources: Carbon Plan Executive Summary, Dec 2011

What needs to happen?

To cut emissions further (by 80% by 2050), a lot more needs to happen. As stated in the UK's Carbon Plan, energy efficiency will have to increase dramatically across all sectors. Electricity will need to be decarbonised through renewable and nuclear power, and the use of carbon capture and storage (CCS). CCS technology research projects are being strongly backed by the UK, with the aim to turn CCS into a viable option in the coming decades. As greenhouse gas emissions are an intrinsic part of chemistry for some industrial processes, it can only be mitigated through innovative options such as CCS. But the first deployment of industrial CCS is expected in the late 2020s. Decarbonising transport and domestic heating is a priority in carbon reduction plans.

But these ambitions will have to resist a call for a renewed Dash for (shale) gas, as well as attempts to prolong lifetimes of existing coal plants. The UK is also about to pass a new Energy Bill, which would aim to maintain a stable electricity supply. But more notably, the Bill proposes a delay in setting decarbonisation targets under Climate Change Act.

The government has already taken a number of measures, mainly aimed at renewable expansion and prospective CCS introduction *(please refer to the next page for policies and their goals)*.

Sources: DECC; The Carbon Plan: Delivering our low carbon future, 2011

FUEL MIX & ENERGY EFFICIENCY

1 & 2 *Case study recent policies* – To step up the effort in energy efficiency and renewables, new measures were recently introduced. These measures aim to ensure a sufficiently high carbon price, which would stimulate green investments. Measures like Contracts for Difference and the Green Deal complement private funding.

Elements of the Electricity Market Reform 2012:

- Regulatory instrument
- Economic instrument

In the UK, a large share of nuclear and coal plants are gradually reaching the end of their economic lifetimes – around a fifth of the installed capacity will have to be replaced by the next decade. New capacity needs to be based on low-carbon solutions to meet emission targets defined in the Climate Change Act 2008. Electricity Market Reform in 2012 aims at ensuring security of power supply and further decarbonisation, but it has been criticised for complexity and large administrative costs. In addition, the UK is currently debating decarbonisation targets for the power sector for 2030, which are not included in the UK's Energy Bill yet. This would impose additional constraints to the electricity market.*

Emissions performance standards (2012)

Emissions performance standards (EPS), along with the EU ETS, is another instrument to decrease carbon emissions. The reform proposes an emissions performance standard for all new power plants of 450 g/kWh. It would, in fact, mean that coal-fired plants cannot be built anymore, unless they invest in carbon capture and storage (CCS) technology.

The capacity market (2012)

As renewables like solar or wind are intermittent means, additional measures need to be taken to safeguard flexible power generation capacity. The government initiated *a capacity market*. Reliable capacity providers are paid on a kilowatt per year basis for the capacity that a power plant can generate. It provides financial incentives to maintain reliable capacity for when electricity is most needed. On the other hand, the measures can also potentially lead to more gas plants being built, which can be counterproductive for renewable investment stimulation.

Contracts for Difference (2012)

The government introduced *Contracts for Difference (CfDs)*. The goal is to stimulate investment in low-carbon technologies. Generators can earn revenue from selling their electricity at the market price. But, when market reference price is below strike price, they will receive a top-up payment from suppliers for the remaining amount, who, in turn, are likely to pass the costs to consumers via their energy bills. Nuclear is also a part of the deal, which raises concerns about compatibility with the EU's regulation.

Carbon Price Floor (2013)

The UK government believes that fluctuations in carbon price in the form of EU ETS allowances have resulted in uncertainty for investors in low-carbon technologies. In April 2013, the government introduced a *Carbon Floor Price* to strengthen the effect of EU ETS. It is a tax on fossil fuels used in the generation of electricity, if the EU ETS carbon price falls below the set price floor. The tax is now set at £16 per tonne of CO_2, and is planned to increase in future.

The Green Deal (2012)

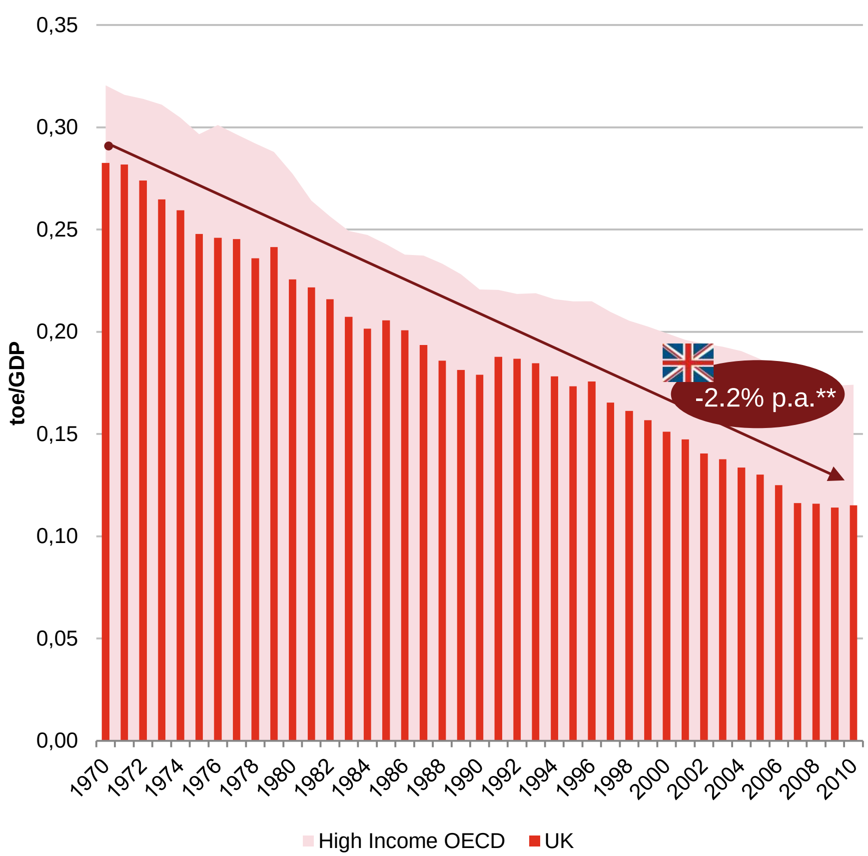
The government also introduced a market-based instrument to improve home energy efficiency and energy efficiency in businesses and the public sector, and to encourage private investment in green technologies. *The Green Deal* providers offer upfront loans for investments, which would be repaid via the energy bills to electricity suppliers.

Sources: Various DECC publications; *Capacity Market, 1 October 2012, DECC

ENERGY EFFICIENCY

2 The UK has reduced primary energy intensity faster than high-income OECD countries. The British government played a proactive role in implementing a large array of policies to stimulate energy efficiency. The measures varied from voluntary instruments to regulatory requirements.

Primary energy intensity (toe/GDP thousand USD)*, 1970-2010



*The energy intensity includes the transport sector
**Change in primary energy intensity; Final energy use intensity decreased by -4,0% annually (1990-2011)

Source: The World Bank

Energy efficiency as a strategy to meet carbon reduction targets

The UK reduced its primary energy intensity at a faster pace than its peers, the high-income OECD countries, i.e. at a rate of 2.2% vs 1.5% reduction per year.

This is largely a result from structural changes in the economy. But energy efficiency policies also contributed to the reduced energy intensity. A part of energy efficiency improvements are offset by a so-called rebound effect as decreased costs enable increased household consumption of energy or other goods and services. The UK tried many different instruments in this area: varying from market-based mechanisms to subsidies or grants for investing in energy efficiency measures.

The ideology concerning the role of the government has changed over time. In the 1970s-1980s, the free market and pricing signals were believed to lead to efficient use of energy. A change in governments (from the Conservatives to the Labour Party) resulted more regulation in the energy efficiency sector.

Primary energy intensity depends on the following factors:

1. Energy use in the energy sector (power and heat production)
2. Energy use by the end user (households, services, industry and transport).

In the UK, the most substantial improvements in energy intensity occurred in businesses (services and industry). Underlying strategies and policy choices will be discussed in the next three pages for:

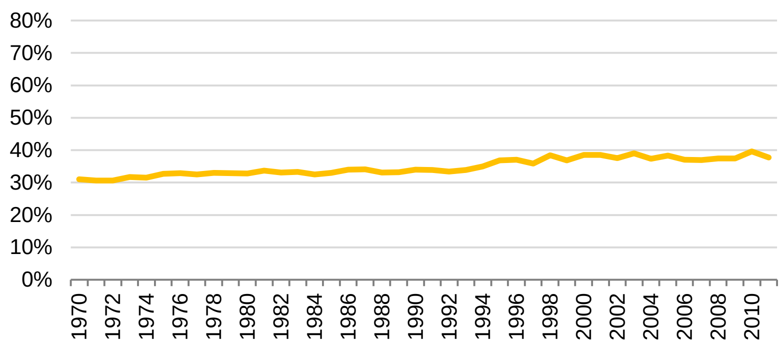
Energy sector + Households + Industry services

In the UK, policies often target households and businesses separately. So we discuss efficiency policies in services together with industrial efficiency. The transport sector is further excluded from our scope.

ENERGY EFFICIENCY

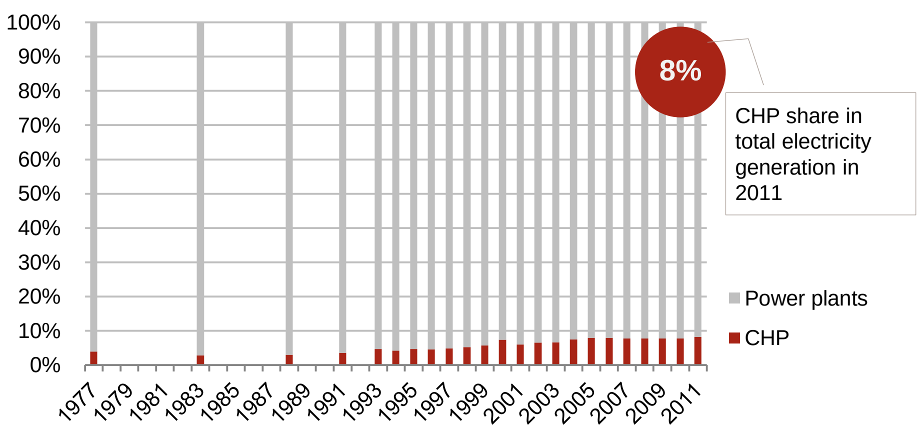
2 Electricity production efficiency has improved slightly in the mid-1990s, when gas was allowed for power production and CCGT technology was increasingly used. Incentives to increase CHP use have yielded only modest results so far.

Development of the electricity transformation* in the UK, 1970-2011



* Data on efficiency in district heating production was not available
Source: Energy Consumption in the UK and DUKES chapter 5, DECC (2012)

Electricity generation by type of producer, 1977-2011



Source: UK DECC

Slightly increasing transformation efficiency

The efficiency of electricity generation (measured as a ratio of energy output and fuel input) has increased from c. 30% in 1970 to c. 40% in 2011, mainly because of the introduction of gas turbines in the early 1990s*.

Generation efficiency can be further improved by increasing the share of combined heat and power generation plants (CHP). The government tried to stimulate investments in CHP plants by introducing several incentives, such as Climate Change Levy exemptions (since 2001), enhanced capital allowances (introduced under the Carbon Trust)** and Feed-in Tariffs. But despite these measures, combined heat and power generation is still very limited in the UK compared to other countries like Denmark and the Netherlands — about 8% of total British electricity generation.

*The generation efficiency of CCGT power plant ranges from 40% to 50%, depending on the mode of operation of the plant; whereas coal-fired stations typically have an efficiency of up to 38% (source: DECC, http://chp.decc.gov.uk/cms/centralised-electricity-generation/)

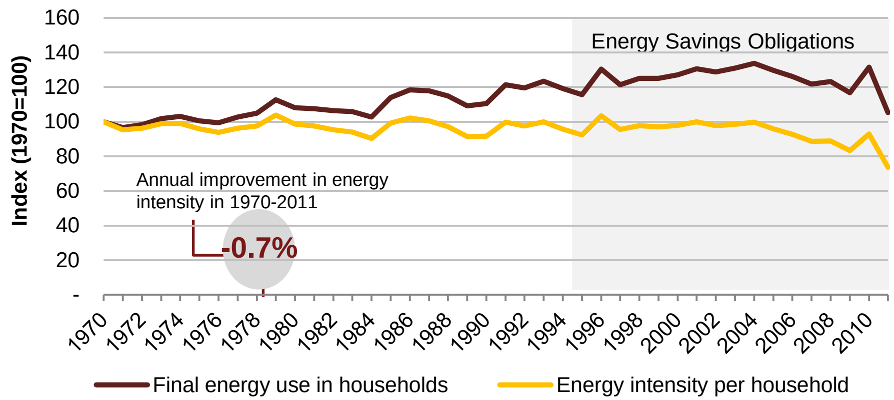
**The Enhanced Capital Allowances (ECA) scheme allows businesses to write off 100% of their investment in CHP against the taxable profits of the period in which they invest.

Source: DECC

ENERGY EFFICIENCY

2 Energy use per household started to decrease only in 2004. A part of the improvement was caused by increasing gas and electricity prices. On a policy side, the UK is driving energy efficiency improvements by holding utility companies responsible for energy efficiency investments.

Total energy use in households and energy use per household in the UK, 1970-2011



Source: UK DECC

Managing domestic energy demand

In response to the first oil crisis, the government focused on reducing energy efficiency. A large variety of measures like technology demonstration programmes, information campaigns and financial support was deployed between 1974 and 1989. Home insulation campaigns were a priority instrument in lowering energy use in households. The UK's DECC reports that improved home insulation and heating systems' efficiency reduced actual energy consumption in homes by 49%* so far.

Energy Savings Trust (EST) in 1993

Traditionally, building regulations (including energy performance standards) and energy labelling for appliances were used to regulate energy use. Increasing urgency to act on emission reduction targets urged the government to found the Energy Savings Trust (EST). The EST proved to be effective in giving a free advice to the public on how to reduce energy bills and use water more efficiently at homes.

Suppliers obliged to save energy at homes

The UK was the first country in Europe to introduce in 1994 Energy Savings Obligations (SO) for energy suppliers to save energy at homes. The savings targets were set as annual energy savings. Eventually, the targets were changed to carbon emission savings in 2008, aligning the SO with the wider climate policy landscape. These targets were also raised over time. The current obligation scheme is called *Energy Company Obligations*, introduced in 2012.

The energy regulator (OFGEM) sets targets for each energy company, which, in turn, contracts installers of energy-saving measures, for instance insulation work, or may choose to set up their own insulation business. A share of utility companies' obligation to reduce emissions has to be executed at low-income homes, addressing fuel poverty issue. From 2002 to 2008, energy suppliers spent c. €2bn for the savings obligation, of which most costs have been passed on to consumers**.

Introduction of VAT

In 1994, the government introduced a 8% VAT on domestic power and fuel use for the first time in the UK's history. It should have served two purposes: as a revenue for the state budget and as a price signal to save energy. Since 1997, the UK's consumers pay a reduced rate of 5% on electricity, gas and other fuel to reduce fuel poverty in the country. On the one hand, tax reduction reduced energy cost burden for households, but on the other, it indirectly subsidises fossil fuels, which undermines emission reduction targets.

Effect of energy prices

Policies do contribute to efficiency improvements, but the largest decrease in energy use per household occurred since 2004, when gas and electricity prices started increasing sharply ***.

*Savings are based on how much additional energy would be required if insulation and/or heating systems' efficiencies had remained at the 1970 levels.

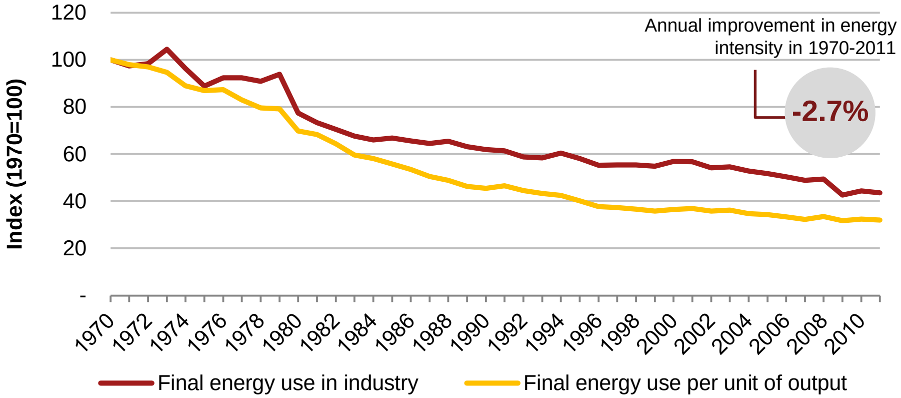
Sources: **Rosenow, J. (2012); *** Great Britain's Housing Energy Fact File 2011; Pearson, P., Watson, J. (2012)

ENERGY EFFICIENCY

Energy sector | Households | Industry & Services

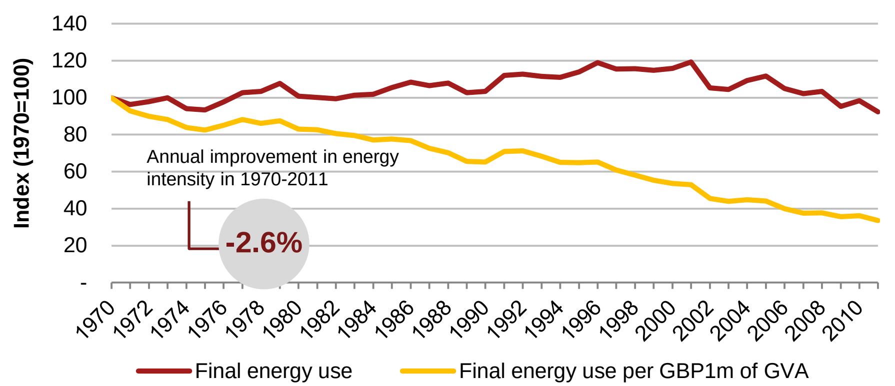
2 Energy intensity in businesses decreased since the 1970s. Energy reduction in industry is mainly related to globalisation and energy-intensive industry moving offshore. Policy effect is likely to be limited until now. Improving building standards and rising energy prices reduced energy intensity in services.

Final energy use and energy intensity in industry, 1970-2011



Source: UK DECC

Final energy use* and energy intensity in services, 1970-2011



*Final energy use in services includes the consumption of public administration, commerce and agriculture

Source: UK DECC

Lower energy intensity in businesses

Energy intensity changes for the industry and services were substantial in the UK. Structural changes in the economy, energy prices and energy policies together stimulated this development. The decrease of energy use in industry was partially caused by structural changes in the composition of the industry sector (more energy-light industry). Total energy use in the service sector increased, driven by economic growth up to 2000, when it started decreasing driven by improvements in building efficiency and sharply rising energy prices.

Policy development

Early energy policies to increase efficiency focused on demonstrating technology. The Conservative government changed the policy focus towards less government intervention. It argued that energy efficiency investments pay off, so businesses are responsible for their own investments. But the market proved to be unable to deliver required energy savings and additional measures were implemented in the 2000s.

In 2001, the government founded *the Carbon Trust*, a structure similar to the Energy Savings Trust, to support businesses. It provided specialist advice on energy efficiency and fuel mix changes. At present, the Trust also includes financing low-carbon technologies (mainly energy efficiency technologies and renewables).

Since 2001, energy-intensive industries (with a ratio of energy expenditure to value of output of 12% or higher) can enter into voluntary *Climate Change Agreements* (CCAs) which allow them to pay a reduced rate of Climate Change Levy (up to 65% reduction) if they meet energy efficiency or carbon-savings targets. Again, there is a considerable debate about the ability of the CCAs to deliver real emission reductions as it is a rather complex system.

Large non-energy-intensive businesses in the service sector (outside the EU ETS), accounting for 12% of the UK's emissions, have to buy emissions allowances from the government at £12/CO_2 tonne since 2010 (a so-called *Carbon Reduction Commitment Energy Efficiency Scheme*). It is expected to reduce energy use in the service sector.

FUEL MIX & ENERGY EFFICIENCY

1 & 2 Fossil fuel taxation has a long history in the UK. The first oil revenue tax was turned to fossil fuel levy, later replaced by the Climate Change Levy. Incentives are provided to use renewables or operate CHPs and, indirectly, to improve energy efficiency.

Current energy tax rates in the UK, 2013

Taxable commodity	CCL	Fuel duty	
		Fuel oil	Gas oil
1. Electricity (supply)			
From non-renewable generators	0.509 p/kWh	-	-
From CHP generators	0 p/kWh	-	-
2. Gas			
Gas as supplied by a gas utility	0.182 p/kWh	-	-
Gas supplied for CHP or electricity producers	0 p/kWh	-	-
3. LPG			
LPG supplied for heating	1.137 p/kg	-	-
LPG supplied for CHP or electricity producers	0 p/kg	-	-
4. Solid fuel			
e.g. Coal, coke, lignite, petroleum coke	1.281 p/kg	-	-
Solid fuel for CHP or electricity producers	0 p/kg	-	-
5. Oils			
All uses	-	10.74 p/l	11.18 p/l
For electricity generators	-	0 p/l	0 p/l

Sources: HM Revenue & Customs (2012)

Climate Change Levy as the UK's energy tax

The UK started with fossil fuel taxation in 1975. The government then introduced oil revenue tax for oil companies. In 1990, it was replaced with a broader Fossil Fuel Levy, which lasted till 2001. The current energy taxation scheme is built on two pillars: Climate Change Levy (CCL, 2001) and fuel duty on oils. CCL is a tax on the supply of energy products (power, gas and fuel) for business consumers (*please refer to the adjacent table for exact rates).*

The taxation policy excludes households and the transport sector. Households are excluded because of the concerns on fuel poverty but they pay (reduced) VAT rates.

Fuels used for electricity production are exempted from both the Climate Change Levy and fuel duty to avoid double taxation as electricity suppliers pay a levy per each kilowatt supplied to.

Energy-intensive industry exemptions

Energy-intensive industries are companies which have a ratio of energy expenditure to value of output of 12% or higher, or industries with international competitiveness concerns. The ones that enter into Climate Change Agreements (CCAs) with the government are partially exempted from the CCL. They can receive up to 65% CCL rate reduction in return for meeting energy efficiency or carbon-saving targets.

Renewable and efficiency (CHP) exemptions

Industries using renewable energy or energy used or produced by CHP are eligible for Levy Exemption Certificates (LECs). This certificate exempts the industries from having to pay the levy.

Sources: UK government

Economic Impact of the Energy and Climate Policies

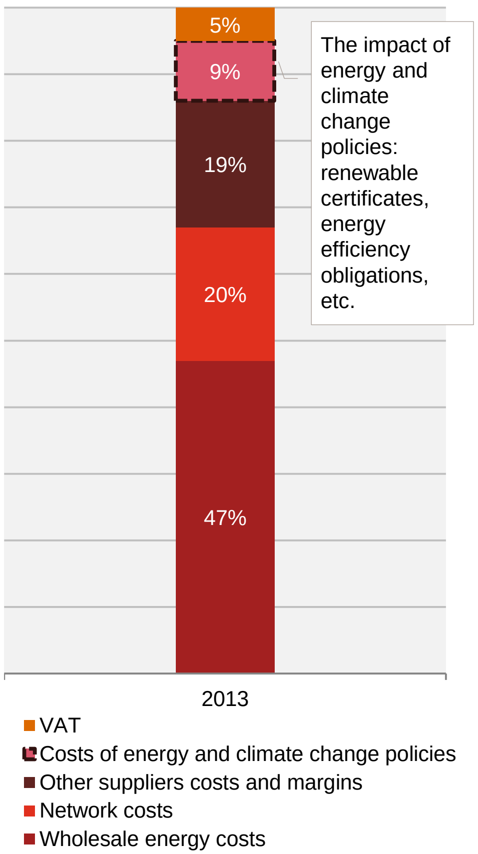
Guide to next section:

- Competitiveness
- Growth (new industries)
- Climate
- Security of supply

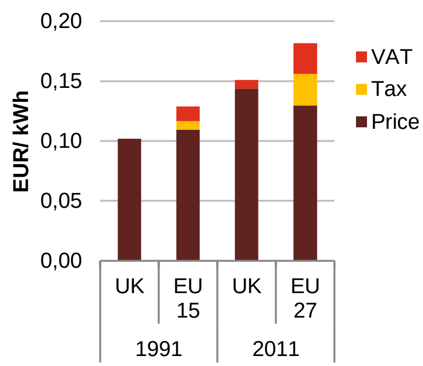
Energy prices for households in the UK are lower than the European average but follow a global upward trend. Energy and climate change policies also contribute (c. 9%) to the energy cost increases. Measures were taken to constrain a further price increase but fuel poverty remains an issue.

Competitiveness | Growth | Climate | Security of supply

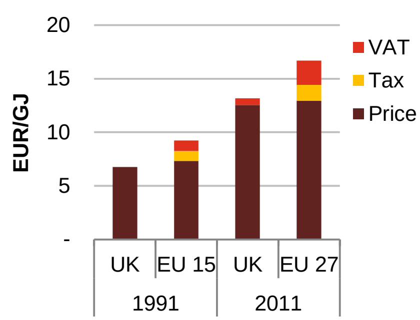
Estimated breakdown of average household dual fuel (gas and electricity) bill in the UK in 2013



Electricity prices for domestic consumers in 1991 and 2011*



Gas prices for domestic consumers in 1991 and 2011*



* New methodology was adopted in 2007. So values before 2007 and after 2007 are not comparable. 2011 EU data includes 27 member states, whereas 1991 includes EU-15. Prices are not corrected for purchasing power.

Source: Eurostat; DECC (2013)

Increasing energy prices

In the UK, the electricity and gas prices are relatively lower than in the EU-27. They have been steadily increasing over the last 10-20 years. Increasing primary fuel prices and a larger number of energy and climate change policy measures are two important drivers of this trend.

Policies to constrain price increases introduced…

UK households pay relatively low retail gas and electricity price, compared to the EU average. The reason is that the UK's households pay reduced VAT rates and are excluded from energy taxation. Some energy policy costs are still passed on. The DECC estimates that the costs of current energy and climate change policies account for 9% of the household energy bill. Efforts to improve home insulation and modernise heating systems to a certain extent reduced the impact of rising prices, but energy efficiency in the UK's houses is still lagging behind the Northern European counterparts. A relatively lower efficiency also contributed to fuel poverty and make emission reduction in home a challenging task. But at the same time, it still remains one of the most cost-effective ways for the UK to reduce emissions in the housing sector significantly.

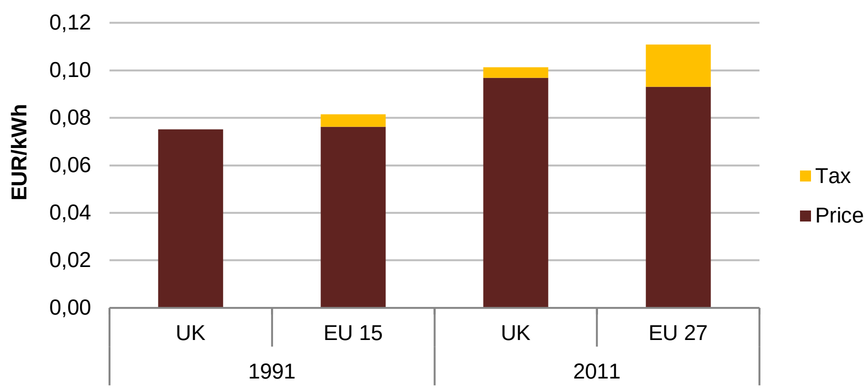
..but fuel poverty is increasing

The Labour government policy was explicit in trying to protect households from energy price rises. But the reality shows that fuel poverty has not been reduced in the UK. On the contrary, the number of fuel poor households rose nearly twice since 2000.

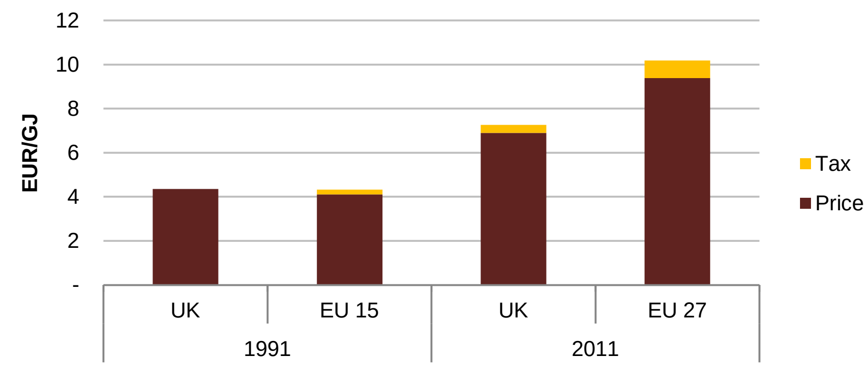
Source: DECC, 2013; The United Kingdom Climate Change Levy: A study in political economy (OECD, 2005); Annual Report on Fuel Poverty Statistics 2013

Energy prices for industrial consumers have increased, driven by a general upward trend in fuel prices and environmental policy measures. But they are still relatively low compared to the EU average. Energy-intensive industries pay reduced tax rates to protect their competitiveness.

Electricity prices for industrial consumers in 1991 and 2011*



Gas prices for industrial consumers in 1991 and 2011*



* New methodology was adopted in 2007. So values before 2007 and after 2007 are not comparable. 2011 EU data includes 27 member states, whereas 1991 includes EU-15. Prices are not corrected for purchasing power.

Source: Eurostat

Energy prices increase for industry

Similar to households, energy prices for the UK's industrial users have gone up in the last two decades. Primary fuel prices for electricity or heat production, and gas prices in particular, are one of the main drivers of the upward trend. As CCGT is a dominating technology, the UK's power prices are more in line with gas price fluctuations, as c. 60% of costs to generate electricity from gas-fired CCGT plant is fuel costs. Whereas, for instance, only c. 24% o f costs to generate electricity from coal is fuel costs*.

Unlike households, industry is also required to pay the Climate Change Levy (the UK's energy tax equivalent). Increasing policy measures will raise the prices further, as the costs of the measures (Feed-in-Tariffs, the Renewable Obligation etc.) are passed on to industrial consumers.

Impact of increasing prices

The average energy costs as a proportion of total operation costs of businesses in non energy-intensive industry is estimated at only about 3%**. In comparison, c. 14% of total costs is energy costs in the iron and steal industry. So increasing energy prices can reduce the industry's competitiveness, especially if the industries from other countries are either less dependent on energy or have access to cheaper electricity or heat.

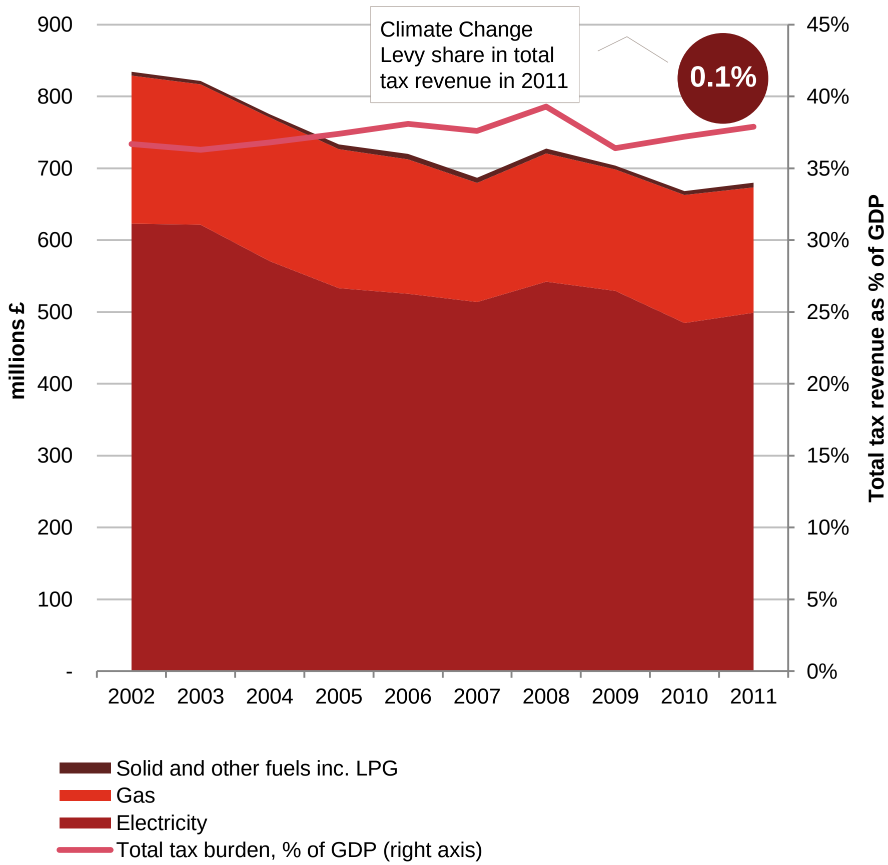
In the UK, many energy-intensive industries are located in areas of higher unemployment and so the government sees their continued operation as vital to the economies of those regions with foregone jobs often difficult to replace*. The government addressed the competitiveness issue by granting the Climate Change Levy exemptions to the energy-intensive industry. Government is also seeking to exempt energy-intensive industries from the costs of Contracts for Difference (introduced in 2012). The government has also offered compensation package worth c £250m per year to energy-intensive industries to address the impacts of the Carbon Price Floor.

Source: * Royal Academy of Engineering (2004); **DECC (2012); Environmental Audit Committee (2013)

The Climate Change Levy, the UK's energy tax, was implemented as a revenue-neutral measure. So total tax burden on a macro level did not increase in the UK. The CCL revenue only comprises a rather small share of total UK's tax revenue.

Competitiveness | Growth | Climate | Security of supply

Climate change levy and its share in GDP in UK, 2002-2011



Source: Eurostat; HM Revenue and Customs

Revenue-neutral taxing and earmarking

The effects on the environmental taxes on a macro (national) level are either welfare reducing or neutral, if the taxes replace other taxation. To assess the impact of the UK's CCL, we estimated the total tax burden as a percentage of GDP and compared it to the development of the CCL revenue.

The CCL was designed as part of a revenue-neutral reform in 2001 (meaning that the introduction of the Levy would not lead to the increase of the total tax burden) and was intended to not harm competitiveness. So the revenue from the CCL is returned to the contributing industries by lowering burden on labour taxes (with around 0.3%). But in 2002, labour taxes were increased by 1%, diminishing the effect of 'recycling' of the CCL revenues. Overall, the total tax burden stayed rather stable in the UK. This means that on a macro level, additional environmental taxation did not result in a welfare loss. Certainly, some industries or sectors could have been adversely affected.

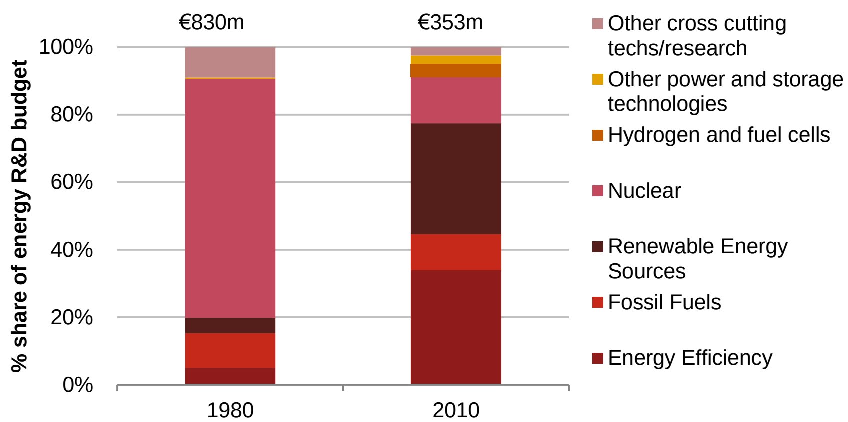
The total revenue of the Climate Change Levy is only a small part (0.1% in 2011) of the total tax revenue. The reason, partly, is that domestic users (households) and transport are not subject to this levy. A small share of the revenues is used to fund energy efficiency and decarbonisation initiatives like the Carbon Trust (which received around 4% of the total revenues from the CCL). This trust was used to stimulate adopting low-carbon technologies.

Source: OECD (2005)

Competitiveness | Growth | Climate | Security of supply

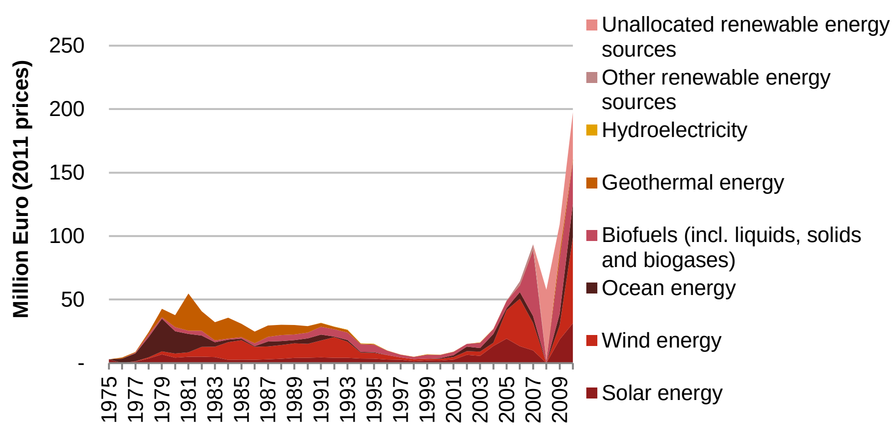
Most of the UK's early energy R&D efforts were devoted to nuclear research. As the future of nuclear energy in the UK was uncertain, the effort shifted to renewables and energy efficiency.

R&D government investments in R&D in the UK



Source: IEA

R&D Budgets for renewable energy in the UK, 1974-2010



Source: IEA

R&D investments for new economic activities

Replacing fossil fuels with low-carbon energy sources and reducing energy intensity require technological development and innovation effort. Economic impact can be maximised, if the demand for renewables and energy efficiency measures is met with domestic products and services. Resulting domestic specialised industries could increase economic benefits further by exporting to other countries. The rise of such industries takes place in a complex interaction between many factors such as wholesale prices driven by trends in global markets, the development of consumer purchasing power, returns from locally owned renewable energy sources etc. R&D support by the government and market formation programmes impact the development of new economic activities.

R&D support

In the UK, nuclear research dominated the 1970s-1980s, but the funding began to decrease in the mid-1980s, following public debates. Energy R&D has been rather moderate since then and mainly targeted renewables and energy efficiency. But the amount of funding never reached the levels of nuclear R&D funding. Since 2003, the budgets were raised substantially, as the government realised that the UK could still become a technology leader in offshore wind.

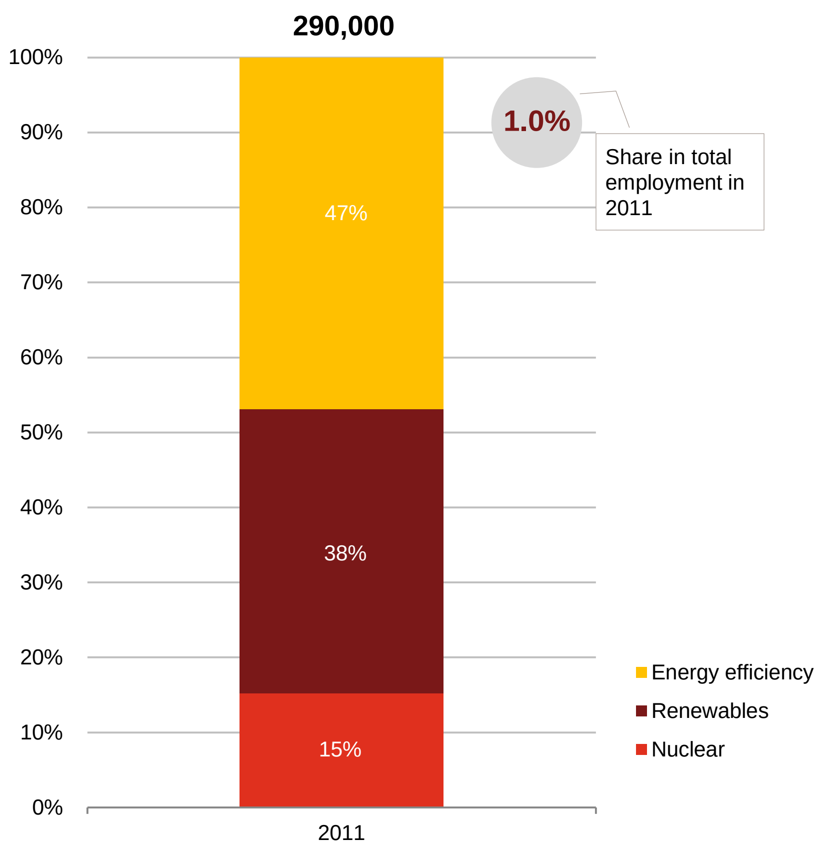
Market formation

R&D effort is best used if there is sufficient market for technology that was created. The dynamics of renewable energy, nuclear energy and energy efficiency markets can contribute to the country's growth and result in a substantial economic impact. *For the current estimated economic impact, please refer to the next page.*

Demand for renewables in the UK did not become large enough to stimulate the rise of a domestic industry. As the government historically favoured energy efficiency measures, the energy efficiency industry has emerged as the 'winner'. But still, the generated economic activity was significant.

Competitiveness | **Growth** | Climate | Security of supply

Employment in low carbon industries, 2011



Source: BIS (2011); DECC UK Renewable Energy Roadmap Update 2012

The UK has not developed large renewable or energy efficiency technology industries that would compete worldwide. But the economic impact of energy and climate change policies, supported by autonomous economic structural developments, was still large at a local level. To address the lack of industrial policy in the low-carbon energy sector, the new government aims to develop such a plan that stimulates low-carbon technology growth.

Development of the energy efficiency sector

The first energy demand reduction policies were developed in 1974 in the UK in response to oil shocks. Many different approaches have been taken since then to improve energy efficiency. Some were successful, some less so, but the efforts stimulated the rise of an energy efficiency industry (for instance, insulation solutions, more efficient industrial processes, better use of heat, energy efficient lighting, smart metering etc.).

Energy efficiency was also seen as a way of improving UK industry's competitiveness, which was falling behind Japan or the US. The government believed that energy efficiency could not only reduce carbon emissions and climate change but also improve the competitiveness of industry and reduce energy costs for households (a 'win-win-win').

Employment in low-carbon industries

In addition to the energy security argument, energy efficiency is known to contribute directly to economic growth. Installing energy efficiency measures most of the time requires local labour. The energy efficiency sector in 2011 created about 136,000 jobs in the UK (or 47% of jobs of renewables, nuclear and energy efficiency sectors together).

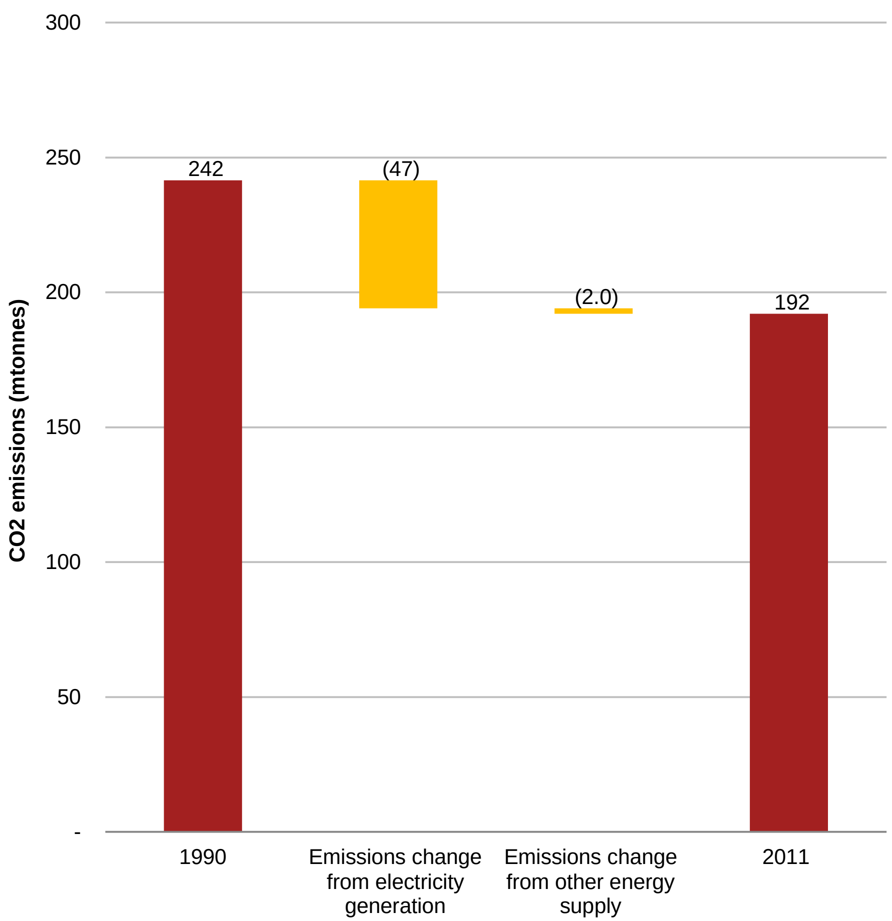
The energy efficiency sector, renewable energy sector (technology and production) and nuclear generation together employed about 290,000 people in the UK in 2011. These were direct jobs and immediate supply jobs. Obviously, a share of the jobs could have replaced jobs in conventional power generation. A gross value added estimate of these sectors has not been consistently reported in the UK.

Source: DECC (2012)

Increasing gas-fuelled electricity generation and end-user efficiency improvements resulted in avoided CO_2 emissions.

Competitiveness | Growth | Climate | Security of supply

Change in observed CO2 emissions in the energy sector, 1990-2011



Source: UK DECC

The electricity sector to contribute to large CO_2 savings

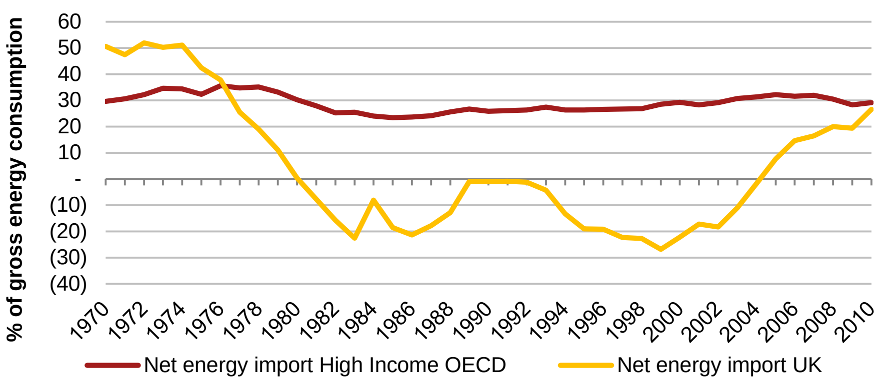
Lower energy demand and lower CO_2 intensity of power and heat generation can result not only in direct economic benefits or costs, such as investments in new energy sources and emerging technology or increasing energy prices. Avoided CO_2 emissions provide indirect savings too. For example, there are savings related to the costs of emission permits or carbon and/or energy taxation (micro benefits). In addition, CO_2 emissions are an externality. So avoided carbon emissions reduce related future social costs of climate change.

If the same fuel mix and energy intensity level were continued from 1990 onwards, CO2 emissions would have increased compared to the actual current level of emissions. CO_2 savings are a result of a few factors. Structural changes effect energy demand. As a share of the UK's industry moved offshore or was replaced with less energy-intensive economic activities, the demand for energy dropped. Electricity generators switched to cleaner fuels, namely natural gas and, increasingly, renewables, which is largely a result of the interaction between policy measures. If the sector continued to produce electricity and heat with the fuel mix prior to the 1990s, the current CO_2 emissions would have likely been significantly higher than they are now.

Competitiveness | Growth | Climate | Security of supply

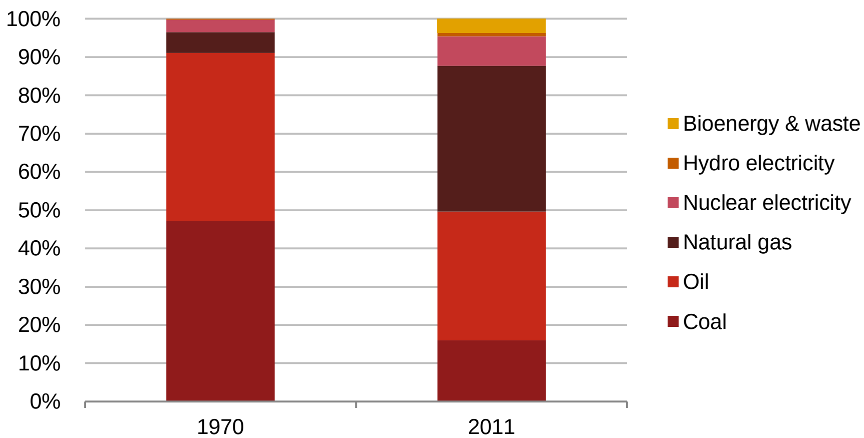
Natural gas was the UK's energy security guarantee after the oil crises, until the last decade, when the discovery of new reserves was not keeping up with depletion rates. The UK became an energy importer again. Large dependence on fossil fuels remains, posing new challenges.

Net energy imports in UK and high-income OECD, 1970-2010



Source: The World Bank

Primary gross fuel mix (incl. transport) in the UK, 1970 and 2011



Source: DECC

As energy is a prerequisite for economic activity in a country, security of energy supply is an important economic benefit. This can be stimulated by i) independence of energy supply (not relying on other countries) and ii) fuel diversification.

i) From importer to exporter… and back again

In the early 1970s, the UK largely depended on energy imports, c. 50% of its energy consumption was covered by imports. The oil crisis urged the government to increase domestic production. Allowing natural gas to be used for power generation led to less dependence on imported oil or coal. But in 2004-2005, the UK's energy trade balance became negative again. The natural gas resources started depleting faster than the discovery of new reserves. The energy security issue returned and renewable power generation started getting more political support.

ii) Fuel diversification in the UK: new challenges and opportunities

The use of natural gas for power generation since the 1990s, nuclear expansion in the late 1980s-1990s and more recently growing renewables have diversified the UK's fuel mix. This complemented coal and oil use, which dominated in the 1970s.

A large share of gas and coal plants (about one-fifth) will have to be replaced in the coming decade. Another share (coal plants) is also subject to closures as a result of the Large Combustion Plant Directive (LCPD). This offers opportunities to increase both decarbonisation of the economy and security of supply through diversification. The uncertainty about real costs of the nuclear power generation may limit the opportunities of nuclear-based decarbonisation. So renewables are likely to be a key driver of further decarbonisation. But the energy security (increasing energy imports) and a fuel poverty issue led to the first long-term contracts with shale gas providers in the US, another highly debatable topic in the UK and Europe. If shale gas revolution materialises, this can destabilise the investment climate for renewables.

Case Study NL

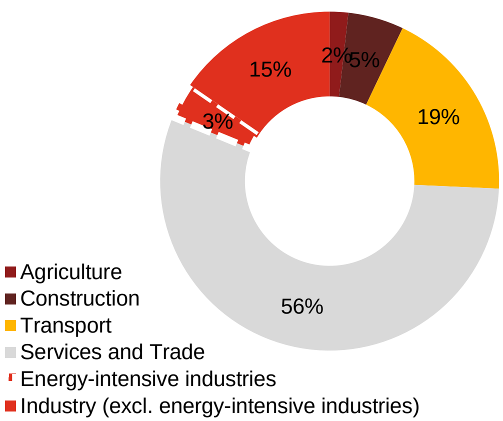
Decarbonisation in the Netherlands: *Carbon intensity is relatively low in the Netherlands compared to high-income OECD countries due to the high use of natural gas. Carbon intensity has been decreasing steadily since the 70s. The Netherlands decarbonised its economy through increased energy efficiency, stimulated by various policy measures.*

Though carbon intensity decreased, at an absolute level, emissions have increased, unlike in other countries in our study. Emissions increased due to rising energy demand being covered by expanding the use of carbon emission rich fossil fuels, instead of low carbon energy sources. Increasing nuclear capacity was not an option due to public resistance. Renewables were seen as a solution, but the transition to renewables has proved to be difficult.

The economic impact of decarbonisation policies: *Dutch electricity prices remained competitive but gas prices are above the EU average, mainly driven by taxes. Dutch government aims to protect competitiveness of energy-intensive industry by using tax exemptions combined with energy efficiency agreements.*

Decarbonisation through energy efficiency and renewable energy has resulted in a modest contribution to economic growth. Security of supply has decreased due to increased imports of energy, which could not be offset by increasing use of renewable energy.

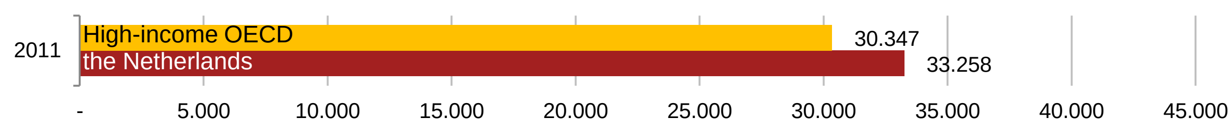
Gross value added by sector in the Netherlands (2010)



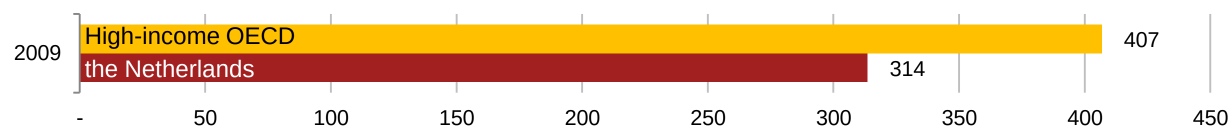
Source: Eurostat, CBS
Energy-intensive industries include manufacturing of paper, products, chemicals, (basic) metals and coke/refined petroleum products

GDP (2011): €555bn | Population (2011): 16.4m

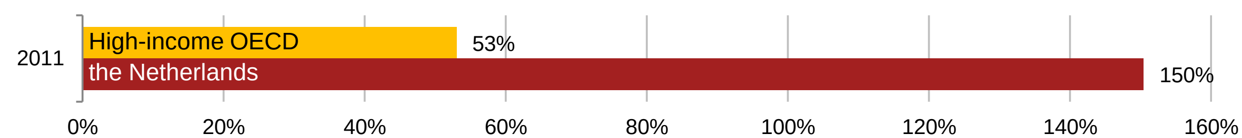
GDP per capita (in EUR)



CO2 emissions (ktonnes) per GDP (m EUR)



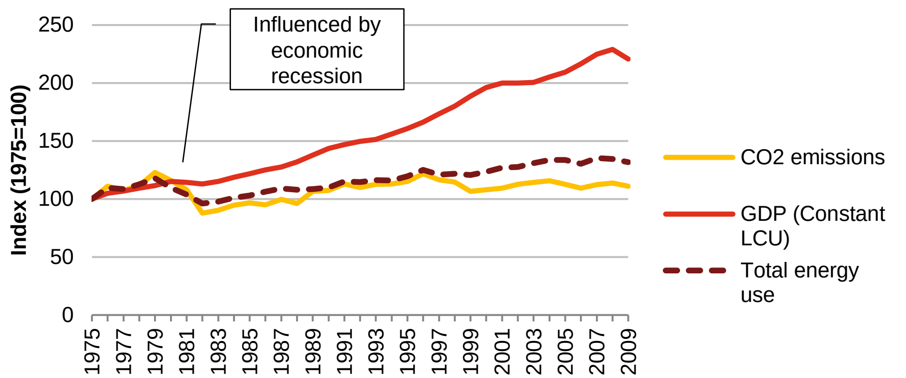
Trade intensity (imports and exports value as a percentage of GDP)



Source: The World Bank

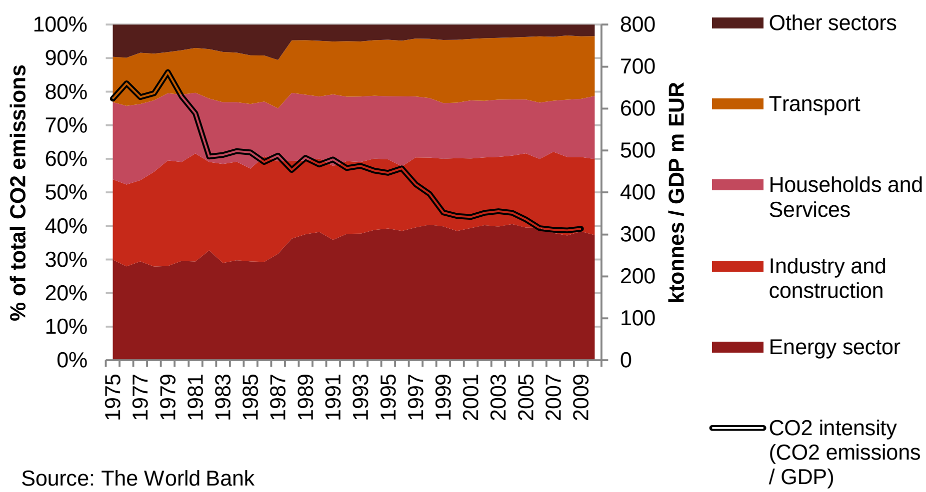
Although CO_2 intensity of the Dutch economy has been decreasing, CO_2 emissions have been rising since 1975. Only recently emission levels have started to stabilise.

GDP, energy use and CO_2 emissions in the Netherlands, 1975-2009



Source: The World Bank, CBS (Total energy use)

CO2 emissions per sector and CO2 intensity, 1975-2009



Source: The World Bank

Decoupling of CO_2 emissions and GDP development

The Dutch economy is an open, trade-intensive economy, with a high contribution of transportation, horticulture and energy-intensive industries. Cheap and abundant domestic gas reserves are one of the reasons for the historical emergence of relatively large chemical industry.

Over 1975- 2009, Dutch economic activities have more than doubled. This economic development could have led to a steep rise of CO_2 emissions, but CO_2 emissions and energy use seem to have decoupled*from GDP development. From 1996, a structural break in the decoupling of GDP from CO_2 emissions is apparent, indicating increased decoupling.

Structural changes in the economy as well as energy and climate policies have influenced this development. Growth of the Dutch economy was mainly driven by the development of the commercial and public services sector (60% of the increase in GDP over 1998-2009 originates from the service sector), which are by nature relatively less energy intensive and, so, less CO_2 emission intensive.

However, emissions have increased, largely driven by energy

Although Dutch CO_2 intensity has decreased over time and is currently below the OECD average *(please refer to the adjacent graph and the previous page)*, the CO_2 emissions have increased at an absolute level over 1970-2009. Only recently (from 2002 onwards) emissions seem to have stabilised. The rise in emissions is partially driven by increasing emissions from the energy sector (CAGR +1.5% p.a. '75-'10), which currently contributes 37 % to total emissions.

In this country case study, we focus on the fuel mix for electricity and heat production and end-user efficiency connected to electricity and heat demand, as drivers of carbon emissions**. We will start by describing the energy policies that have stimulated decarbonisation in the next section, after which we will analyse the impact on the economy in the last section for this country.

* During this period, 1% growth in GDP coincided with 0.44% increase of CO_2 emissions and 0.92% increase in energy use, meaning that both have achieved relative decoupling.

**82% of total emissions is in scope (transport sector not in scope)

Energy and Climate Policies

Guide to next section:

1 *FUEL MIX*	2 *ENERGY EFFICIENCY*
Electricity	Energy sector
Heat	Households, services
	Industry

Political vision –As a response to the oil crises Netherlands has aimed at increasing energy efficiency and the use of coal and (domestic) natural gas. More recently, the Netherlands tried to increase the use of renewables, but this proves to be difficult due to an unstable investment climate.

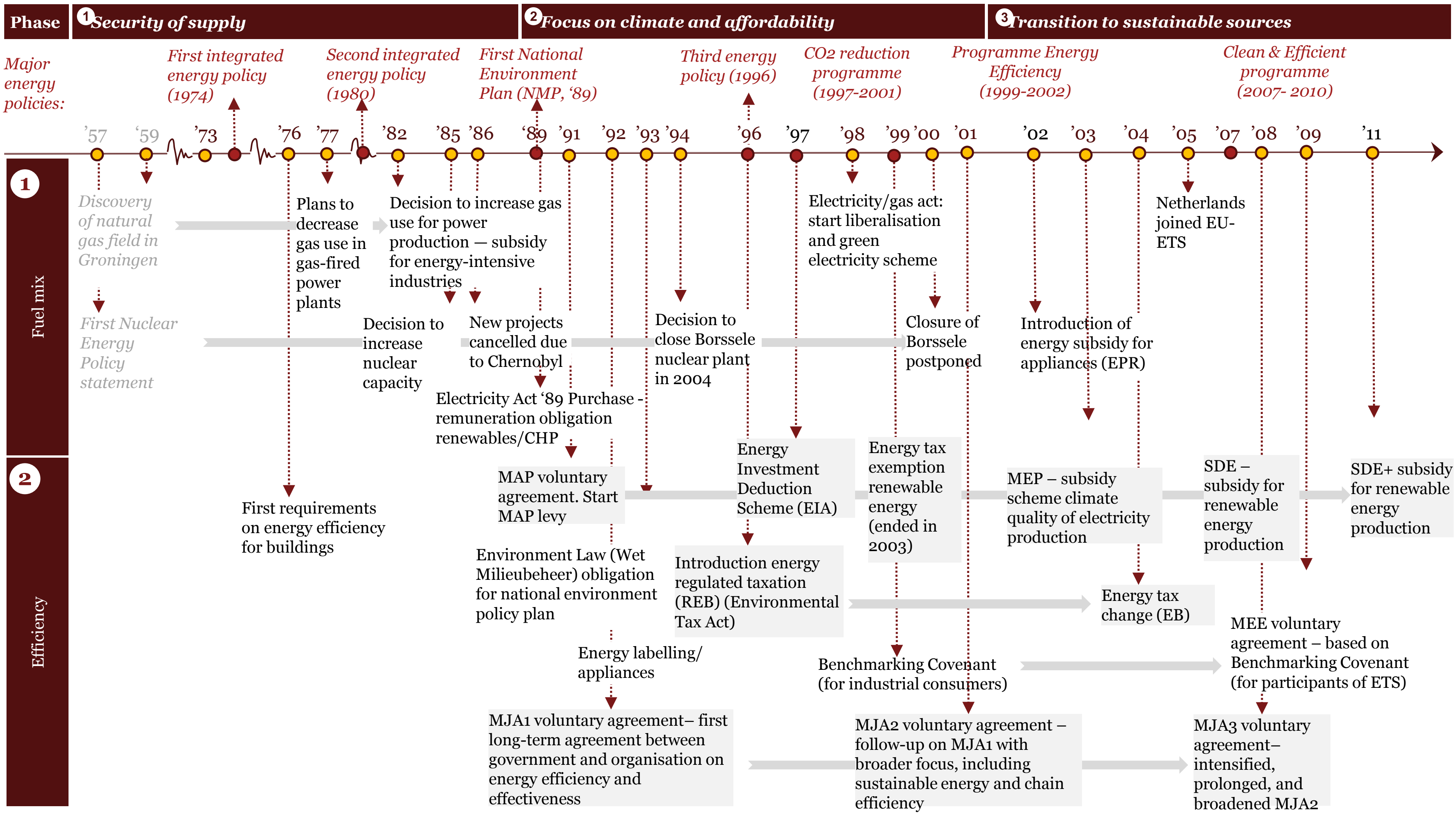
Evolution of the focus of energy policies in the Netherlands

International events

- '73 – First oil crisis
- '79 – Second oil crisis, nuclear accident in the US
- '86 – Chernobyl disaster in Ukraine
- '89
- '96 – First EU electricity and gas liberalisation directive
- '97 – Kyoto Protocol, adopted in 1997, enforced in 2005
- '98 – Liberalisation of the gas and electricity market
- '02
- '05 – Introduction of the EU ETS
- '07 – EU Council adopts 20-20-20 goals
- '08 – Global financial crisis

	1 *Security of supply*	2 *Focus on climate and affordability*	3 *Transition to sustainable sources*
Phase	**Strong dynamics regarding fuel mix**	**Increasing awareness of efficiency and climate**	**Difficulties in realising a low carbon energy system**
Policy focus	***Until 1989*** At the time of the oil crisis, the Netherlands was highly dependent on oil from Arab countries. The oil crises stimulated an energy policy shift towards guaranteeing security of supply by means of increasing energy efficiency and saving domestic resources for the long term. Dutch natural gas had to be saved for the long term, leading firstly to a temporary increase of emissions since oil use replaced the part of the gas use in power production. Secondly, in the 1980s, new coal fired power stations were built which led to increased emissions from the power sector. Nuclear energy became restricted in this period. After the Chernobyl accident in 1986, all plans to increase nuclear capacity were reversed, limiting the options for the Netherlands to decarbonise.	***1989-2002*** Increased awareness on climate change led to the first National Environment Policy Plan (1989), which initiated a wave of policy instruments and agreements to reduce dependency on fossil fuels and improve energy efficiency. But the dependency on fossil fuel did not decrease and energy consumption increased further. Growth of energy consumption was fuelled with natural gas and coal. Renewables only increased marginally during this period. Next to increased attention for decarbonisation, the policy goal of affordability was implemented through the liberalisation of the Dutch electricity and gas markets. So energy policy making became increasingly complex.	***From 2002*** The period from 2002 can be characterised by the *energy transition* – which aims to switch to a sustainable energy system. Also, concerns over security of supply and affordability played a role in energy policy making. Subsidy instruments for renewable energy have resulted in increased use of renewables, but the Dutch fuel mix is still strongly dominated by fossil fuels. Subsidy schemes have been changed various times leading to uncertainty in the market, combined with limited public support, increased risks for investors and hindered the development of renewable energy. In the last decade, Dutch government started using industrial policies (innovation agenda and top sector policies) aimed at maximising the economic impact of the energy transition.
Political context	**Political involvement in energy sector** The Dutch political system is based on a multi-party system, which (frequently) requires coalitions of several parties to form a cabinet. The period until 1990s (dominated by Centre Right parties, 1959-1989) is characterised by an increasing involvement and influence of the Dutch government. Dutch (energy) policy making historically included the involvement of different stakeholder groups. This consensus building approach is also referred to as the 'polder model'.	**Debates on government intervention** Driven by the international trend of liberalisation of markets, a debate on the roles and responsibilities of the government was intensified, strongly influencing energy policy making. From 1995, the so-called Paars-I cabinet (mix of right, middle and left parties,1994-2002)) focused on increasing market competition. Consequently, appropriate instruments had to be initiated to realise energy and climate policy goals.	**Lacking long-term vision in politics** In this period, climate goals used were frequently changed. Centre Right Cabinets (2002-2010) implemented more ambitious climate goals than set in EU climate goals of 2007. Right/Centre Cabinet of 2010 did not continued the national target for energy efficiency and even lowered the targets for the share of renewable energy and the level of greenhouse gas emissions to the (by the EU) required level. The Cabinet of 2012 recently increased the renewable energy goal.

Implemented policy instruments – Over the years, changes in the fuel mix were stimulated by using a set of subsidy measures that changed frequently over time. For energy efficiency, most measures have had a voluntary character, supported by fiscal subsidies.

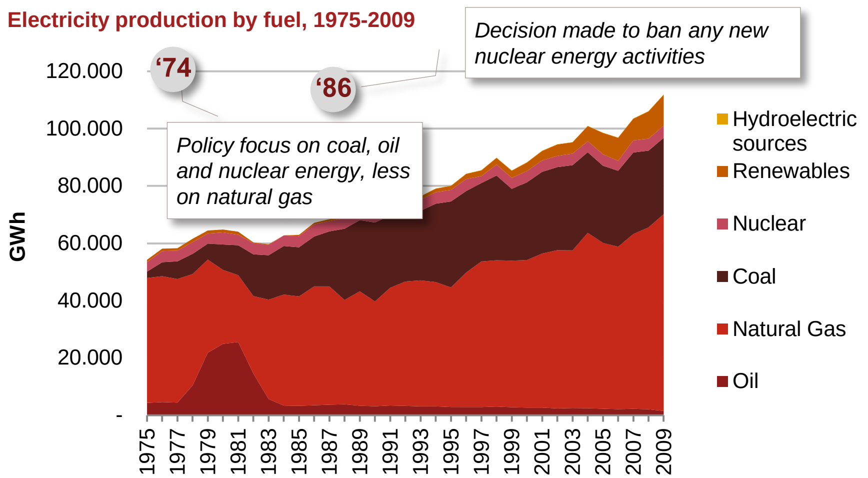


FUEL MIX

Electricity | Heat

1 Despite the Dutch government's focus on diversifying the fuel mix, the electricity fuel mix has historically been dominated by natural gas. Coal was decided to be the main fuel used to diversify the electricity fuel mix in the eighties. This has led to increased carbon emissions of the power sector.

Electricity production by fuel, 1975-2009



Source: World Bank

Phase 1 (until 1989) - Focus on security of supply

The fuels of choice for electricity generation in the Netherlands historically differed, driven by impactful (international) economic and environmental events (i.e. discovery of natural gas reserves, the oil crises and Chernobyl). The period from the first oil crisis in 1973 to the late 1980s was mainly focused on increasing security of supply through fuel mix diversification and energy savings *(please refer to p. 12-16 for policies on energy efficiency)*.

Natural gas dominance

Natural gas has been the backbone of Dutch energy provision ever since the 1960s. As the Groningen natural gas field (1959) was discovered, the Dutch energy provision quickly shifted from coal to natural gas. This shift was driven by government policies, such as the development of a natural gas network *(please refer to the page 11 for a natural gas case study).*

Natural gas use has ranged between 50% and 60% of the fuel mix for electricity production in the past 30 years and has fuelled part of the increase in electricity use over the years.

Diversification to nuclear and coal

As from 1974, after the first oil crisis, energy security became a key theme in Dutch energy policies. In the Energy nota of 1974, the first Dutch integrated energy policy vision, goals until 1985 were defined for decreasing the depletion rates of the natural gas reserves, realising three nuclear plants and diversifying electricity production by increasing the use of coal. As coal and nuclear plants still needed to be built, the oil use increased temporarily in electricity production from 1977 onwards, driven by agreements between the government and the energy sector (CIEP, 2005). In 1981, due to a gap in the state budget, this strategy was reversed and the use of natural gas for power production increased again.

Nuclear energy became restricted in this period, which limited the options for the Netherlands to decarbonise towards the future. In the late 1950s, nuclear energy was seen as an important future fuel. In 1969, the first test plant was commissioned in Dodewaard, followed by the commissioning of the first (and only) nuclear plant of the Netherlands in Borssele in 1973. In the 1980s, the protest against nuclear energy grew, driven by the Kalkar levy on the energy bill (to fund an international research plant) and broader societal protest movements. The accident in the reactor in Chernobyl (1986) led to the government decision to build new plants being cancelled.

The plans to increase the use of coal in power production were more successful. In the early 1980s, as part of the second Energy nota, the goal was set for 2000 to increase the use of coal in power production to 40% of electricity production. This would, next to diversification, stimulate the affordability of electricity, which was beneficial to the Dutch energy-intensive industry. New coal-fired power plants were commissioned in the 1980s. This decision however 'locked in' carbon emissions of the sector for the coming decades.

Renewables became relevant for policy makers when general concerns arose on the effects of carbon emissions on climate change as from the 1990s (*phase 2 and 3 as described on the next page*).

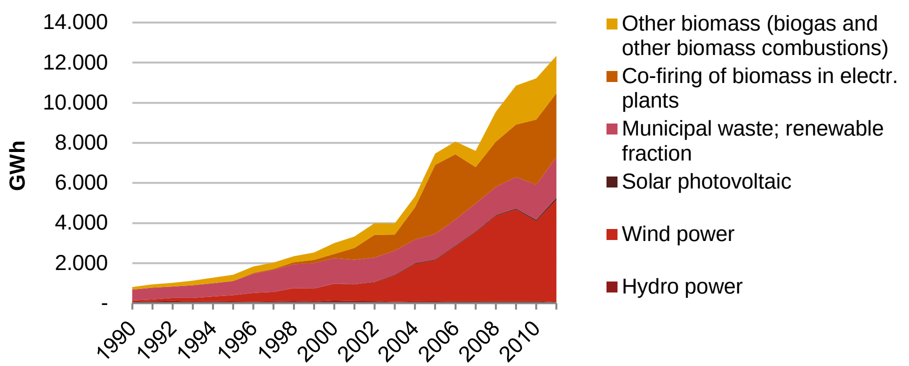
Source: CIEP (2005), NOS (2010), J.H.L. Voncken (2009), Hajer, M., Houterman, G. (1985),

FUEL MIX

Electricity | Heat

1 From the late 80s, concerns over climate change led to increased focus on renewable energy. Nuclear energy was restricted, limiting the options to decarbonise. So far, renewable energy use is below the EU average and the Netherlands faces the challenge to achieve climate goals.

Renewable electricity production by type, 1990-2011



Source: CBS

Phase 2 (1989-2002) - Focus on climate and affordability

After a publication of the UN Brundtland Commission in 1987, Dutch environmental and energy policies started to merge, driven by insights on the impact of carbon emissions on climate change. In 1989, the first national environment plan (NMP) was created, which included a target for emission reduction. Dutch energy policies focused on increasing renewable energy use and energy efficiency.

The divided public opinion on nuclear energy, reflected in politics, limited the possibilities to use nuclear energy as a carbon emission reduction strategy. In '94, it was decided to close the nuclear reactor in Borssele. But after 2000, it was decided to postpone the closure of the reactor, partly driven by climate change concerns. The debate on nuclear energy has continued over the years.

Using renewable electricity as a second option for decarbonisation, was initially stimulated by R&D programmes, a purchase and remuneration obligation (Electricity Act '89) and subsidies, mainly targeted towards wind and biomass use. Environment action plans of the distribution sector (Milieuactieplan, MAP 1991), financed via a levy on the energy bill and supplemented with subsidies, are an illustration of early policy measures. When energy tax was introduced (1996), discussions on the tax burden led to the levy being cancelled in 2001.

Phase 3 (2002-now)- Increasing focus on energy transition

In the past decade, renewable electricity use has increased, driven by several policy goals and measures. The Dutch energy transition programme (Energy report 2002) focused on increasing energy efficiency as well as renewable energy. The ambition level of climate goals have changed frequently over time in the last decade, depending on the coalition of parties present in the Cabinet.

Although the government has focused on increasing renewable energy use over the past two decades, current contribution of renewables to electricity generation (10%) is still limited compared to European average (20%). Incentives for green electricity varied over time, which is believed to have contributed to the still modest role of renewable energy (*please refer to the case study on the next page)*. Also, 'Not in my backyard' feelings among the Dutch population, reflected in political support for renewables, negatively impacted the investment climate for renewable energy. This could be caused by limited private ownership of renewable energy assets.

The Dutch government decided in the last decade to permit the construction of new coal-fired power plants. This will lock in future carbon emissions and decrease the need for additional (renewable) capacity, as reserve capacity is expected to be sufficient for the coming years. The EU Emission Trading Scheme (started in 2005) is now not incentivising the energy sector to move away from coal, as prices for emission allowances are low. Also, the shale gas revolution in the US results in decreasing coal prices, which stimulates the use of coal-fired power plants.

These developments, combined with a recent government decision to increase the renewable energy goal to 16%, increases the challenge for the Dutch to meet climate goals. Current renewable policies are not expected to provide sufficient incentives to fulfil this objective.

Sources: Ministry of Housing, Spatial Planning and the Environment (2009), IEA (2008), Ruijs A., Vollenbergh R.J (2013), ECN (2001), CIEP (2005).

FUEL MIX

Electricity | Heat

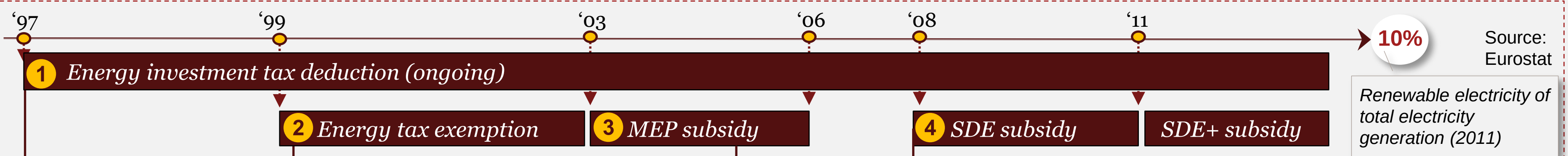
1 *Case study incentives* renewables - In the last two decades, the Dutch government has tried to increase renewable energy, mainly though fiscal incentives and subsidy schemes,. These have been frequently changed over time and has negatively influenced market formation for clean technology.

Changes and early cancellations of incentive schemes…

To stimulate renewable energy, different kinds of instruments have been used, focused on producers (large-scale) or consumers (small-scale renewables). Some examples are shown in the figure below*. Other instruments, like renewable energy supply obligations were considered but never agreed upon.

…impacted market formation

Some subsidies have been stopped before the intended end date, which resulted in unstable market formation. This impacts confidence of investors to invest in products and services related to renewable energy.



The *Energy investment tax deduction (EIA),* is a fiscal subsidy for companies to stimulate renewable energy use and energy efficiency. Part of investment costs for certain (renewable) energy technologies could be deducted from taxable profits, which reduced the payback period and the need for financing (upfront payment). Different renewable energy sources were stimulated over time including wind, hydro, solar energy and biomass installations. The instrument was improved over time by, among others, reducing the overlap with other subsidy schemes like VAMIL (accelerated depreciation) which eliminated the overlap of technologies eligible for each subsidy. In 2010 EIA stimulated investments of over €1 bln in value (0,6% of total investments in 2010). The EIA was closed earlier than planned in a couple of years as the budget was depleted early.

In 2003 a subsidy scheme Environmental Quality of electricity production (*Milieukwaliteit Elektriciteitsproductie, MEP*) was introduced, which replaced the energy tax exemption. The subsidy scheme stimulated renewable electricity and CHP. The Dutch government included subsidies for co-firing of biomass in coal-fired power plants. Depending on the technology, a fixed premium was earned on top of the revenue gained on the wholesale market through the sale of electricity. Subsidies were granted for maximum of ten year for renewable electricity and one year for CHP. Both programmes lacked a budget cap and were terminated early due to goals as set being met.

After liberalisation of the electricity market, an energy *tax exemption* applied for renewable electricity. This exemption was implemented by energy distribution companies (suppliers), that had to apply the reduced tariff for their customers. Also, a system for trade in green certificates was developed to assure the authenticity of renewable electricity supply. Renewable electricity delivered (for which the tax exemption applied) had to be covered with *green certificates*.

Sustainable Energy Production (SDE) succeeded MEP in 2008 and stimulated both renewable electricity and renewable gas. Subsidies for co-firing in power plants were not continued. The programme provided subsidies for 12 to 15 years to cover the unprofitable part of the project and gave stability to investors by guaranteeing a floor price. Moreover, it also acted as a ceiling for subsidies, as no subsidies were received if the market price exceeded the ceiling price. As from 2013, the *SDE+ scheme* subsidies will by financed by using a levy on the energy bill.

*Several other small subsidy schemes have been used over time, for example for solar panels (2012/2013), or renewable heat (2008-2010).

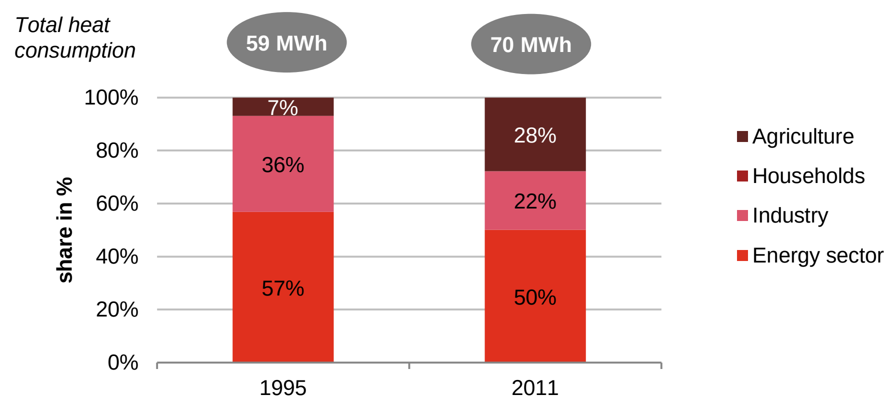
Sources: Ministry of Housing, Spatial Planning and the Environment (2009), IEA (2008), CIEP (2005), Ruijs A., Vollenbergh R.J (2013), Algemene Rekenkamer (2004)

FUEL MIX

Electricity | Heat

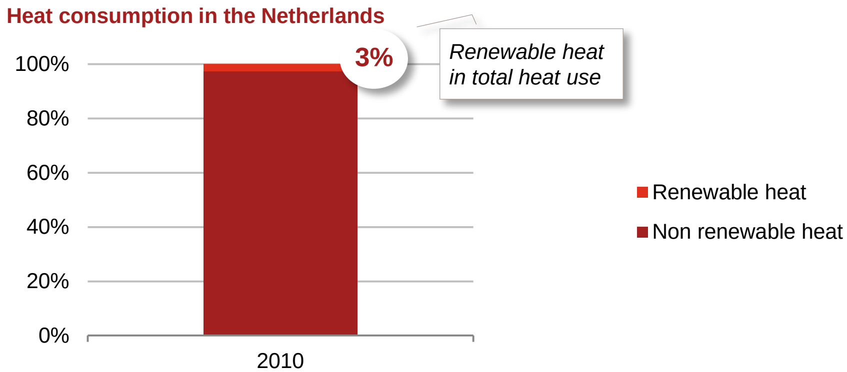
1 **The fuel mix for heat use in the Netherlands is largely based on the use of natural gas, driven by the historical dependence on domestic natural gas reserves. Few energy policy measures were used to change the fuel mix for heating. Policies largely focused on improving efficiency.**

Heat consumption per sector, 1995 and 2011



Source: CBS

Heat consumption in the Netherlands



Source: Agentschap NL (2013)

Relatively stable fuel mix and little policy measures

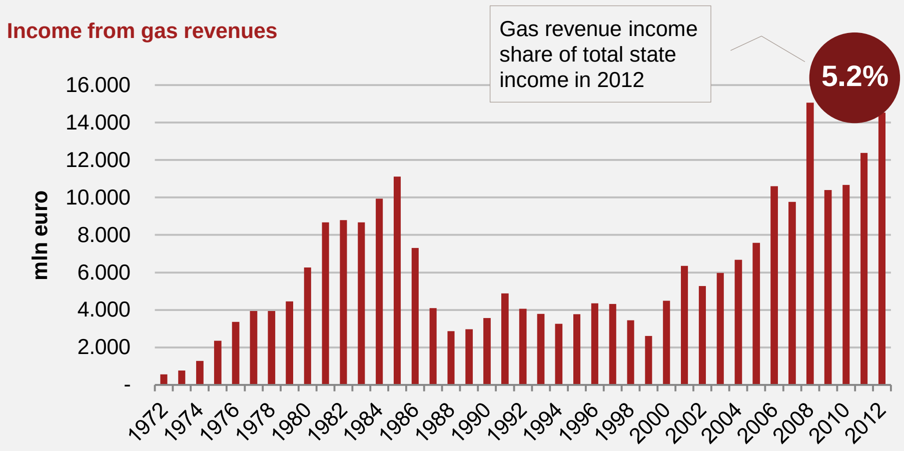
Changing the fuel mix for heating has not been the main priority of energy policies in the Netherlands. Emission targets could be reached more (cost) efficiently by increasing energy efficiency (for example by using boilers with a higher efficiency) than by changing to using another fuel for heating, as this frequently implies large changes to the energy system of the house.

The dominance of natural gas, driven by the availability of an extensive natural gas network, is reflected in the fuels used by end users for heating. Natural gas fuels almost all space heating in the Netherlands (IEA, 2008). Households switched to using natural gas, instead of coal or other (more carbon intensive) fossil fuels.

Some subsidy schemes as described on the previous pages applied to increasing the use of renewable heat, like *EIA*. In recent years, increased *energy performance standards for new buildings* stimulate a switch to renewable energy sources like Aquifer Thermal Energy Storage. Also, from 2008-2010, *subsidies* for sustainable heat (solar boilers and heat pumps and micro CHP have been implemented. But, the impact of these policies is still relatively low: in 2010,only 3% of heat us in the Netherlands originated from renewable heat. So far, the use of renewable energy in electricity production is more successful that the use of renewables for heat production.

FUEL MIX

1 *Case study of natural gas* – The Dutch dependence on natural gas was driven by the financial benefits of domestic gas reserves. Gas policies focused on preserving domestic resources for the long-term and maximising benefits. Several attempts to diversify the fuel mix did not lead to a substantial shift from gas to other fuels.



Natural gas has played an important role throughout the history of Dutch energy provision. Energy policies were partly driven by natural gas interests.

The discovery of the Groningen gas reserve

After the first discovery of natural gas in the Netherlands the supplies were seen as public utility and had to be sold for c. €0.02/NM3. The discovery of the large Groningen natural gas field in 1959 made the government realise the economic potential of the gas reserve. In 1962, the market value principle was introduced, which coupled the gas price to the oil price (IEA 2008) and allowed for higher revenues.

Between 1962 and 1974, Dutch gas policy was driven by the assumption that nuclear energy would dominate the energy sector by the end of the century. The state stimulated Gasunie (which was partially state owned) to develop the natural gas infrastructure and to extract and sell as much gas as possible. This availability of the gas network increased sales to domestic users. Secondly, export to premium markets was stimulated by Gasunie covering transportation costs. The Netherlands became an important natural gas supplier for European countries.

Save the best for last

But in 1974, after the first oil crisis, the policy focus changed towards preserving natural gas and thus increasing the long-term potential of the domestic fields. The depletion rate was decreased by increasing gas price due to the rising oil price, (temporary) limitations on the use of gas for electricity production and the 'small fields policy' of 1974. The small-fields policy required the main supply company, by then Gasterra, to purchase natural gas from marginal fields at a competitive price. Gas from marginal fields was given priority over natural gas from the main Groningen field.

State involvement remains high

As the gas market was liberalised driven by EU policies, the market structure changed. Gasunie (the transport branch) became completely owned by the state and Gasterra (the supply branch) had a 10% state interest. The gas sector has remained a priority in Dutch policy-making. Because of expected future depletion of the gas reserves, the government is looking for ways to maintain economic benefits from gas. The gas roundabout strategy (2007), which positions the Netherlands as an important hub for the transportation, storage and export of natural gas, was developed to stimulate economic growth and secure future energy provision.

On balance…

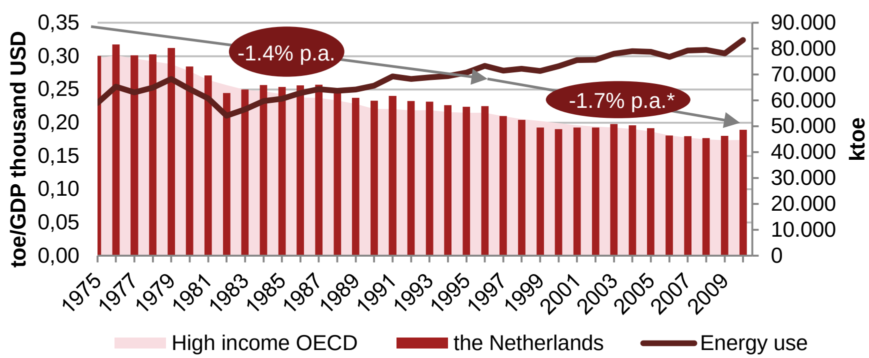
Natural gas has brought the Netherlands wealth and a relatively low carbon intensity compared to other high-income OECD countries. But dependence on natural gas is posing challenges in realising further steps in the decreasing CO_2 emissions, to be able to meet EU targets. The presence of the network still determines the fuel choice for heat use in the Netherlands. Gas revenue income still covers 5,2% of total income of the Dutch state, which makes stimulating a decrease of natural gas use to decrease carbon emissions a difficult balancing act.

Sources: Ciep (2010), Ganzevles, J. (2010)

ENERGY EFFICIENCY

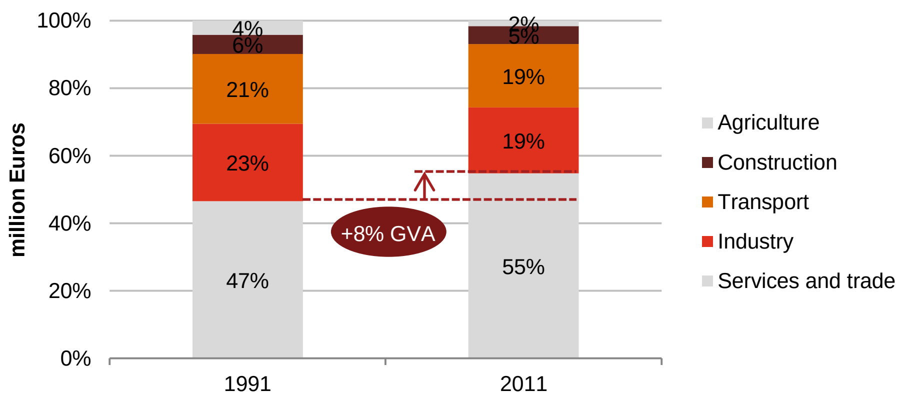
2 Energy efficiency has been an ongoing policy goal for the Dutch government since the oil crises. Energy intensity decrease was driven by energy efficiency improvements in the transformation of energy and shift to a service- and trade-oriented economy.

Energy intensity (toe/GDP thousand USD) and energy use, 1975-2010



Source: World Bank

Gross value added per sector, 1991 and 2011**



Source: CBS (not available before 1991)
*Change in primary energy intensity; Final energy use intensity decreased by -1,9% annually (1990-2011)
**Energy consumption extracted from primary energy carriers

Energy conservation as an important strategy to decarbonise

Energy efficiency has been an important topic of the Dutch government since the first oil crisis. The First Energy Nota (1974) aimed at decreasing energy use instead of stimulating energy use, which was often done in previous energy policies. After a decline in oil prices in the mid 80s, attention for energy savings decreased. After 89,the need for energy savings increased driven by climate change discussions *(as described on p. 7).*

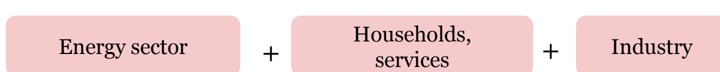
From the 1980s, energy consumption in the Netherlands started to increase. Between 1995 and 2005, this was largely driven by increased non-energy use of fuels (for example in the production of plastics).

Between 1980 and 2010, energy intensity decreased at a similar rate as the average of high-income OECD countries, which was partially stimulated by structural changes in the economy (a shift to a more service- and trade-oriented economy, *please refer to the adjacent graph).*

Primary energy intensity depends on the following factors:

1. Energy use in the energy sector (power and heat production)
2. Energy use by the end user (households, services, industry and transport)

Improved transformation efficiency in the energy sector has contributed to the change in energy intensity. The underlying strategies and policy choices will be discussed in the next pages for the following:

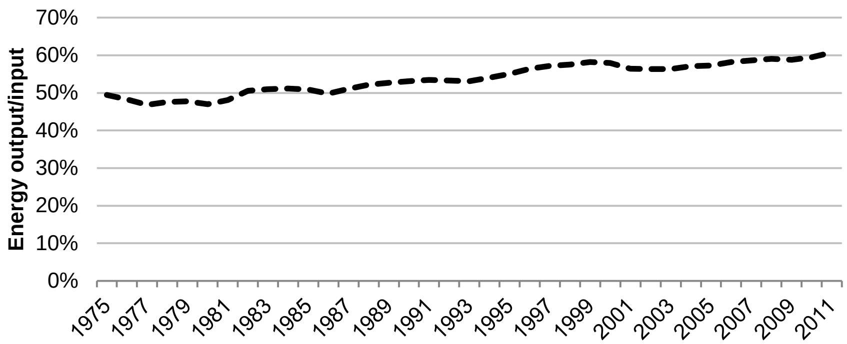


Sources: Ministry of Housing, Spatial Planning and the Environment (2009), Ministry of Economic Affairs (2011), Verbong et al. (2001).

ENERGY EFFICIENCY

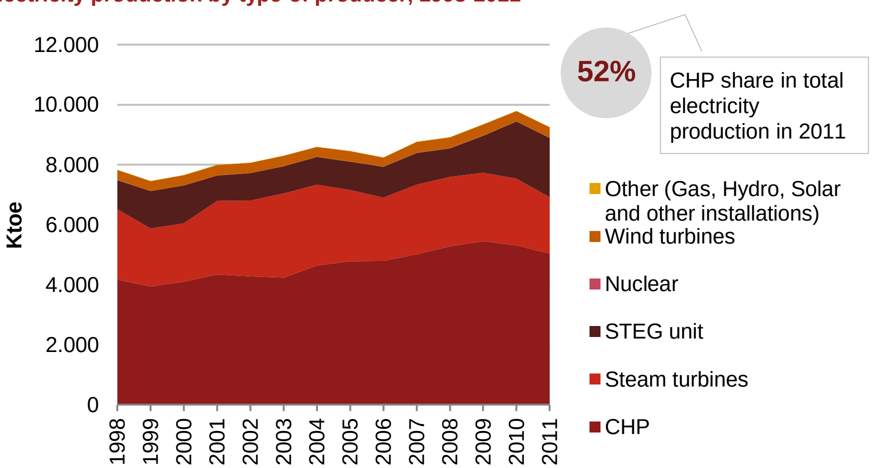
2 **The Netherlands was very successful in improving efficiency of energy transformation through Combined Heat and Power (CHP). CHP gained popularity in the 1980s as a direct result of government policies. At present, it is responsible for over than half of the electricity production in the Netherlands.**

Efficiency in energy sector (total electricity and CHP production), 1975-2011



Source: CBS

Electricity production by type of producer, 1998-2011



Source: CBS
* Information is only available from 1998

Stimulated by the Electricity Act and financial incentives, CHP grew rapidly between 1980 and 1998

Before the first oil crisis, CHP generation capacity in the Netherlands contributed 11% to the total capacity. In the 1980s and 1990s CHP was actively stimulated by the government.

The government used a target during the 90s to stimulate CHP as well as several policies. *Investment subsidies* were provided (up to 1997) as well as *discounted gas prices* (until 2000). Also, until 1995, the Electricity Act of 1989 provided a *guaranteed cost-based price* for feeding energy into the public net (which stimulated optimally sized CHP plants, based on heat demand).

A large part of CHP capacity is used for industrial purposes and was created during the 90s by *joint ventures* of industrial parties and energy distribution companies. Distribution companies were separated from production companies through the Electricity Act of 1989 and were looking for ways to secure low-cost supplies of electricity. Industrial users were stimulated to switch to CHP for heat demand to save costs, and CHP could be used to meet goals set in long-term (voluntary) energy efficiency agreements with the government.

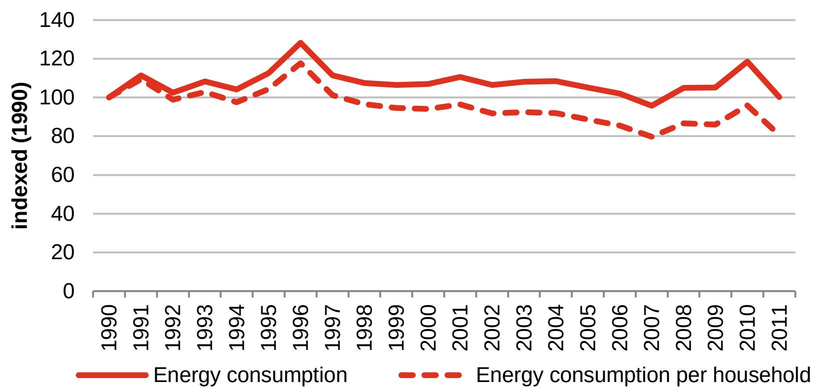
The Electricity Act of 1998 changed the CHP landscape because the feed-in tariffs became market price based. Consequently, CHP use decreased. To reverse the decline in CHP use, new feed-in tariffs were implemented (though the *MEP subsidy*), CHP plants were *exempted from energy tax* on natural gas and *fiscal subsidies* were applied *(EIA)*.

Sources: ECN (2007, 2010, 2012); CIEP (2005); The international CHP/DHC Collaboration (2007), COGEN Europe (2006)

ENERGY EFFICIENCY

2 The government stimulated energy-efficiency improvements in households and services from the 1970s. A modest increase in energy efficiency per household has occurred in the past two decades, which is the result of measures, like energy performance standards for buildings and appliances.

Energy consumption of private households, 1990-2011



Source: CBS

Instruments for households

Total energy consumption of private households has remained at the same level compared the past twenty years. Increased use of appliances was partially offset by energy savings through higher efficiency of condensing boilers and electrical appliances driven by government policies. The government has used an array of instruments to increase awareness on energy efficiency and stimulate investments in energy efficiency among households and services, such as subsidies, informative measures, voluntary agreements and fiscal instruments to stimulate energy efficiency.

New buildings need to comply with *energy performance standards* as prescribed by the government in the Building Decree (initiated in 1992 and tightened over the years). Also, following EU regulation, appliances need to comply with energy performance standards. *Energy Premium Rebate* (EPR, 2002) is an example of a *subsidy* which was introduced to finance investments in efficient appliances.

The Regulatory Energy Tax (REB, 1996), followed by Energy Tax (EB, 2004), was introduced to discourage climate-polluting activities. *Informative measures*, such as energy labelling (from 2002), were implemented to increase awareness of consumers of energy performance. Other instruments were based on *voluntary agreements*, which include programmes such as 'More with Less' (Meer met Minder, 2008) and the Covenant energy savings by housing corporations (2011).

Energy performance standards for buildings and appliances are seen as the most effective policy measures (ECN, 2012). Also, energy efficiency for households was highly influenced by the *Environmental Action Plans* *(please refer to p. 8).*

Instruments used in the service sector

Some policy measures for households also apply to the service sector, such as the *energy performance standards* and *energy tax*. Additional measures with a moderate to high impact on efficiency for the service sector are *subsidies*, such as energy market innovation (MEI), energy savings investment measure (IRE), and *fiscal instruments* like Accelerated Deprecation on Environmental investments (VAMIL, 1991) and Energy Investment Tax Deduction (EIA and EINP, 1997).

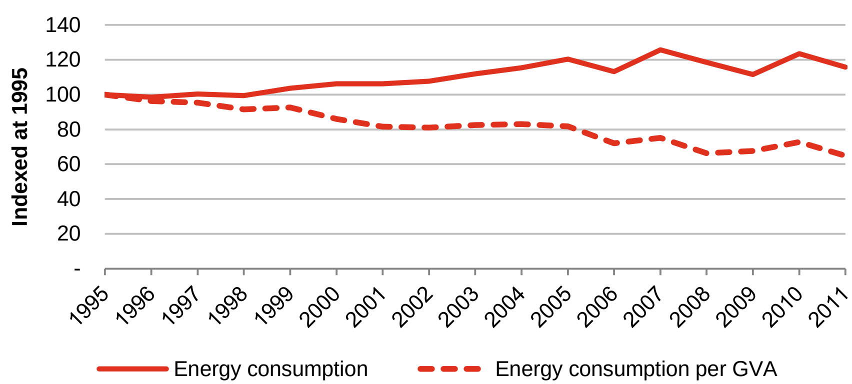
Source: ECN (2012)

ENERGY EFFICIENCY

Energy sector | Households, services | Industry

2 The energy use by the industrial has stabilised and energy intensity has decreased. The long-term voluntary agreements supported by fiscal instruments have contributed to this, as well as structural changes in the sector and economic cycles.

Energy consumption (and per GVA) in industry, 1995-2011



Source: CBS

Energy intensity improved in the past 20 years

Energy use in the industry can serve two purposes: for combustion to create process heat or electricity or for non-energy purposes (as a resource for producing for example plastics). The energy consumption level of the industrial sector increased over 1995-2005, mainly driven by increased energy use for non-energy purposes, but has stabilised since 2005. Energy intensity has decreased over time, which was caused by structural changes in the sector as well by increased energy efficiency.

Long-term voluntary agreements…

The government has been using *long term agreements* (LTAs), to increase energy efficiency in the industry (MJA1 – 1992; MJA2 – 2001; MJa3 – 2008) to stimulate competitiveness as well as reduced carbon emissions*. The LTAs contained goals for energy reduction and companies participating had to create energy efficiency reduction plans every four years and commit to taking measures. Progress had to be reported. The use of voluntary agreements is a frequently used policy instrument originating from a long history of consensus-based policy making in the Netherlands.

The first LTA (MJA1) was focused on process efficiency. The second LTA (MJA2) increased the scope with sustainable energy and value chain efficiency. The most recent LTA (MJA3) continued and intensified the agreements of MJA2. Efficiency agreements for large industrial organisations were specifically addressed in the Energy Efficient Covenant Benchmarking (1999), followed by LTA for EU ETS companies (MEE, 2009).

… supported by fiscal subsidies

The government initiated (fiscal) subsidies to support the LTAs. An example is the *Energy Investment Deduction Scheme* (EIA, 1997). Investment costs regarding energy savings and sustainable energy equipment are deductible from fiscal profits, while at the same time, the *Regulatory Energy Tax* (REB, 1996 *please refer to the next page for more information*) increased the cost price of energy. Both measures improve the business case for energy efficiency measures. Other examples of policy instruments are *accelerated depreciation* on environmental investments (VAMIL, 1991) and *climate investment deduction* (MIA, 2002). The latter allows a reduction of fiscal profits by deducting the amount of investment.

Which instruments were effective?

Evaluation of the effectiveness of the LTAs is complex since effects cannot easily be isolated. For MJA3 goals have been met, but the question is raised if the goals were ambitious enough and if different sectors should have the same target. Compared to European energy efficiency progress, Dutch companies were not outperforming European companies. The cost effectiveness of the MJA3 is assessed to be lower than instruments like *energy taxes* and the *EIA*, but it has improved compared to MJA2 (Ecorys, 2013).

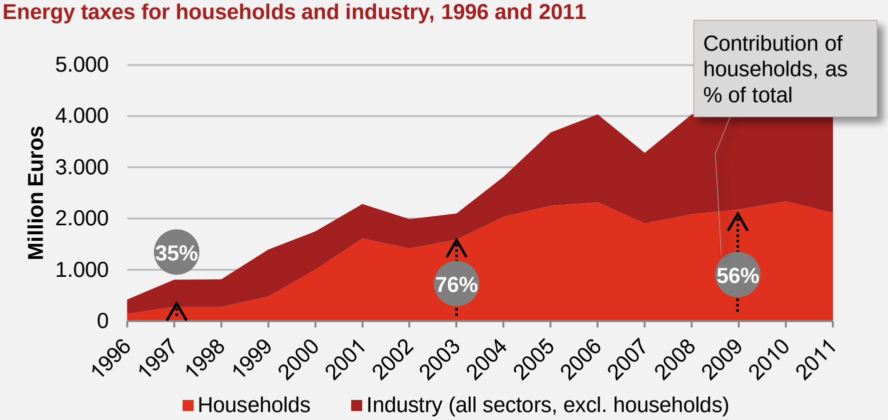
*Energy intensive industry is historically large in the Netherlands, in energy use as well as contribution to GDP. In 2010, it used about a quarter of total energy used (TNO 2013).

Sources: Ministry of Housing, Spatial Planning and the Environment (2009); Ruijs, A., Vollebergh, H.R. (2013), ECN (2011, 2012); Ministry of Economic Affairs (2011); ECN (2012)

FUEL MIX & ENERGY EFFICIENCY

1 & 2 Case study taxes – Energy taxes were introduced to stimulate energy efficiency and use of sustainable energy. Over time, several exemptions were granted, which increased taxation imbalance among consumer segments.

Energy taxes for households and industry, 1996 and 2011



Source: CBS. Includes taxes from gas, electricity and certain mineral oils.

Energy tax in Euro / ton CO_2 (excl. VAT)

Segment and level of usage	Gas €/ton CO_2	Electricity €/ton CO_2	Typical consumer
Group 1: 0 - 5.000 m3 / 0 - 10.000 kWh	€ 0,1862	€ 0,1165	Households
Group 2: 5.001 - 170.000 m3 / 10,001-50,000 kWh	€ 0,1862	€ 0,0424	SME, services, government
Group 3:170.001 - 1 mln m3 / 50.001 - 10 mln kWh	€ 0,1862	€ 0,0113	Industrial
Group 4 Over 1 million - 10 mln m3 / > 10 million kWh (non business)	€ 0,0160	€ 0,0010	Industrial, for electricity non business users
Group 5: > 10 million m3 / > 10 million kWh (businesss)	€ 0,0115	€ 0,0005	Energy companies, steel, aluminium (EU-ETS), participant of covenant

Source: CE Delft, Covenant Benchmarking Energie-efficiency 2010, Rijksoverheid

Energy taxation for SMEs and households introduced in 1996

The *Regulatory Energy Tax* (REB, 1996) was introduced after a failure to introduce a European carbon tax, and aimed to stimulate energy savings and reduce climate-polluting activities. Energy taxation applies to several energy carriers – electricity, natural gas, light fuel oil, heating oil and LPG.

Originally, the tax only applied to SMEs and households*. Large energy users were at that time stimulated through the LTAs to reduce energy use and use sustainable energy. To compensate small firms for the additional tax burden, corporate tax was reduced and EIA was introduced. For small users, a tax refund was applied ('heffingskorting') to avoid fuel poverty.

Large spread between tax rates and type of users

An Energy Efficiency programme (1999-2002) included an accelerated efficiency target of 2% per year. As a result, the energy taxes were increased for small consumers, while large consumers received a relatively lower tax rate if they chose to participate in the LTA (focused on energy efficiency). Consequently, households were carrying a larger part of the burden than large users (76% of total energy taxes, *please refer to the graph for insight in the division of taxes between households and businesses)*.

To spread the burden more evenly, the Dutch government harmonised national taxes and fees on energy in 2003 (the REB was then named *Energy tax*). This led to increased energy taxes for businesses. But currently households still contribute about half of the energy taxes.

Tax exemptions were used by the government to stimulate policy goals like decarbonisation or protect competitiveness of energy intensive industries. For example, tax exemption for green energy was used (1999-2003) and different fee calculation rules were applied to different user segments *(please refer to the table)*.

* <170,000 m3 gas and < 50,000 kWh electricity

Sources: CIEP (2005), The International CHP/DHC Collaborative (2007); Ruijs A., Vollenbergh R.J (2013)

Economic Impact of the Energy and Climate Policies

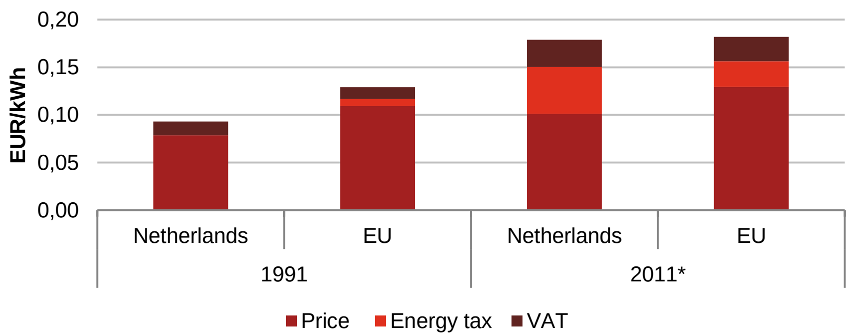
Guide to next section:

Competitiveness	Growth (new industries)
Climate	Security of supply

Dutch electricity prices for households equal the European average. Dutch gas prices are higher than average, mainly due to the higher tax and VAT burden. Energy costs for households have increased over time driven by the introduction of energy taxes and global upward trend in fuel prices.

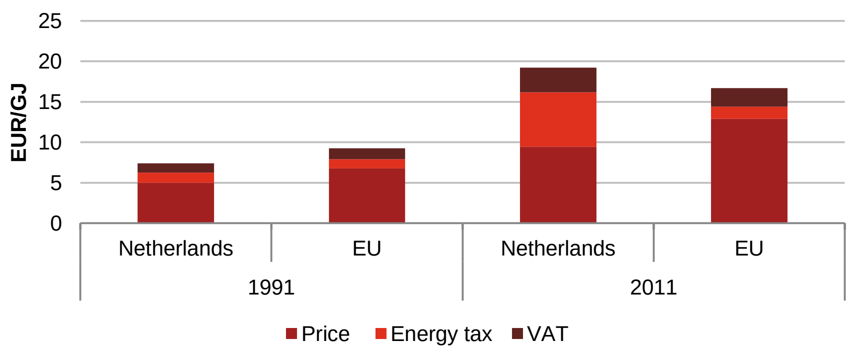
Competitiveness | Growth (new industries) | Climate | Security of supply

Average electricity prices for domestic consumers in the Netherlands and EU, 1991 and 2011*



Note: consumer segment - new methodology: 2,500 -5,000 kWh; old methodology: ~3,500 kWh
Source: Eurostat

Average gas prices for domestic consumers in the Netherlands and EU, 1991 and 2011*



Note: consumer segment - new methodology: 20 -200 GJ; old methodology: ~83,70 GJ
Source: Eurostat
* Values prior to 2007 may not be comparable with recent data due to methodology revision. The 2011 EU data includes EU-27, whereas 1991 includes EU-15. No energy taxes reported in 1991.
** Gas prices were historically coupled to the oil price.

Tax and VAT burden for domestic consumers above EU average

The end price that domestic consumers paid for electricity in 2011 was equal to the European average, whereas in 1991, the Dutch energy price was 28% lower. The increase is mainly caused by the relatively large tax burden in the Netherlands. The energy tax and VAT burden combined is a relatively larger share of the total price, compared to the European average (43% vs 29.% in 2011). The tax component in the prices is expected to increase further, since in 2013 a levy on the energy bill was introduced to cover for the costs of the SDE+ subsidy scheme.

Gas prices for domestic consumers more than doubled in 20 years, from €7.30 to €19.24 per GJ. Similar to electricity prices, the tax and VAT burden is 32% of the total price (compared to 8% of the European average).

Energy costs for households increase

Fuel prices have increased over time, driven by the introduction of energy taxes and a global upward trend of fuel prices**. The increase in prices could have partially been offset by increased energy efficiency, but since we have seen earlier that energy use per household has not improved, this effect will be negligible. Consumers spend an increasing amount of their disposable income on energy use (raised from 4% to 6% of the disposable income in the past 20 years).

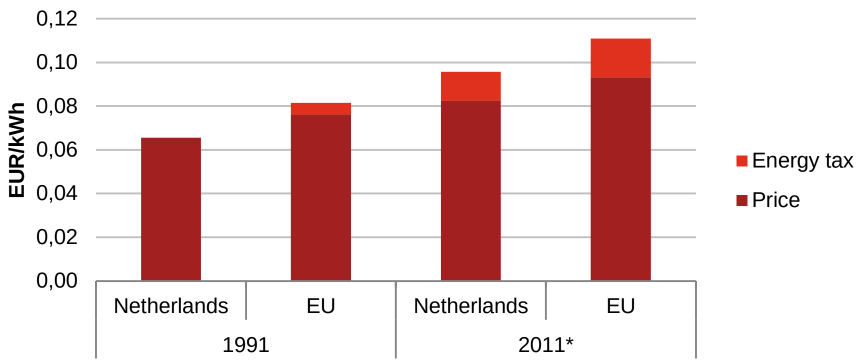
The Dutch government does not tax basic energy needs, to avoid fuel poverty. So an energy tax rebate is applied for the energy that is necessary to cover basic energy needs. Effective prices per kwh for lower usage segments will therefore be lower than for higher usage segments.

Source: PBL (2012)

Dutch gas prices are above EU average, mainly driven by energy tax. The Dutch government aims to protect competitiveness of the industry sectors through tax exemptions and lower tariffs.

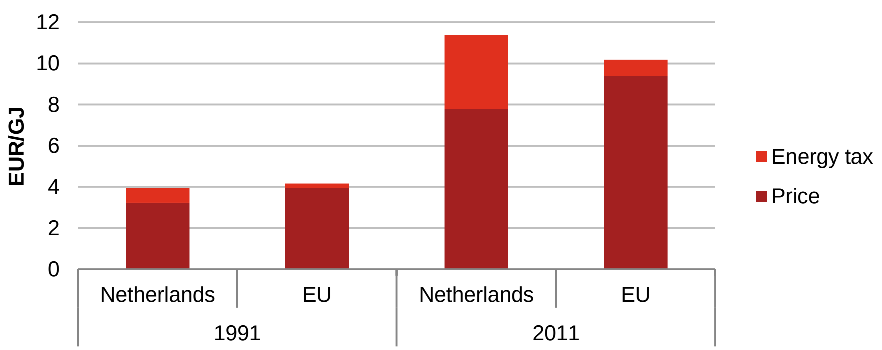
Competitiveness | Growth (new industries) | Climate | Security of supply

Electricity prices for industrial consumers in the Netherlands and EU, 1991 and 2011*



Source: Eurostat

Gas prices for industrial consumers in the Netherlands and EU, 1991 and 2011*



Source: Eurostat
* Values prior to 2007 may not be comparable with recent data due to methodology revision.
Electricity: consumer segment - new methodology: 500 -2,000 MWh; old methodology: ~2,000 MWh
Gas: consumer segment - new methodology: 10,000 -100,000 GJ; old methodology: ~41,860 GJ
The 2011 EU data includes EU-27, whereas 1991 includes EU-15.

Similar price composition in electricity prices, but different development in gas prices is apparent

The average electricity prices for industrial consumers have been consistently lower than the European average in the past 20 years. In contrast to the electricity price, the gas price is higher than in European countries (Dutch taxes contribute 32% to the total price versus 8% for the European average). The Dutch government aims to protect competitiveness of energy-intensive industries through lower tax rates and tax exemptions (connected to long-term energy-saving agreements). The contribution of companies to state energy tax income has historically been low compared to the contribution of households (*please refer to the Energy Taxation case study on p. 6)*.

Next to increased energy taxes, fuel prices have increased over time. After liberalisation of the market, the wholesale electricity price has stabilised, partly driven by integration of energy markets which led to converging Dutch and German wholesale prices. Natural gas wholesale prices followed the upward trend in oil prices, as the natural gas price in the Netherlands is historically linked to the oil price.

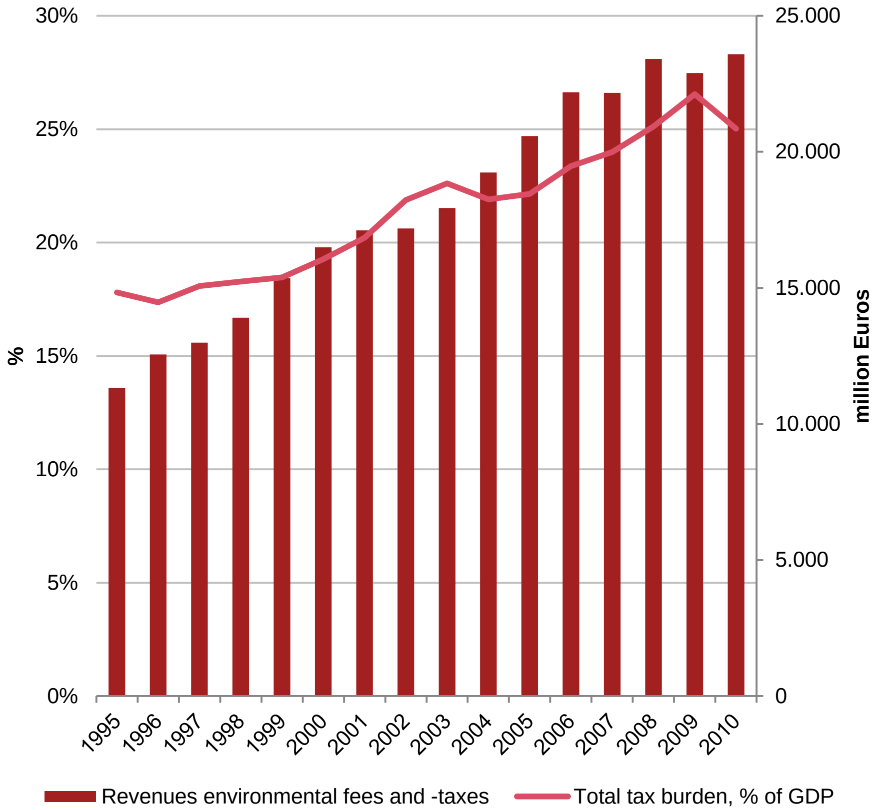
The effect of rising prices could partially have been offset by increased energy efficiency.

Sources: CIEP (2005), APX-ENDEX

At a macro level, environmental taxes do seem to have increased the total tax burden in the Netherlands

Competitiveness | Growth (new industries) | Climate | Security of supply

Revenues environmental fees and –taxes* and total tax revenues as % of GDP, 1995-2010



Source: CBS
*Environmental includes taxes such as motor, road, vehicle and energy tax. In the Netherlands revenues from environmental taxes are added to the general government budget and are not used to finance specific environmental policies (source CBS).

Environmental fees and taxes grew in parallel with the total tax burden

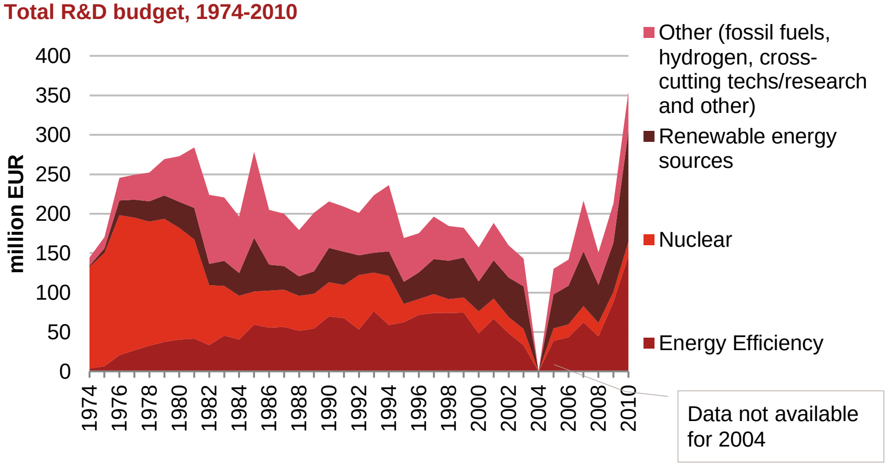
The effects on the introduction of environmental taxes at a macro (national) level are either welfare-reducing or neutral, if the taxes replace other taxation.

The regulated energy tax was originally designed as a revenue-neutral tax. The tax burden caused by environmental taxes* has however increased over time, as well as total tax revenues as a share of GDP. So, environmental fees and taxes contributed to an increased tax burden in the Netherlands.

Government funding shifted from nuclear R&D to energy efficiency and renewable technology. But market formation for these technologies has been unstable, which influenced willingness to invest and subsequently build up new domestic industries.

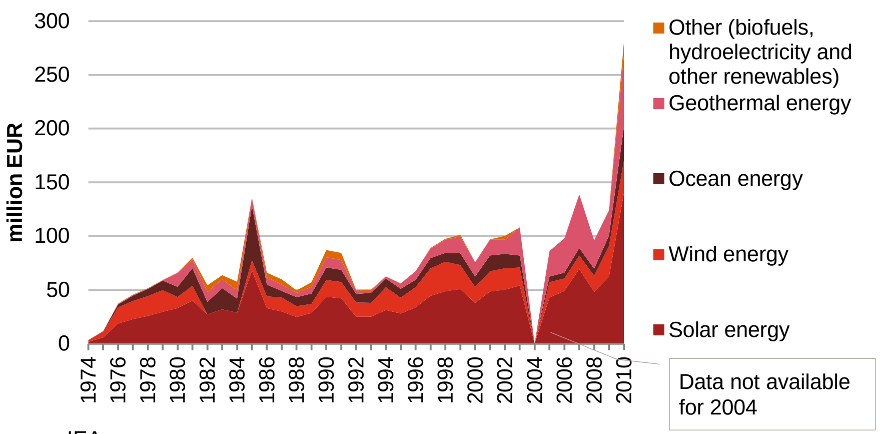
Competitiveness | Growth (new industries) | Climate | Security of supply

Total R&D budget, 1974-2010



Source: IEA

R&D budget for renewable energy sources, 1974-2010



Source: IEA

Sources: IEA, Battelle Energy R&D in the Netherlands (1999), CE Delft Ecofys (2011), TNO (2013)

Creating beneficial circumstances for new economic activity

The economic impact of decarbonisation can be maximised, if the demand for renewables and energy-efficiency measures is met with domestic products and services. Resulting domestic specialised industries could increase economic benefits further by exporting to other countries.

The rise of domestic industries takes place in a complex interaction between many factors such as specific expertise available at companies, public and political support, and beneficial industrial policies (like R&D support and stable market formation programmes).

R&D activity

The Dutch government provides public R&D funding to long-term energy research, while leaving deployment and commercialisation of technology generally to the private sector.

The government R&D in the 1970s was focused on nuclear energy. Since the 1980s, total R&D budget decreased and shifted from nuclear energy to energy efficiency and fossil fuels. From 2004, R&D funding of Carbon Capture and Storage (CCS) was increased as a solution to decarbonise future coal-fired power. Recently, a steep growth has been apparent in R&D funding, mainly in energy efficiency. In 2010, energy efficiency and renewable energy captured 80% of the Dutch R&D budget, clearly reflecting the government's priorities.

Market formation

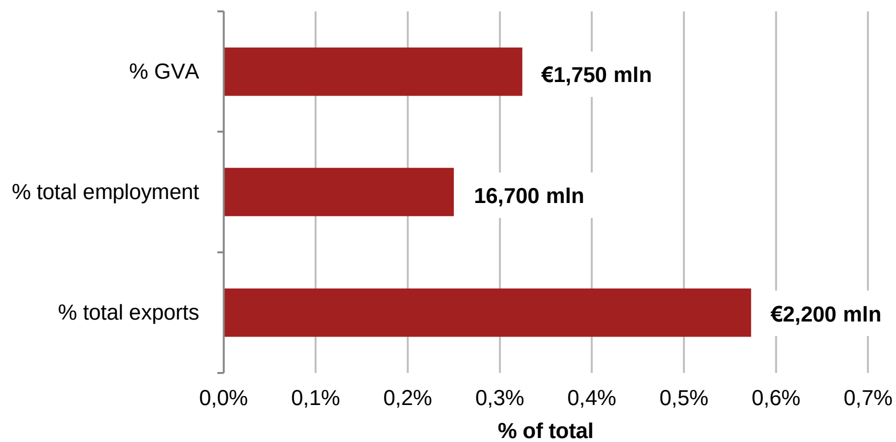
R&D effort is most effective combined with the actual market demand for technology that was created. In the Netherlands market, formation for renewable technology was unstable due to the lack of an integrated policy vision, changing incentive schemes and problems with public acceptance. This increased financial risks and influenced the willingness of capital providers entrepreneurs to invest in technology development.

For the current estimated economic impact please refer to the next page.

Economic effects of decarbonisation are modest in the Netherlands. The value added of the sustainability sector in the Netherlands is c. 0.3% of total GVA and the sector contributes 0.25% to Dutch employment.

Competitiveness | Growth (new industries) | Climate | Security of supply

Contribution of the sustainable energy sector to the economy in the Netherlands (2009)



Source: CBS (2012)

Government tries to increase economic benefits

In the last decade, the Dutch government started using industrial policies (such as the innovation agenda of the Clean and Efficient Programme of the government and so-called top sector policies) aimed at maximising the economic impact of the energy transition to a low-carbon energy system. Different target areas were defined, which were supported with R&D funds from 2008 onwards *(please refer to the rising R&D investments in the graph on the previous page)*.

Economic effects are modest, but are increasing

The impact of these innovation programmes of the government is not yet clear. Currently, the contribution to the Dutch economy of renewable energy and energy efficiency sectors is still modest.

The value added generated by the sustainable energy sector* was €1,750 mln in 2009 which contributes 0.3% to GVA in the Netherlands (CBS 2012). Energy efficiency is one of the main contributors to the GVA of the sustainable energy sector. The exploitation phase (production of renewable energy) as well as the pre-exploitation phase (e.g. companies active in R&D, production of technology, energy savings) are included in these economic impact figures. Most economic impact is currently generated in the pre-exploitation phase.

More than 16,700 jobs were generated in 2009 through the sustainable energy sector, which coincides with 0.25% of employment in the Netherlands. Over the available period (2008-2010), employment in the sector has been increasing by 4% per year.

*Included are the following sectors: solar PV, solar CSP, solar thermal energy, biogas, biomass (solid) & waste, biofuels, bio-refining, wind on land, wind at sea, heat & geothermal energy, energy from water, energy saving, electric transport, smart grids, hydrogen technology and CO2 capture and storage'

Energy policies have lead to CO_2 emissions being avoided, which has a positive economic impact. Efficiency improvements and structural change in the economy have had the biggest impact on preventing emissions. Fuel mix changes have also resulted in CO_2 emissions being prevented.

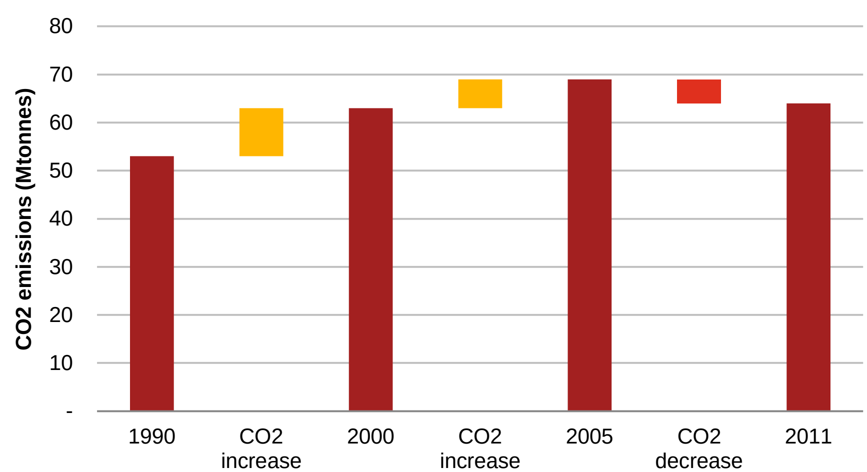
Competitiveness | Growth (new industries) | **Climate** | Security of supply

CO2 emissions increased in the energy sector

The emissions of CO_2 in the Netherlands have increased significantly since 1990, driven by the energy sector, though emissions have decreased recently driven by economic crises as well as policy measures *(please refer to the chart below).*

Energy and climate policies have lead to emissions being prevented. Avoided CO_2 emissions provide indirect economic savings. If the same fuel mix and energy intensity level were continued from 1990 onwards, CO2 emissions would have increased compared to the actual current level of emissions. This would have led to additional direct and indirect costs for society.

Observed CO2 emissions of the energy sector, 1990-2011



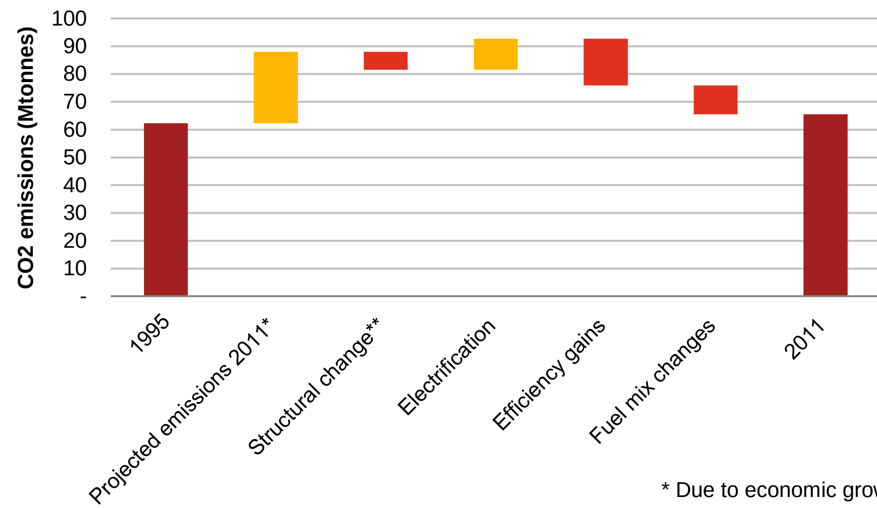
Source: CBS

Causes for avoided CO2 emissions

Since the fuel mix changed over time and energy efficiency increased, emissions were avoided. *Please refer to the graph on the right part of the page for our analyses on the causes for prevented CO_2 emissions.*

The biggest contribution to preventing CO_2 emissions came from energy-efficiency improvements, which were driven by structural changes in the economy (for example less energy-intense products) as well as energy policies. Secondly, fuel mix changes in the energy sector (switch to natural gas or renewables) have avoided CO_2 emissions. But, the switch of energy consumption of end users towards electricity (electrification) has increased the need for electricity. Economic growth combined with these electrification effects, lead to an increase in CO2 emissions from the energy sector.

Avoided CO2 emissions for the energy sector projected from 1995 to 2011, and factors mitigating these CO2 emissions



* Due to economic growth

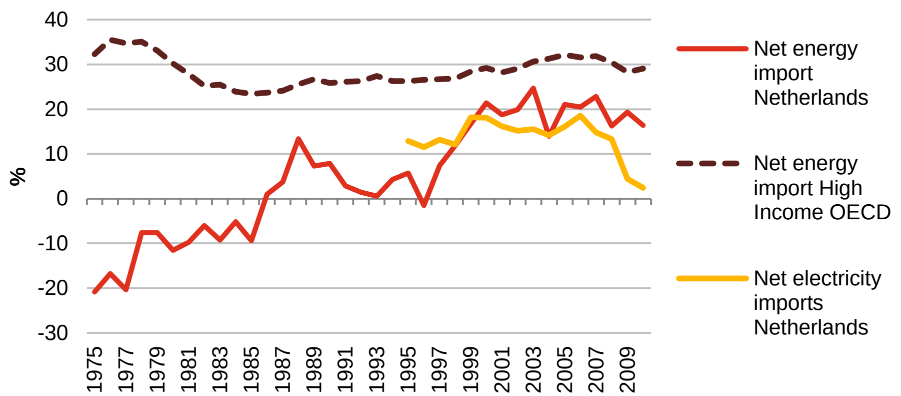
** % contribution of different sectors to GVA

Source: PwC analysis

Supply security in the Netherlands was historically affected by a switch from being a net exporter to being a net importer of energy. Though the fuel mix is more diverse currently than in 1975, dependence on imported fuels is still large.

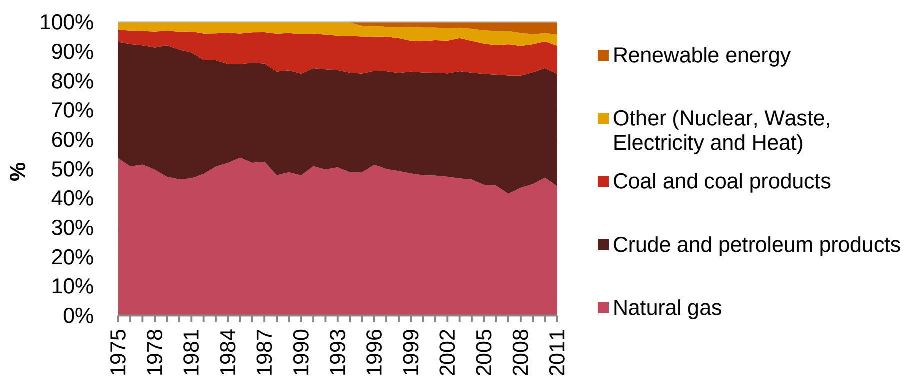
Competitiveness | Growth (new industries) | Climate | Security of supply

Net energy and electricity imports (of total energy consumption), 1975-2010



Source: The World Bank, CBS (Net electricity imports Netherlands)

Fuel mix of total energy use in the Netherlands, 1975-2011



Includes fuels used for transportation
Source: CBS

Becoming dependent again on imports

The Netherlands, for a long period, was a net exporter of energy. But driven by energy policies, the Netherlands became a net energy importer as from 1985. The Netherlands is currently still a net exporter for gas, but oil and coal are being imported.

For electricity supply, the Netherlands also depend on neighbouring countries, although the imports have decreased substantially in the last five years. This was caused by deregulation, increased interconnection and market integration.

Remaining dominance of fossil fuels in the fuel mix

The fuel mix of the total energy use in the Netherlands was diversified over time, but is at present still dominated by natural gas (44% of total energy use, 2011). The Dutch government still aims at diversifying the fuel mix, as the current dependence on gas and oil decreases supply security. The dependence on natural gas and oil exposes the economy to price shocks in these commodities.

Renewable energy could help to diversify the fuel mix, but the contribution to the fuel mix is currently too improve security of supply. On the negative side, large scale integration of intermittent renewable sources for power production generates new challenges for assuring stability of the network, and therefore a satisfying level of security of power supply.

Sources: IEA (2008), CBS Energiebalans; kerncijfers Invoersaldo

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Glossary

Term	Definition/Meaning
PwC view	Our view in the context of the scope of our work and the circumstances at the time of our field work
PwC	'PwC' is the brand under which PricewaterhouseCoopers Accountants N.V. (Chamber of Commerce 34180285), PricewaterhouseCoopers Belastingadviseurs N.V. (Chamber of Commerce 34180284), PricewaterhouseCoopers Advisory N.V. (Chamber of Commerce 34180287), PricewaterhouseCoopers Compliance Services B.V. (Chamber of Commerce 51414406), PricewaterhouseCoopers Pensions, Actuarial & Insurance Services B.V. (Chamber of Commerce 54226368), PricewaterhouseCoopers B.V. (Chamber of Commerce 34180289) and other companies operate and provide services. These services are governed by General Terms and Conditions ('algemene voorwaarden'), which include provisions regarding our liability. Purchases by these companies are governed by General Terms and Conditions of Purchase ('algemene inkoopvoorwaarden'). At www.pwc.nl more detailed information on these companies is available, including these General Terms and Conditions and the General Terms and Conditions of Purchase, which have also been filed at the Amsterdam Chamber of Commerce.