MSc Program
Renewable Energy in Central and Eastern Europe

How to achieve 40% CO_2 reduction in the EU by 2030

Analyzing the correlation of EU-ETS
and the support for renewables in Austria and Germany

A Master's Thesis submitted for the degree of "Master of Science"

supervised by
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September 30th, 2016

Affidavit

I, **Mario Michael Grassl**, hereby declare
that I am the sole author of the present Master Thesis, *" How to achieve 40% CO_2 reduction in the EU by 2030 Analyzing the interrelation of EU-ETS and the support for renewables in Austria and Germany ",* 113 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and

1. that I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

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Date Signature

Abstract

" . . . the idea of the future being different from the present is so repugnant to our conventional modes of thought and behavior that we, most of us, offer a great resistance to acting on it in practice."

John Maynard Keynes, 1937

Our current period is defined as Anthropocene, describing the major influence of humans on our planet. Increasing population and industrialization, based on fossil fuels, is consuming resources of the planet in the highest speed noticed in mankind. This threatens the base of life of all species on earth.

An important improvement of existing and future coexistence with nature on this planet is the limitation of greenhouse gases emitted, if not achieved, will result in global warming of the atmosphere and cause devastation of big areas needed for living for a still growing population. In December 2015 an important agreement on COP21, Paris has been agreed to limit greenhouse gas emissions on a global level. Papua New Guinea has submitted already the binding INDC (Intended Nationally Determined Contribution) for 2030 to be 100% renewable energy reliant. Norway presented the vision to be 100% carbon neutral in 2030. At the moment of handing in this thesis 47% of the signatories have deposited their instruments of ratification, acceptance, approval or accession. Reaching 55% the treaty will be effective. The collection of the voluntary measures defined by all signatory parties of the Paris COP21 (INDCs) will not allow to achieve the needed CO_2 limits to avoid overshooting the 2-degree Celsius goal and intensified global joint efforts are needed to reach the goal.

EU has already defined binding limits for its member states up to 2030, to be achieved by using EU-ETS and effort sharing actions in non ETS emitted greenhouse gases.

Starting from a description of the historic development of GHG emissions and renewable energy, this paper will analyze the effectivity of the current EU-ETS system as well as the valid REN support systems in Germany and Austria on achieving the defined goal of 40% CO_2 reduction by 2030, compared to 1990.

More than 10 years after EU-ETS has been started, an evaluation of its implementation as well as an evaluation of the existing measures to achieve the goals in 2030 will be performed.

Having in mind the 40% reduction goal for 2030 as well as the decarbonization ambition for the second half of this century, this period will see the most radical change in energy production and consumption known in history.

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1. INTRODUCTION

Manmade emissions have been identified and scientifically confirmed as one of the main root causes for global warming. The base of our todays welfare are economies, industries and energy production, as well as mobility and agriculture, based on fossil fuels. At the same time fossil fuels are the main source for green house gas (GHG) emissions, be it in their sourcing, processing, distribution and finally usage. 1990 first agreements on a limitation of GHG emissions have been signed in New York, at the United Nations. The 1997 Kyoto Protocol (KP) paved the way for a process to reduce emissions globally. In this first internationally binding agreement more than 37 nations signed to reduce their GHG emissions on average by 5% compared to the base year 1990.[1]

The EU28, back then EU15, agreed to move as one region and developed after the year 2000 the EU Emission Trading Scheme (EU-ETS) as a framework to gradually reduce industrial GHG emissions in the most cost effective way within all members in order to fulfill the Kyoto Protocol targets. For the EU28 this goal was set at an average 8% GHG reduction compared to 1990 in the timeframe 2008 to 2012.

1.1 Motivation

Our society is built on economic growth. The energy for this growth has been mainly provided for with fossil fuels. Economic growth historically is coupled to energy growth. Higher energy consumption in fossil fuels results in higher GHG emissions and finally global warming. Renewable energies cause significantly less GHG emissions over the comparable life span. Support of energy production and consumption has been integral part of the economic development over the last 50 years. Shifting this support to renewable energy in a focused way will speed up the transition to a carbon free society, enable economic growth and slow down and eventually stop global warming.

Climate change, resources stress and continuous urbanization are three of several global megatrends effecting our society now and increasingly in the next decades[2]. The Kyoto Protocol and EU-ETS (Emission Trading Scheme) have clearly formulated goals[3] for the path towards a decarbonization of the economy. The EU-ETS is covering more than 12.000 installations in the EU28 plus Norway, Iceland and Liechtenstein, as well as emissions from airlines

[1] (UN Framework Convention on Climate Change, 2014)
[2] (KPMG International, 2014)
[3] (Commission, European, 2013)

flying between European airports. This represents approximately 45% of the GHG emissions of this area. Industry and big producers of energy have been part of the EU-ETS from the start of its implementation in 2005. Excluded from the EU-ETS is the impact of the transport sector, agriculture, LULUCF and private heating. Subsidies for renewables focus primarily on electricity, heat and fuel produced in a renewable way and also support sectors not included in the EU-ETS.

For 2020 the EU defined a 20% CO2 reduction goal accompanied by a defined 20% of renewable energy share in final electricity consumption as well as a 20% efficiency improvement goal (the “2020 climate & energy package”).

The goal of reducing GHG emissions in 2030 by 40% against 1990 levels[4] is clearly stated, and is valid for Germany as well as for Austria under the current EU-ETS system.

1.2 Core objectives

The thesis aims at giving an overview on the EU-ETS and the results achieved so far, in GHG reduction in the EU, with additional focus on Austria and Germany. Further focus is laid on an analysis of the renewable energies development and the support systems in place in the EU and these two countries.

In addition, this document will present a possible scenario of passenger transport development in Asia (India, China, Japan) compared with US and EU, based on the Kaya equation, in o order to find out the potential GHG emission impact of transportation in that geographic areas.

Analysing the EU ETS, which is the worlds first cap and trade system in this size, functioning since 2005 following questions arise:

1. What lessons can be taken from the first 10 years of its execution?
2. Are measures and support systems in place today enhancing the development of renewable energy in Austria, Germany and the EU sufficiently to reach the 40% reduction goal by 2030 ?
3. Which sectors should be focused on and which activities are the most urgent for GHG reduction in regards to a decarbonization of our economy?

[4] (Commission, European, 2014)

1.3 Methodology

The main part has been developed with literature research in order to describe the existing systems under the current valid legislation.
Participation in conferences and communication with experts has been an important support to enhance the knowledge and input to the document.
Own scenario simulations based on existing technologies for passenger cars contribute to the conclusions.

1.4 Structure of the Thesis

The thesis is starts with an Introduction and is divided in the following chapters:

Chapter 2 describes the Global CO_2 emissions and the EU-ETS as well as the renewable energy as part of the total energy production in the EU. An overview on how energy is supported in the EU28 is included in this chapter.
Chapter 3 describes the framework for GHG reductions, the development of GHG emissions in Austria, the energy consumption of the individual sectors as well the corresponding renewable energies and their support over the last 20 years, as well as their currently valid support schemes.
Chapter 4 describes the framework for GHG reductions, the development of GHG emissions in Germany, the energy consumption of the individual sectors as well the corresponding renewable energies and their support over the last 20 years as well as their current support schemes.
Chapter 5 describes potential scenarios for passenger transport emissions in Asia (India, China, Japan), the US and EU, based on the variables defined in the KAYA equation.
Chapter 6 concludes on the core objectives.

2. Global CO_2 emissions and EU-ETS

The industrial revolution has been possible through technical innovations, consuming increased volumes of fossil fuel, namely coal. The growth of industry and the supply of always increasing amounts of goods for a growing population led to a continuous energy need. Cost of production always included energy but neglected external cost for environmentally or socially detrimental effects. With GHG levels causing global warming and increasingly visible negative effects for the whole society, these elements are taken into consideration. This chapter is providing an overview on CO_2 development as well as the measures to limit and to reduce emissions over the near and distant future in the European Union.

2.1 Global energy consumption, CO_2 emissions, drivers and consequences

Manmade emissions have been identified and scientifically confirmed as one of the main root causes for global warming. First studies go back as far as to Prof. Svante Arrhenius[5], describing the influence of CO_2 on the temperature of air above ground.
Coal, biomass, water and horsepower have been the major source of energy at that time. With the beginning of the 20th century petrol and gas had been found in big quantities. The technologies for their application have been developed, and the usage of fossil fuel for all energy needs increased rapidly.

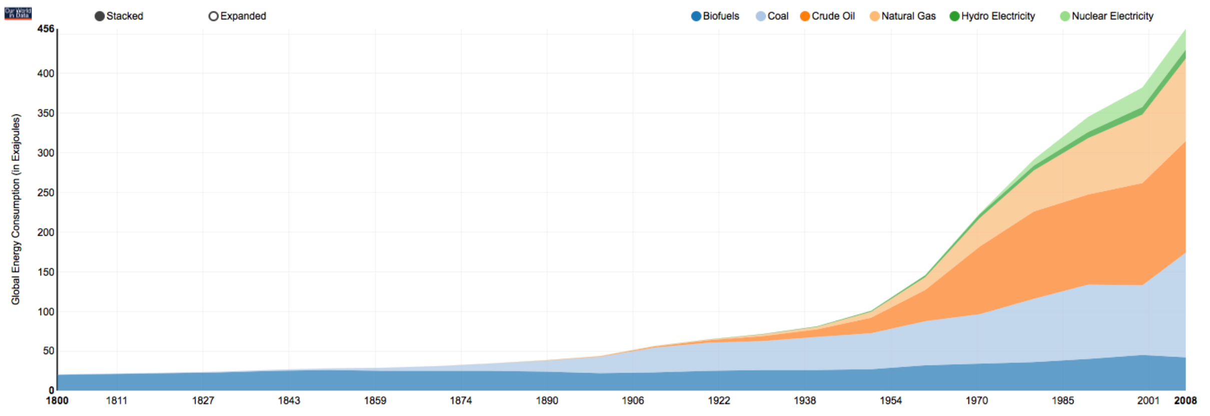


Figure 2-1: World energy consumption by source, Source: 1800-2000- Vaclav Smil, 2010 – Energy Transitions

[5] (Arrhenius, 1896)

Figure 2-1 shows the overview of the global energy consumption by source increasing from 25 Exajoule in the second half of the nineteenth century to more than 450 Exajoule today. Energy has been provided mainly by easy accessible and affordable fossil energy, enabling the economic development of many countries and regions, with fast rising consumption resulting in continuous increase of CO_2 emissions over time.

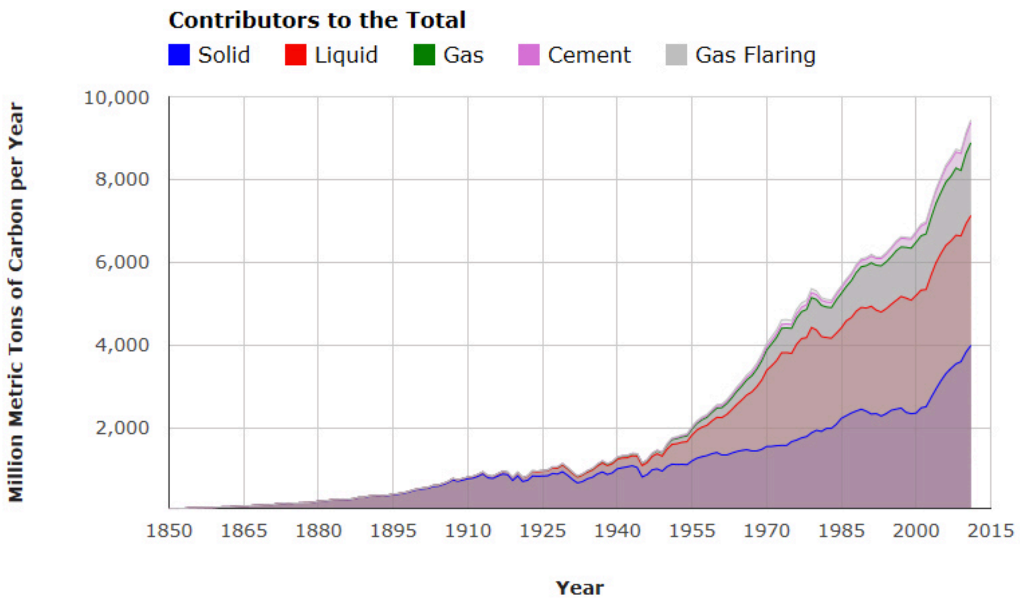


Figure 2-2:Global CO2 Emissions from fossil fuels, Source: Boden, T.A., G. Marland and R.J. Andreas 2015, Global, Regional and National Fossil-Fuel CO_2 Emissions, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn. U.S.A.#

Figure 2-2 shows the development of Carbon emissions over the last 165 years. The steep increase is in line with the steep increase in usage of fossil fuels in the industrialized economies.

Global warming has been confirmed as a result of increased carbon emissions on a global level. The threshold of 350 ppm has been identified as the CO_2 emissions acceptable for the global climate to keep a long term balance. This value has been surpassed years ago, and by reaching the threshold of 400ppm in 2015, an average warming of 1 degree Celsius on the globe is happening. Figure 2-3 shows the development of CO_2 emissions over 800.000 years. The pre-industrial value hovered around 250 to 300ppm over that time horizon.

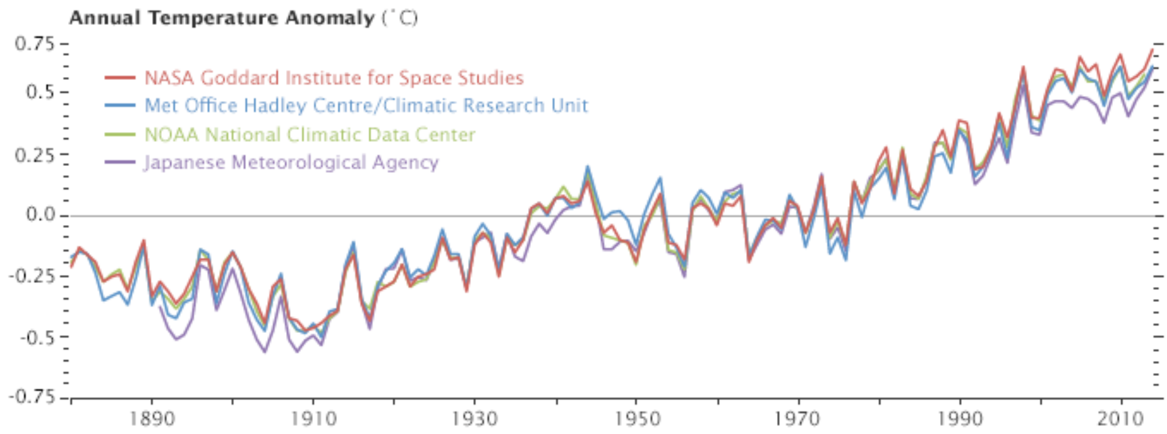


Figure 2-3: Annual Temperature Anomaly, Source: http://earthobservatory.nasa.gov/Features/WorldOfChange/decadaltemp.php, May 2016

In Figure 2-3 above you can see temperature anomalies measured over the last 130 years from 4 independent institutes proposing a temperature rise of 0,5 degrees.

The described development on climate change, back then documented in the first IPCC[6] assessment report released in 1990 lead to discussions, and finally to an agreement how to limit CO_2 and GHG emissions globally, in order to avoid severe climate change and the related detrimental effects for our ecosystem and finally all humans.

In 1990 at the UN General Assembly negotiations on a framework convention started after IPCC´s first assessment report had been released[7], and a treaty to combat climate change has been signed. After several years of negotiations in 1997 the Kyoto protocol was adopted, and after a lengthy ratification process entered into force in 2005[8]. In the first period 37 countries agreed to legally binding GHG emission reduction targets (in average 5%) to be reached between 2008 and 2012, compared to 1990 levels.

The following figure 2-4 shows the contribution to CO_2 increase from fossil-fuel use and cement production by regions between 1990 and 2014. Industrialized countries stabilized their GHG emissions and reduction efforts show visible results over the last 10 - 15 years. Developing

[6] (Intergovernmental Panel on Climate Change, 1990)
[7] (UNFCCC, 2014)
[8] (UNFCCC, 2014)

countries with high population growth and increased attractiveness for producing labor intensive and energy intensive products for the global consumer market increased CO_2 emissions significantly and will continue that trend for some years to come[9].

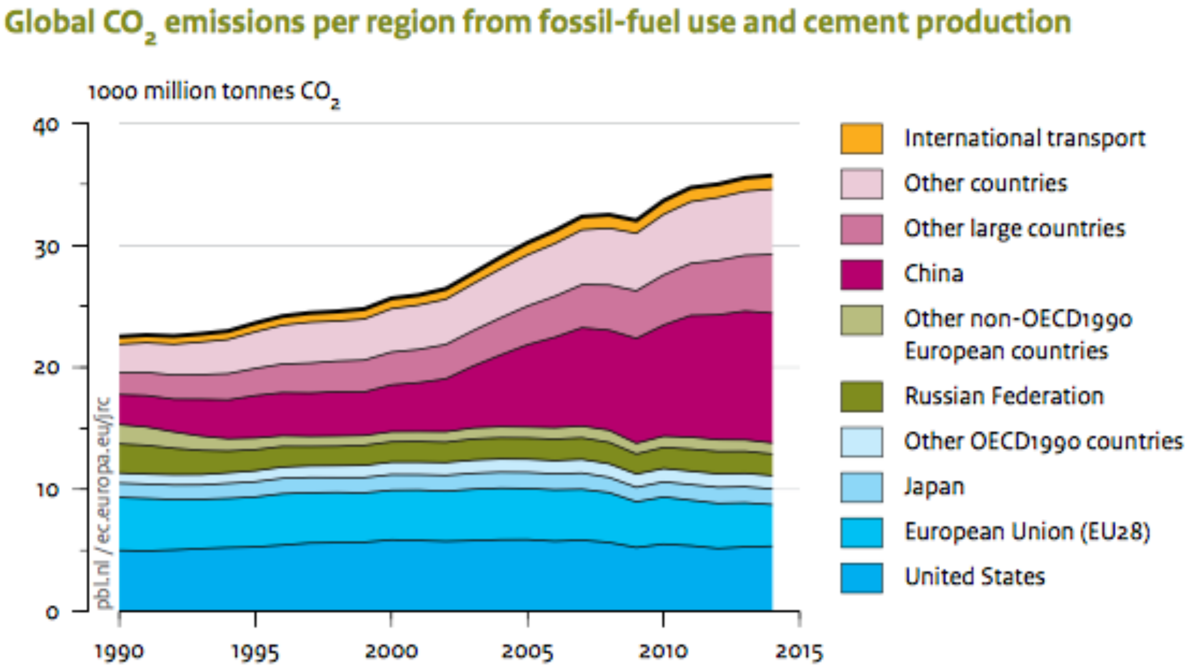


Figure 2-4: Global CO2 emissions per region from fossil-fuel use and cement production, EDGAR, 2013, Source: EDGAR 4.3 (JRC/PBL, 2015 (1970 – 2012; notably IEA 2014 and NBS 2015); EDGAR 4.3 FT2014 (2013-2014);BP 2015; GGFR 2015; USGS 2015;WSA 2015

EU28 contributed app. 19,1% of total emissions in 1990[10]. Political and economic development since 1990 had significant influence on the emissions development. Europe could reduce the emissions by 21% %, Russia reduced by 25%, partially due to the total restructuring of economies and closing down of heavy industry after the fall of the "iron curtain" in 1989, whereas the United States increased by 6% in 2014 compared to 1990[11]. China and economies of large developing countries increased emissions substantially over that time period. Overall CO_2 emissions increased globally to 35,7 billion tons, increasing almost 60% since 1990.

2.2 Kyoto protocol and EU goals build the base of EU-ETS

In line with Kyoto protocol the EU developed joined targets to combat climate change. Having successfully achieved the 8% reduction compared to 1990 by 2012, new reduction goals for 2020, 2030 and a roadmap towards a low carbon economy as of 2050[12] have been developed.

[9] (PBL Netherlands Environmental Assessment Agency, 2015)
[10] (Olivier, 2015)
[11] (Olivier, 2015)
[12] (Commission, 2014)

The 2020 climate & energy package[13] is based on a set of binding legislation aiming at meeting climate and energy targets for the year 2020, by a

- 20 % cut in GHG emissions compared to 1990
- 20% of final energy from renewables
- 20% of energy efficiency

Based on the 2020 climate & energy package, for the next decade to 2030 the climate and energy framework has been agreed within the member states with the goal of

- 40% reductions in GHG compared to 1990
- 27% share for renewable energy
- 27% improvement in energy efficiency

Building on this targets the roadmap to a low carbon economy in 2050 has been defined:

- 80% reduction of GHG compared to 1990 / 60% reduction by 2040

All sectors of the economy have to contribute so that the execution will be feasible and affordable[14]. The agreed goals for all all EU member resulted in legislation and policies supporting the future development on European, national, regional and local level. One important tool to jointly move towards GHG reductions is the EU-ETS, which will be described in the following paragraphs.

2.3 Functioning of EU-ETS

2.3.1 Basic Concept of the EU-ETS

The first commitment period (2008 to 2012) of the Kyoto Protocol signed by 37 industrialized countries and the EU defined an average 5% reduction on GHG emissions compared to 1990 levels[15]. It covers more than 45% of carbon dioxide (CO_2) and greenhouse gases (GHG) like nitrous oxide ($_{N2O}$) and Perfluorinated Chemicals (PFC).

Accepting the fact that higher efforts from richer nations are possible, the EU agreed on a target of 8% reduction for the period 2008 to 2012. This was the foundation for the EU strategy to introduce the EU-ETS covering industrial and combusting installations in various steps.

[13] (Commission, ec.europa.eu/clima/policies/strategies/2050, 2014)
[14] (Commission, ec.europa.eu/clima/policies/strategies/2050, 2014)
[15] (UNFCCC, 2011)

The basic concept of the EU-ETS is that of a multi-national cap and trade program[16], encompassing the following advantages:

- defined volumes available for all market participants and their development over time,
- cost-effectiveness: all participants face the same price for carbon, emissions are cut where cost are lowest
- Revenue through auctioning of GHG emissions, 50% of which usable for measures to tackle climate change
- Transparent definition of all installations covered by the EU-ETS, which cover app. 45% of the total GHG of the EU member states

Figure 2-5: EU-ETS Phases 2005 to 2021, Source: EU ETS Handbook, 2012, http://ec.europa.eu/clima/publications/index_en.htm, own graph

Figure 2-5 shows the time-line of the EU-ETS in phases.

- Phase 1 intended to reach a 6,5% reduction compared to 2005 level
- Phase 2 aimed for reaching the 8% below 1990 level -> as signed in the Kyoto protocol
- Phase 3 currently is aiming at a reduction of 20% reduction of GHG versus 1990.
- Phase 4 defined a 40% reduction compared to 1990 on GHG goal.

In line with the EU policy, emission targets have been set for operators of industrial installations and power plants[17] Allowances distributed to the operators of these installations give the holder the right to emit one ton of CO_2 (or the equivalent GHG) for one allowance.

2.3.2 Sectors covered by the EU-ETS

All operators must monitor, verify by a third party, and report their emissions each year and surrender emission allowances in equal amounts as annual emissions produced.[18] They can choose either reducing their own emissions, purchase allowances on the European carbon market or hand over CDM/ JI credits under the Kyoto flexible mechanism. In Table 1 you

[16] (European Commission, 2012)
[17] (European Commission, 2012)
[18] (https://www.gov.uk/guidance/participating-in-the-eu-ets)

can see the installations covered in Phase I and additions for Phase III, as well as the GHG effected.

Table 1: EU-ETS: Installations covered in Phase I - Phase III, Source, EDF, CDC, IETA: European Union, The World´s Carbon Markets: A Case Study Guide To Emissions Trading, 2015, page 5, own summary

Sector	Phase included	GHG Coverage	Coverage Treshold
Power stations and other combustion	I	CO2	25 MW
Refining of mineral oil	I	CO2	-
Coke	I	CO2	-
Cement	I	CO2	530t/day (rotary kilns)
Ceramic products by firing	I	CO2	75t/day
Glass	I	CO2	20t/day
Iron or steel	I	CO2	2,5t/hour
Lime or calcination of dolomite or magnesite	I	CO2	50t/day
Metal or roasting	I	CO2	-
Pulp	I	CO2	-
Paper or cardboard	I	CO2	20t/day
Black carbon	III	CO2	20t/day
Bulk organic chemicals by cracking reforming, partial or full oxidation	III	CO2	100t/day
Drying or calcination of gypsum	III	CO2	20 MW
GHG from capture, transport and geological storage	III	CO2	-
Hydrogen , syntheis gas by reforming or partial oxydation	III	CO2	25t/day
Mineral wool insulation material	III	CO2	20t/day
Nitric acid	III	CO2, N2O	-
Production of adipic acid	III	CO2, N2O	-
Production of glyoxal	III	CO2, N2O	-
Production or processing of ferrous metals and of non-ferrous metals	III	CO2	20 MW
Production or processing of primary al	III	CO2, PFC	
Production or processing of secondary aluminium	III	CO2	20 MW
Soda ash and sodium bicarbonate	III	CO2	-

The operators of these installations received certificates in line with their historical emissions for free, as defined within the National Allocation Plans (NAPs), presented from each EU member (grandfathering).[19] All installations and respective allowances have been documented in the National registries of their countries. Operators with higher emissions than certificates could buy those, on the back then, newly defined GHG certificates market (EEX, Leipzig founded in 2002 (European Energy Exchange AG, 2015)[20]). In Phase I a penalty of 40 EUR/ t of CO_2 for not handing over EUAs was in force. This has been increased to

[19] (Commission)
[20] (European Energy Exchange AG, 2015)

100 EUR/t CO_2 as of Phase II in 2008 and is currently effective with this amount.
The EU registry has replaced the EU Member States' national registries in June 2012. EU ETS operations were centralized in a single EU registry, developed, operated and maintained by the European Commission.[21]

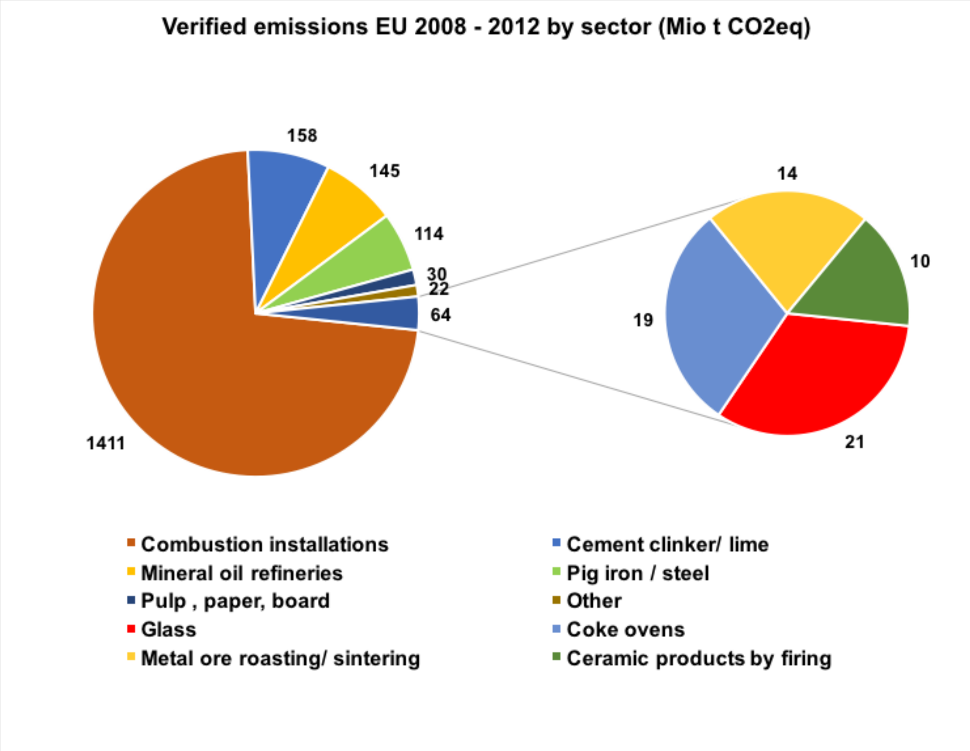


Figure 2-6: Verified emissions EU 2008 – 2012 by sector, Source: (EEA, 2015), own presentation

Figure 2-6 shows the distribution of the verified emissions in the period 2008 – 2012 by sectors. An average total of 1944 Mio t of CO_2 has been verified. The biggest sector with 1411 Mio tons of CO_2 emissions is combustion installations. This includes also electricity production. Cement clinker and lime emitted 158 Mio tons, mineral oil refineries 145 Mio tons and iron and steel production 114 Mio tons. These four sectors mentioned add up to 94% of emissions covered by the EU-ETS.

2.3.3 Allocations of allowances

The different ways of allocating allowances will be described in detail below.

[21] (Commission)

2.3.3.1 Free Allocations

Most of allowances had been allocated for free in Phase I and Phase II.
Free allowances are still allocated based on benchmarks, so called carbon intensity targets, and historical production levels. This benchmarks have been developed per product, based on the 10% best performing installations within the EU producing that product.[22]
In Figure 2-7 the increasing development of auctioning volumes can be seen, marked in blue color. In addition, free allocations are granted to the electricity industry in 8 member states joining EU in 2004 as well as to industries under the carbon leakage risk, as described below. Another 5% of allowances are placed into the new entrants reserve (NER) and 3% of the total aviation allowance are added to a so called Special Reserve. Aircraft operators who started after 2010 or increased travel distance in tkm more than 18% between 2010 and 2014 are eligible.

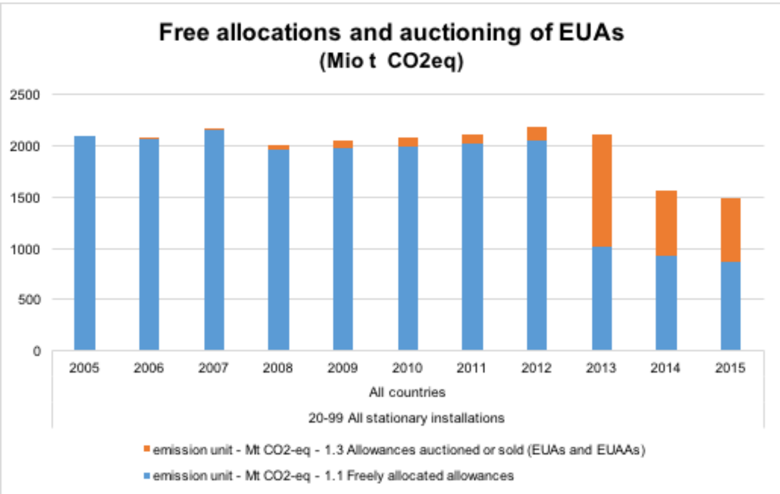


Figure 2-7: EU ETS CO2eq. Free allocations and auctioning of EUAs, 2005 to 2015 Source: EEA Data Viewer, http://www.eea.europa.eu/data-and-maps/data/data-viewers/emissions-trading-viewer

2.3.3.2 Auctions

Whereas in Phase I and II nearly all allowances have been allocated for free, in Phase III (2013 to 2020) auctioning of allowances is the standard method. This is valid for most of the power generation sector. Eight member states who joined EU in 2004 will continue to grant a decreasing number of free allowances to their power plants till 2019.[23]

[22] (CDC, 2015)
[23] (CDC, 2015)

The European Energy Exchange, Leipzig (EEX) is the common vehicle to auction emission allowances. In London ICE Futures Europe is the second platform, installed for the emission market in UK/Great Britain[24]

For 2013 more than 40% of allowances have been auctioned[25]. This is foreseen to increase to 70 % in 2020. Exemptions are still in place for industries under carbon leakage risk. Under carbon leakage risk are those industries which are in competition with non EU operators which do not have to pay for their GHG emissions and therefore would suffer unfair competition. Carbon leakage also counters the risk, that industrial producers would change their production facilities to outside EU-ETS countries, where less stringent CO_2 policies would result in higher emissions of their production, compared to their existing location. Industries under carbon leakage[26] risk continue to benefit from free allocations. Every 5 years the list of eligible industries will be updated.

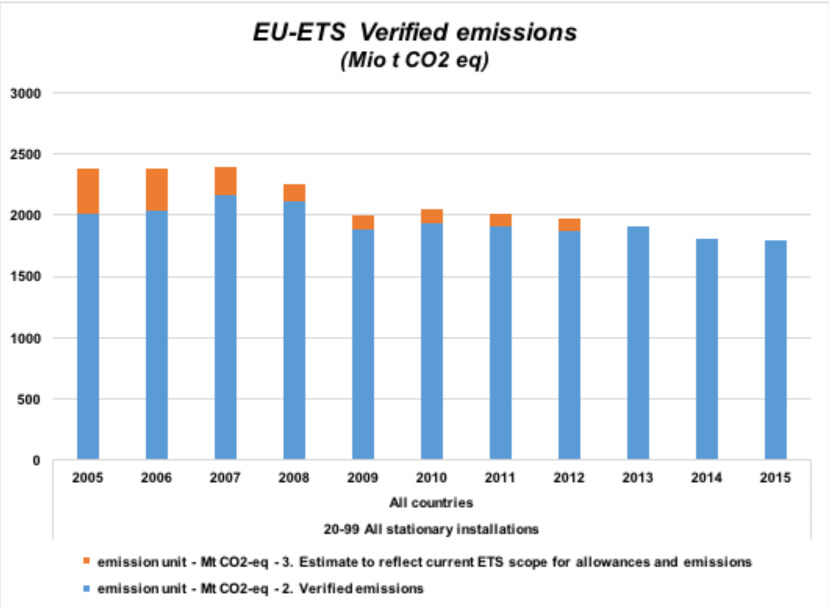


Figure 2-8: EU ETS CO2eq. verified emissions 2005 till 2015, Source: EEA Data Viewer, http://www.eea.europa.eu/data-and-maps/data/data-viewers/emissions-trading-viewer

Figure 2-8 is showing the verified emissions of CO_2 equivalents from 2005 to 2015. The verified emissions reduced from 2,014 billion tons of CO_2 eq. in 2005 to 1,721 billion tons of CO_2 eq. in 2015. As the scope between these years has changed, the orange color shows adequate corrections to compare all involved installations as well as domestic aviation over this time period.

[24] (Government UK, Department of Energy & Climate Change, 2013)
[25] (ECommission)
[26] (European Union, 2013)

Applying todays included countries, EU-ETS related emissions have been reduced by 27% between 2005 and 2015[27].

2.3.3.3 Auction Revenues

EU-ETS Directive foresees a minimum of 50% of auction revenues to be earmarked for GHG reduction measures in the EU (e.g. investment in renewable energy, improving energy efficiency, reducing deforestation and carbon capture and storage projects – CCS)[28].
By selling 300 Mio allowances of New Entry Reserve (NER) in 2012 funds of EUR 1,1 billion. have been made available. Additional EUR 2,0 billion have been added from private investors for more than 20 projects to be realized between 2016 and 2018.

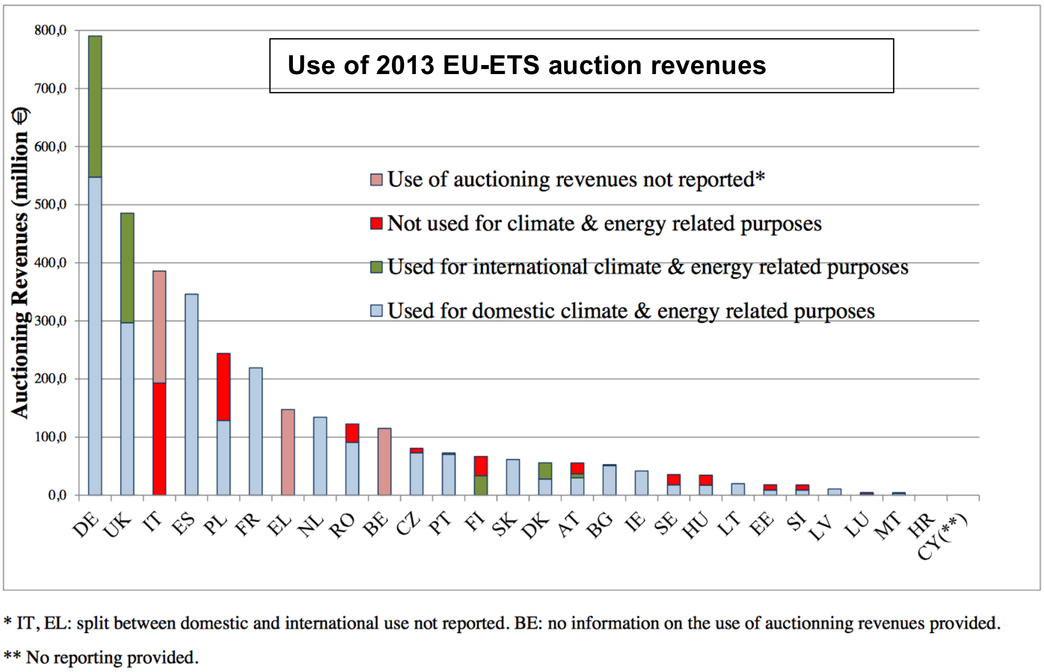


Figure 2-9: Use of 2013 EU ETS auction revenues, Source European Commission 2014, http://ec.eu-ropa.eu/clima/policies/strategies/progress/docs/com_2014_689_en.pdf

Figure 2-9 shows the use of EU ETS auction revenues for the individual countries. While Austria and Germany used the funds as foreseen, the 50% goal has not been followed in all countries. For future auction revenues monitoring of this execution will be of high importance.

2.3.3.4 Allowance acquired through CDM and JI

The allowances under the EU-ETS have been described above. Additional flexible mechanisms foreseen under the Kyoto Protocol are Clean Development Mechanism (CDM) and Joint

[27] (European Environment Agency, 2016)
[28] (European Commission, 2013)

Implementation (JI), derived allowances so called Certificates of Emission Reductions (CERs) and Emission Reduction Units (ERUs), in order to offset GHG in the EU-ETS period from 2005 to 2012. The current discussion of the EU advocates appropriate mitigation actions of industrialized countries and Least Developed Countries.

These international credits for compliance could be used until 2012 like EUAs. For the Phase III operators having CER/ ERU credits available had to exchange them to EUAs by 31.3.2015 in accordance with Article 60 of the Registry Regulations[29] .

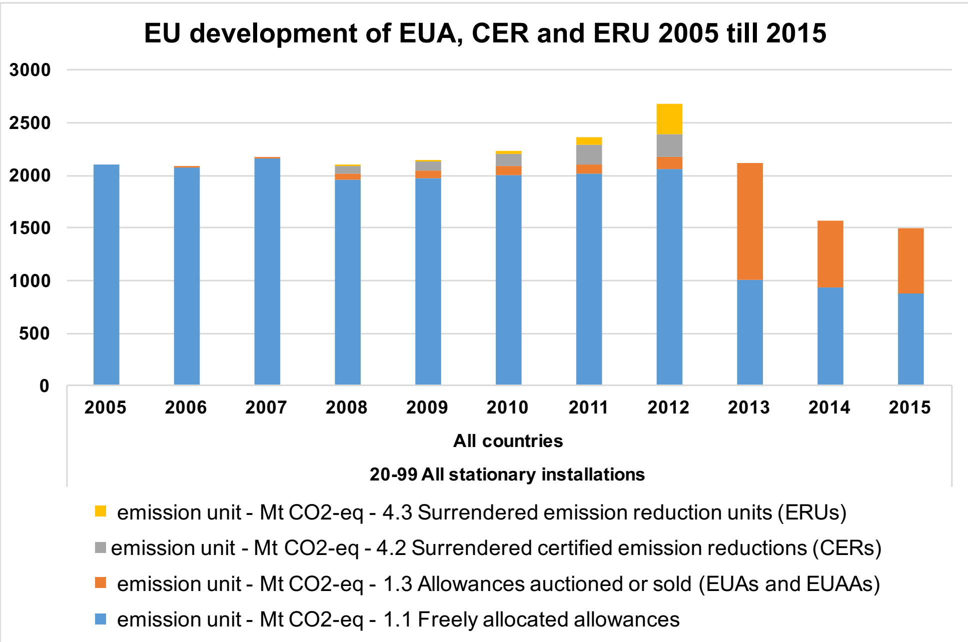


Figure 2-10: ETS CO2eq. Development of EUA, CER and ERU 2005 till 2015, Source: EEA Data Viewer, http://www.eea.europa.eu/data-and-maps/data/data-viewers/emissions-trading-viewer, own presentation

Figure 2-10 shows the cumulating surplus of EUAs, CERs, ERUs in the period 2008 to 2012. This oversupply with allowances resulted in a very low CO_2 trading price and finally in an adjustment of the system towards backloading.

2.3.4 Development of allowance surplus over time

The defined energy and industry sectors and the included installations from each country individually prepared National Allocation Plans (NAP) which had been accepted by the EU, resulted in over allocation of EUAs (European Union Allowances) in the range of 2 to 4% for the first phase of the EU ETS. In Phase II (second trading period) the economic crisis hit mainly industry production and resulted in reduced energy needs and finally lower GHG emissions all

[29] (http://ec.europa.eu/clima/policies/ets/linking/faq_en.htm)

over the EU. In addition, CERs and ERUs in line with the Kyoto Protocol flexibility mechanism have been surrendered. This resulted in a cumulated surplus of 1754 Mio EUAs at the end 2012, carried over to the third trading period.

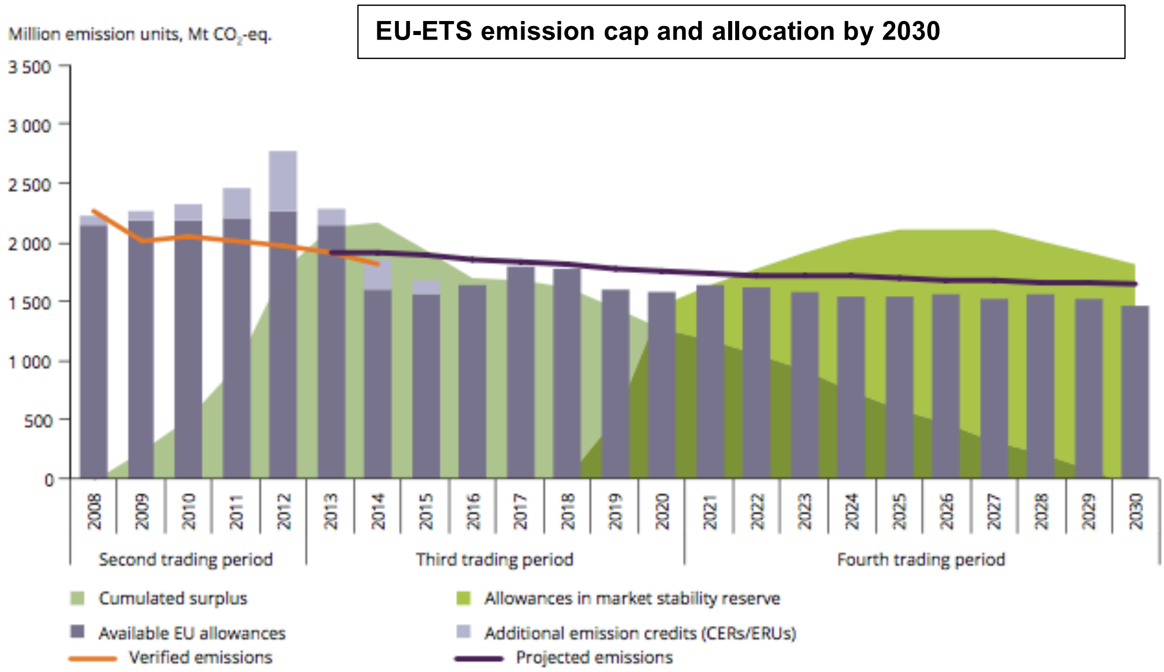


Figure 2-11:EU ETS emission cap and allocation by 2030, Source (EEA, 2015), p.28

Figure 2-11 shows the development of the emission cap since 2008. It can clearly be seen that significantly more allowances have been in the market than needed in line with verified emissions. This led to the backloading and market stability reserve concept explained in the following chapter. With the foreseen and agreed trend in emissions this concept will help to stabilize the market price for allowances over time. The offsets used in Phase I still continue to be used for Phase II. Free allocations will be reduced in Phase III, but are still foreseen as a significant part of the system in Phase IV up to 2030.

2.3.5 Price development of European Union Allowances

The mechanism for the market of EUAs can be demonstrated in a simplified example. Let us assume two operators, receiving 100 Mio EUAs based on historical emissions of 100 Mio tons of CO_2 for a given year.

Operator 1 replaced coal firing by gas firing and results in emitting 90 Mio tons of CO_2, while operator 2 was increasing his production without any technological improvements, resulting in 110 Mio tons of CO_2. Operator 1 surrenders the 90 Mio tons of verified CO_2 emissions in April

the following year and sells the surplus 10 Mio EUAs on the EU carbon market. Operator 2 is buying the missing 10 Mio EUAs on the EEX for the market price at a certain point of time. Both operators could comply and each of them decided which path is more economical at that point of time.
Below in Figure 2-12 you can see the development of the prices for EUAs and CERs between 2005 and 2013.

Price trends for EUAs and CERs, 2005 - 2014

Figure 2-12: Price trends for EUAs and CERs, 2005 – 2014, Source: (EEA, 2015), p.22

The volume of EUAs is defined by the emission cap defined for the EU-ETS for each year as well as by the accepted CERs and ERUs for offsetting emissions.

The total demand of EUAs/ CERs/ ERUs is a result of the emissions of the included installations. The emissions of the installations depend on the technology used for producing their products as well as their success in the market placing them and finally the overall economic development.

As you can see in the Figure 2-12 EUAs reached price levels as high as 30 EUR in the first year and finished close to zero in 2007. In Phase I price levels above 25 EUR/ EUA have been reached, but dropped sharply after verified emissions showed a significant surplus of allowances in the market. Banking was not allowed from Phase I to Phase II. In combination with the volume surplus, the price dropped to almost zero in 2007. The EU climate and Energy package 2020 had a strong influence on the price level in 2008 when prices again showed a level of 30 EUR/ EUA. The financial crisis which hit globally 2009 caused reduction in production and energy usage, and resulted in lower emissions and finally a decrease in demand for EUAs. As no signs of economic recovery has been be visible the demand stayed weak and the prices dropped even more.[30] EUAs fluctuated between EUR 5 to EUR 7 over the last 2 years.

In 2012 a surplus of allowances of 1 billion has been built up and was still expected to grow. The main drivers have been:

- Allocation levels in the NAPs (2005 – 2007) - grandfathering
- Energy efficiency measures adopted for the EU
- Higher than expected penetration rate of renewables
- Increasing energy prices
- Economic crisis since 2008
- Large amount of ERUs/ CERs for compliance as their validity finishes in Phase II
- Leftover of allowances for national new entry reserves Phase II
- Sale of allowances for NER 300 program in 2012
- Early auctioning of 120 million of Phase III allowances

In order to stabilize the price for EUAs, which represents an important signal for investors in renewables as well as in other technologies to reduce CO_2 and GHG emissions, EU implemented two measures in 2014:

Backloading[31] and Market Stability Reserve

The functioning of these adjustments will be explained in the following sections.

2.3.5.1 Stabilizing the EU-ETS - Backloading

This means the temporary reduction of 900 million allowances foreseen for auctioning. The distribution over the years looks as follows:

[30] (2013)
[31] (European Commission, 2013)

Year	*Reduction of auction volumes*
2014	400 million
2015	300 million
2016	200 million

This 900 million allowances are foreseen to be auctioned in 2019 and 2020.These volumes will be placed into the Market Stability Reserve (MSR).

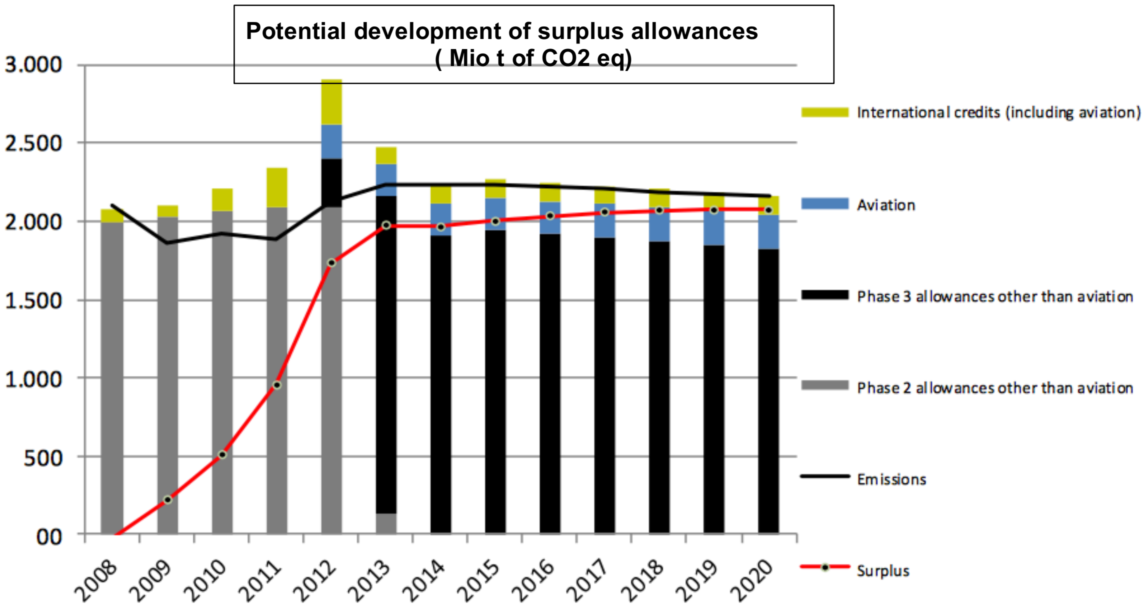


Figure 2-13:Potential development of surplus allowances 2008 to 2020, Source: Staff working document on the functioning of the carbon market (http://ec.europa.eu/clima/policies/ets/auctioning/docs/swd_2012_xx2_en.pdf), p.11

Figure 2-13 shows the build up of surplus of allowances between 2008 and 2013 as well as the potential development till 2020. Without backloading an excessive amount of allowances would be in the market and no increase in prices for allowances could be expected for the next years[32]. The expected effect of backloading is a stabilization of the price of EUAs which again helps investments into renewables. Based on the analysis of potential outcomes for the various scenarios price stabilizations at a level of EUR 7/EUA can be expected[33].

2.3.5.2 Stabilizing the EU-ETS - Market stability reserve (MSR)

Whereas backloading represents a short term measure to stabilize the EUA price levels during the Phase III, market stability reserve is considered a long term solution aiming to reform the ETS as of 2018. It shall be established in 2018 and be operational from January 2019.

[32] (European Commission, 2012)
[33] (European Comission, 2012)

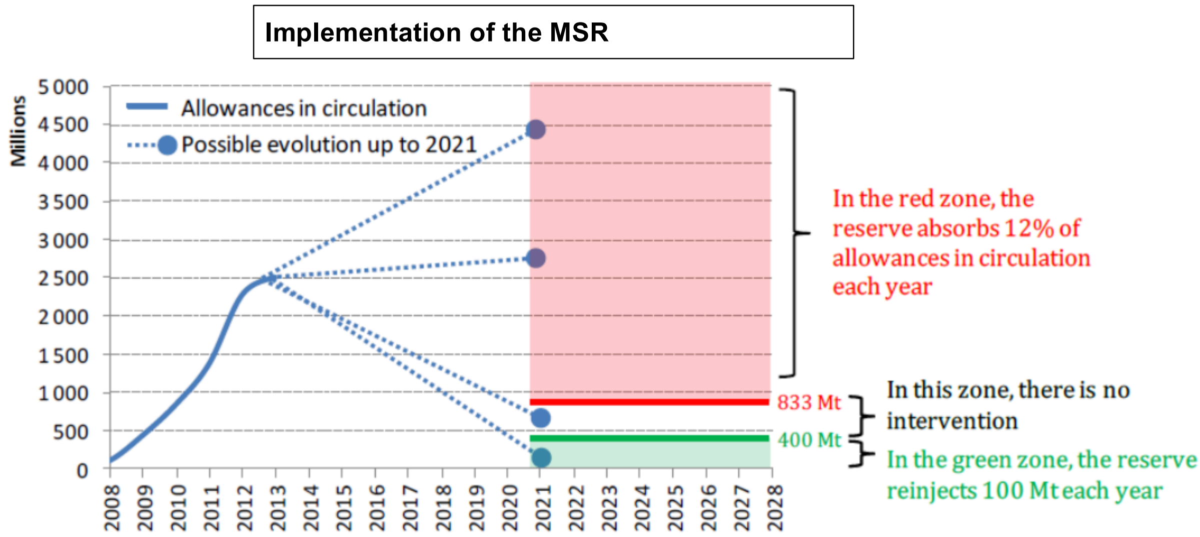


Figure 2-14: Implementation of the EU-ETS market stability reserve, Source: Climate Economics Chair, 2015

With the MSR the annual auction volumes can be adjusted and external shocks to the EU ETS system can be cushioned.

As figure 2-14 shows two limits have been defined for surplus allowances:

>= 833 million and <= 400 million

In case the surplus exceeds 833 million 12% of allowances in circulation will be absorbed by the MSR. If allowance level will fall below 400 million, then additional 100 million will be reinjected from the MSR to circulation. This additional mechanism will help to reach the ambitious goals for 2030 emission limits.

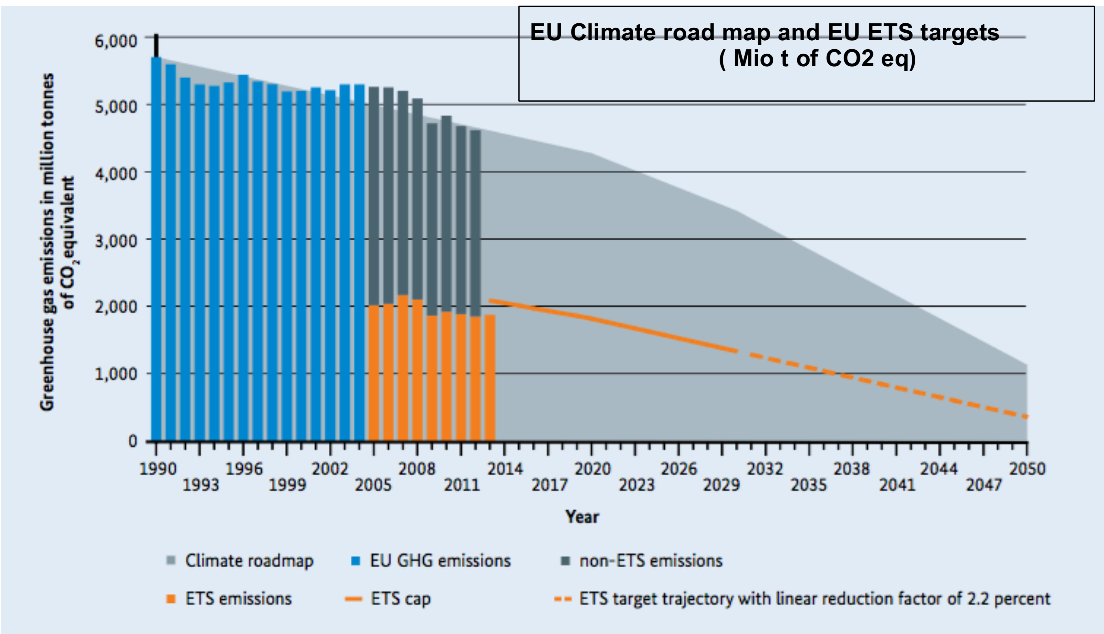


Figure 2-15:EU Climate road map and EU-ETS targets 1990 – 2050 in million tons CO2eq, Source: European Commission

Figure 2-15 describes the development of GHG within the EU since 1990 and targets toward 2020, 2030 and 2050. The blue bars show the development before the EU-ETS has been implemented. The orange bars show the EU-ETS related GHG emissions the straight orange line shows the path towards the EU 2030 goal, with the target trajectory including the linear reduction factor of 2,2%. The dotted line shows the path towards the vision 2050. The grey area above is related to the non-EU-ETS emissions.

2.4 Development of CO_2 emissions and energy consumption in the EU

Total GHG emissions for the EU28 including aviation and excluding LULUCF could be reduced from 5749 Mio t CO_2 equivalent in 1990 to 4611 Mio tons in 2013[34]. This represents a 19,8% reduction over that time period.

Table 2 below summarizes the CO_2 emission values for the EU since 1990. The goals for 2020 have been accomplished already as of 2014. The 2030 goals will be challenging for several member states but are reachable for the EU as a whole. The vision 2050 will need a total different thinking and has to start from a zero CO2 based society working in a non fossil environment.

Table 2 : Development of CO2eq emissions in EU,1990 – 2014, and goals 2020, 2030, 2050, Source: European Commissions, http://ec.europa.eu/clima/policies/strategies/2020/index_en.htm, http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/145397.pdf, https://ec.europa.eu/energy/sites/ener/files/documents/2012_energy_roadmap_2050_en_0.pdf, September30th, own summary

Development of GHG emissions in Mio tons of CO2 eq		
	EU	
1990	5.735	100%
2000	5.284	92%
2005	5.347	93%
2012	4.691	82%
2013	4.602	80%
2014	4.419	77%
Target 2020	4.588	80%
Target 2030	3.441	60%
Vision 2050	1.147	20%
Vision 2050	287	5%

[34] (Eurostat, 2015)

2.4.1 Development of energy consumption in the EU

The Gross inland energy consumption in the EU28 reached 2013 the same value as in 1990, 1667 Mio TOE, and has been peaking in 2006 at 1840 Mio TOE[35].

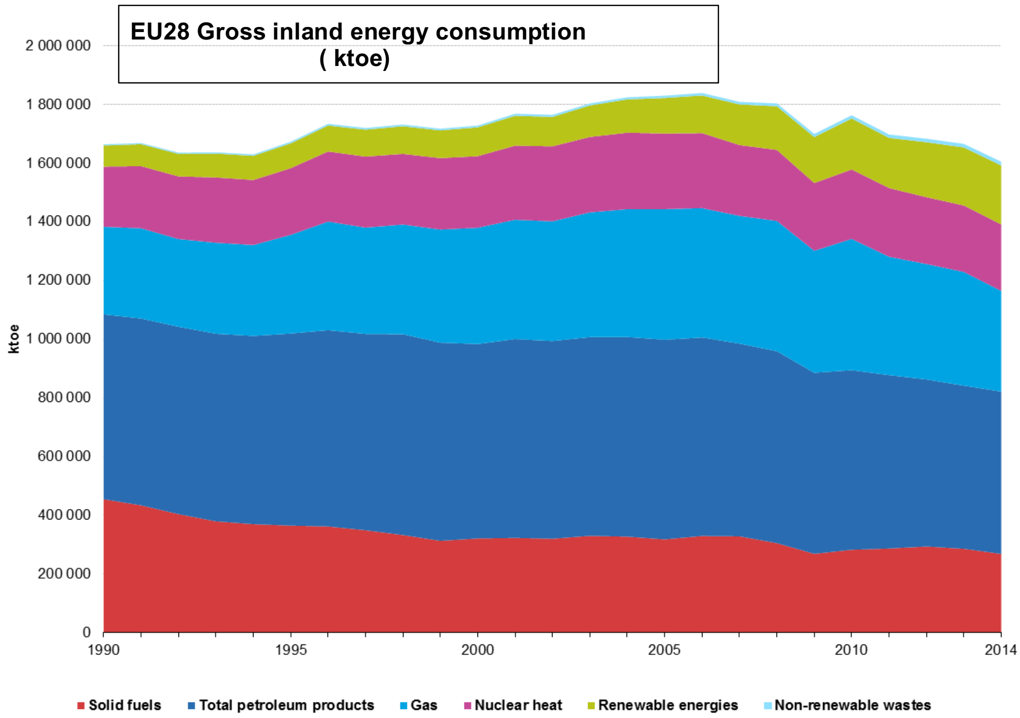


Figure 2-16: EU28 Gross inland energy consumption 1990 – 2014, Source: Eurostat 2015 (http://ec.eu-ropa.eu/eurostat/statistics-explained/index.php/File:Gross_inland_energy_consumption,_EU-28,_1990-2014,_ktoe_new.png)

Figure 2-16 shows the reducing trend in solid fossil fuels, mainly coal, and increasing trends for oil & petroleum products, gas and renewables. The increase for oil and petroleum is caused by the increase in transportation till 2009. Since then a slight decrease can be noticed.

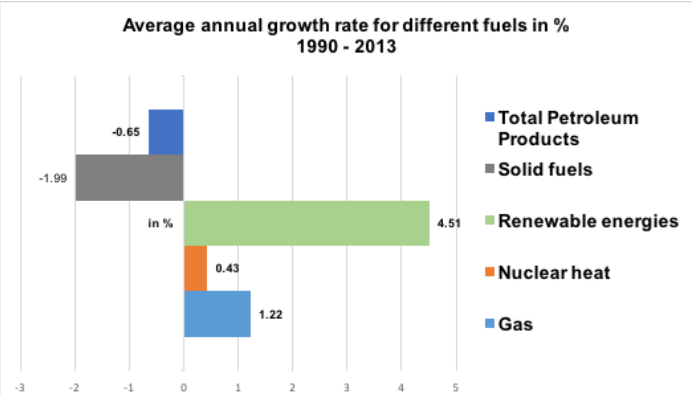


Figure 2-17: EU28 Average annual growth rate for different fuels, 1990 – 2013, Source: EEA, 2015(http://www.eea.europa.eu/data-and-maps/daviz/average-annual-growth-rates-3#tab-chart_4), own graph

35 (Eurostat, 2015)

Figure 2-17 above, shows the average annual growth rate for different fuels between 1990 and 2013. Gas, nuclear heat and renewable energy had a growth over that period. Since 2005 only renewable energy is growing, while all other energy carriers are shrinking in the range of 1% to 3% per year. [36]

In the following Table 3 the development of the primary energy and final energy can be followed.

Table 3: EU28 Energy consumption 1990 to 2013 and target 2020 in Mtoe, Source Eurostat (*http://ec.europa.eu/eurostat/statistics-explained/images/d/d4/Energy_consumption_in_the_EU28_-_2012.png), 2015, own summary*

in Mtoe	1990	1995	2000	2005	2010	2013	Target 2020	
Primary Energy	1.568,7	1.565,8	1.616,6	1.708,9	1.652,5	1.566,6	1.483,0	-8%
Solid Fossil Fuels	453,2	364,0	320,3	316,7	281,6	285,2		
Oil & Petroleum Products	548,9	562,3	566,5	578,2	520,1	472,0		
Gas (Natural & Derived)	282,4	321,2	380,4	429,7	433,7	373,2		
Nucelear Heat	205,2	227,3	243,8	257,5	236,6	226,3		
Renewables	71,3	83,5	97,5	117,6	168,8	196,6		
Other	7,7	7,5	8,1	9,2	11,7	13,3		
Final Energy	1.079,9	1.079,1	1.130,6	1.186,4	1.158,3	1.104,7	1.086,0	1%
Solid Fossil Fuels	124,3	83,0	62,0	54,0	50,5	47,6		
Oil & Petroleum Products	446,4	464,4	489,7	502,6	457,4	425,0		
Gas (Natural & Derived)	229,9	247,2	267,6	281,2	273,2	259,8		
Electricity	186,0	194,3	217,6	239,5	244,5	239,1		
Derived Heat	54,3	45,4	44,6	52,4	53,3	48,0		
Renewables	38,1	43,2	48,1	55,3	76,8	82,2	217,2	20%
Non-renewables waste	0,9	1,6	1,0	1,4	2,6	3,0		

Renewable energy almost tripled between 1990 and 2013, from 71,3 Mtoe to 196,6 Mtoe representing 12,6%. In the final energy it more than doubled from 38,1 to 82,2 Mtoe representing 7,6%. A significant portion of renewables is also included in electricity.

2.4.2 Split of CO_2 emissions between the sectors

In 2012 EU28 emitted 4544 million tons of GHG[37]. Energy Industries, Transport and Industry caused 70% of these emissions[38] as shown in Figure 2-18.

[36] (European Environmental Agency, 2015)
[37] (European Environment Agency , 2014
[38] (European Union, 2015)

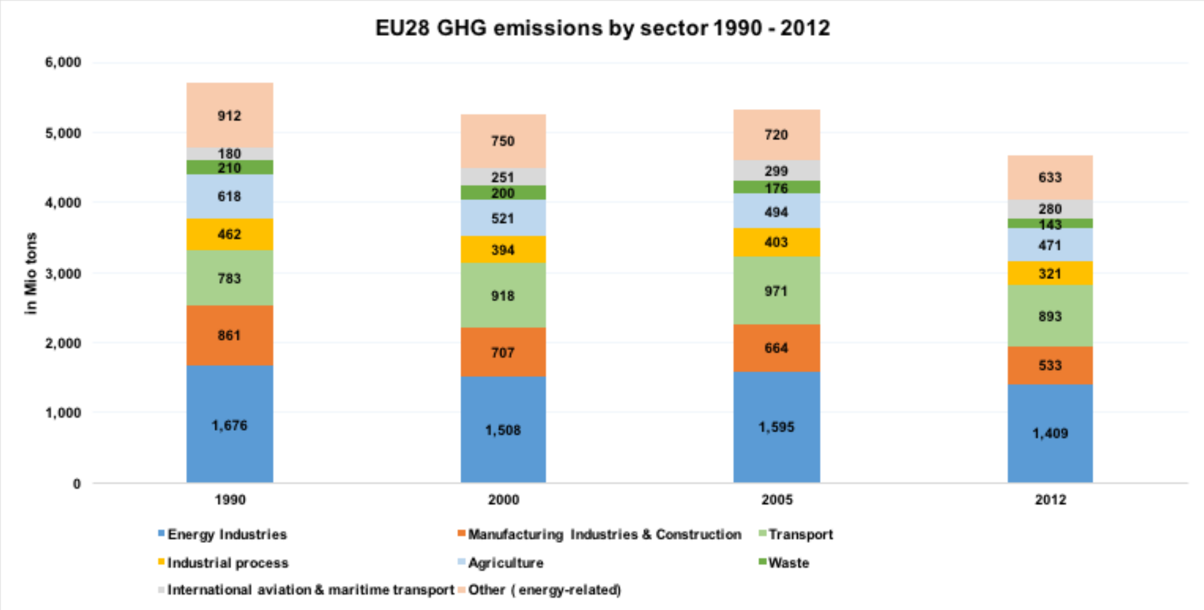


Figure 2-18: EU 28 GHG emissions by sectors in 2012 by sectors, Source: http://ec.europa.eu/eurostat/statistics-explained/index.php/File:GHG_emissions_by_sector_EU-28.jpg,own graph

In 2012 the Transport sector has been responsible for 19,7% of the emissions in the EU. Adding up all sectors EU could reduce GHG emissions in 2012 by 840 Mio t, compared to 1990. Transportation, international aviation and navigation did grow in this period, while energy industries, manufacturing industries and construction as well as agriculture and industrial processes showed CO_2 emissions savings, as shown in Figure 2-19.

CO_2 emissions from biomass increased by 308 Mio t since 1990. If used in a sustainable way biomass related CO_2 emissions are considered neutral.

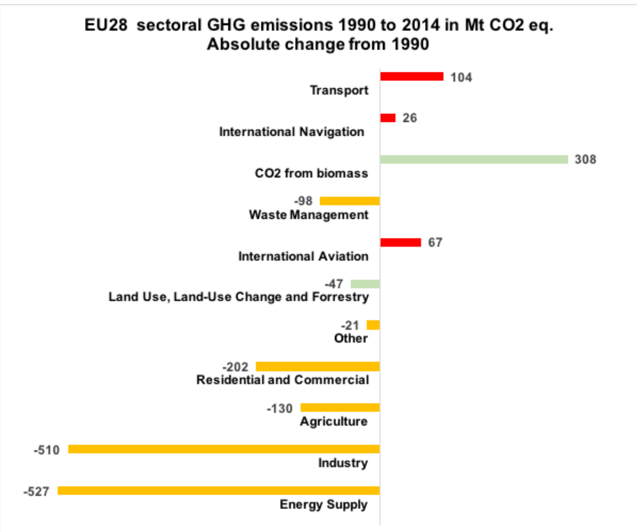


Figure 2-19: EU28 sectoral GHG emissions 1990 to 2014 in Mt CO2 eq., Source: http://www.eea.europa.eu/data-and-maps/indicators/greenhouse-gas-emission-trends-6/assessment , June 21st, 2016

The main source for CO_2 emissions is the usage of fossil energy. In the following section the development of the energy consumption and the part of renewable energy is described.

2.5 Renewable energy development in the EU

Based on the Kyoto protocol GHG emission reduction goals for the EU resulted in focusing on the main emitters, the heavy industry and the energy producers. Technological improvements in industrial processes as well as energy saving measures and productivity increases reduced the energy input for industries. In the climate and energy package 2020 the EU28 member states agreed to increase the share of renewable energy to 20% of the final energy by 2020. In 2014 EU28 could already achieve 16%.

Figure 2-20 includes the development of the different energy carriers for renewable energy. Wood and other solid biofuels had the biggest portion increasing from 40,7Mtoe to 89,5Mtoe in 2014, Wind from some pilot installations in 1990 to 15,5Mtoe, Solar thermal increased to 4,1Mtoe and PV to 7,9Mtoe. The usage of Geothermal energy stabilized at 6,2Mtoe and the Renewable waste sector stabilized at similar levels.

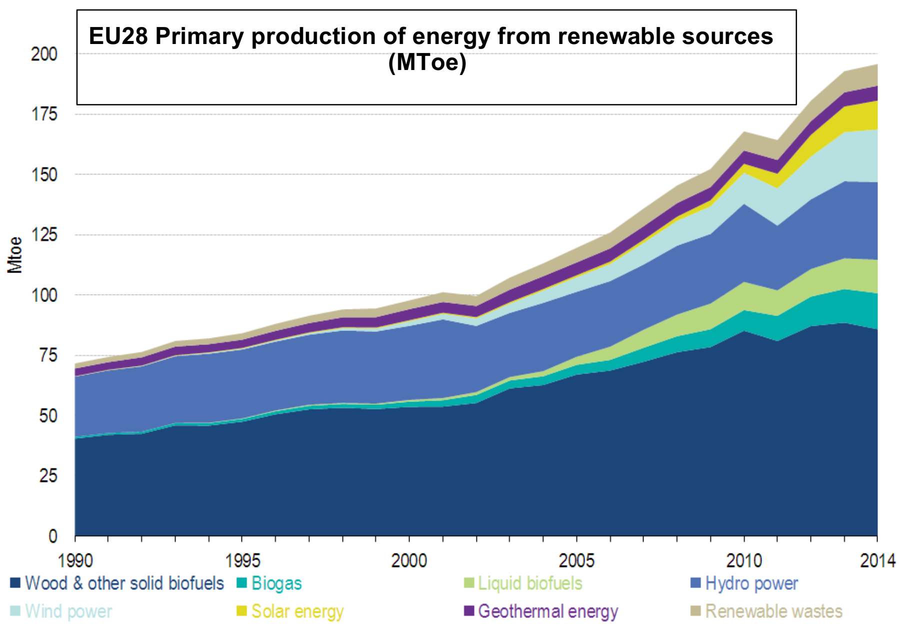


Figure 2-20: EU28 Primary production of Energy from renewable sources in MToe, 1990 . 2014, Source: Eurostat, 2016 (https://epthinktank.eu/2016/06/08/promotion-of-renewable-energy-sources-in-the-eu-eu-policies-and-member-state-approaches/primary-production-of-energy/)

The development of renewable energy within the member states shows big differences. In Figure 2-21 you can see the actual percentage of renewable energy as a % share of gross final energy consumption as of 2013 for selected European countries as well as the target 2020[39] The EU reached 15% in 2013 and 16% in 2014 and is heading to achieve the 20% target in 2020. The Nordic countries have the lead, reaching already 30% (Denmark) or even higher values, as Finland, Sweden, Iceland and Norway, mainly with high percentages in solid biomass. Austria covers already 33% of the gross final energy consumption with renewable energy (details will be shown in Chapter 3), Germany achieving 13,8% (details in Chapter 4).

The 2020 climate and energy package for the EU28 has been casted in legislation and finally is supported with financial subsidies on various levels.

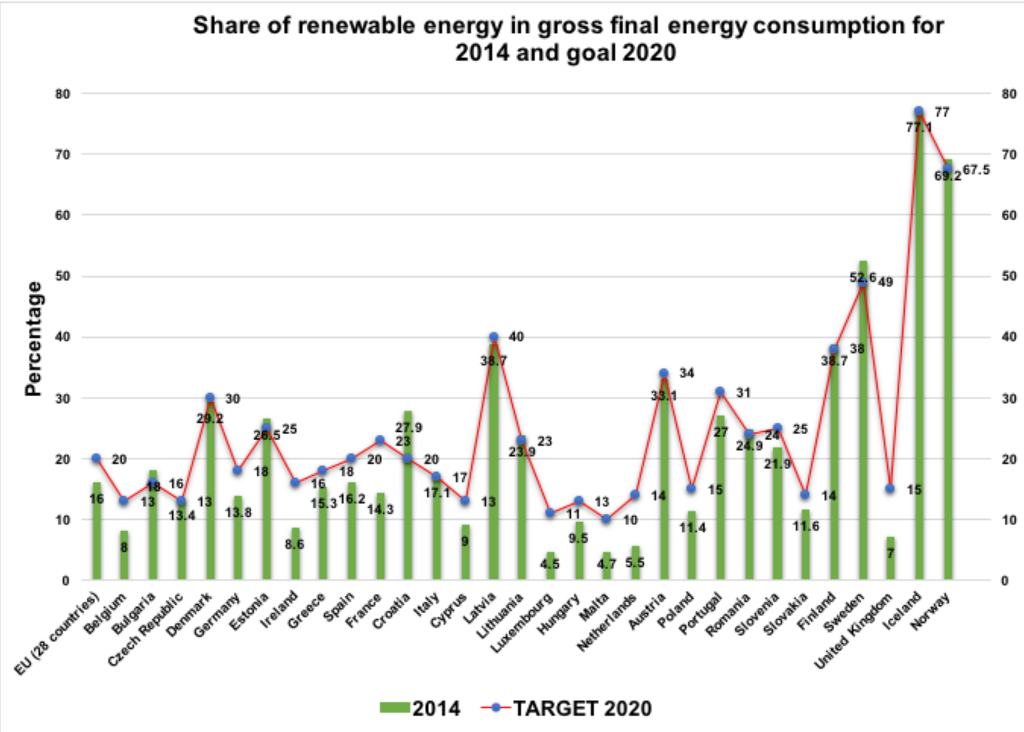


Figure 2-21:Share of renewables in gross final energy consumption in 2014 in selected European countries and the country target share for 2020, Source: Eurostat, http://ec.europa.eu/eurostat/tgm/download.do?tab=table&plugin=1&language=en&pcode=t2020_31, Own graph

2.6 Support of Renewable energy in the EU

The development of renewables has been supported by various programs on EU level as well as national and local level.

The total monetary value of public interventions in energy (excluding transport) in the EU28 has been EUR 113 billion in 2012, covering more than 700 interventions at Member States

[39] (CLEANENERGY WIRE, 2015)

and EU level[40].

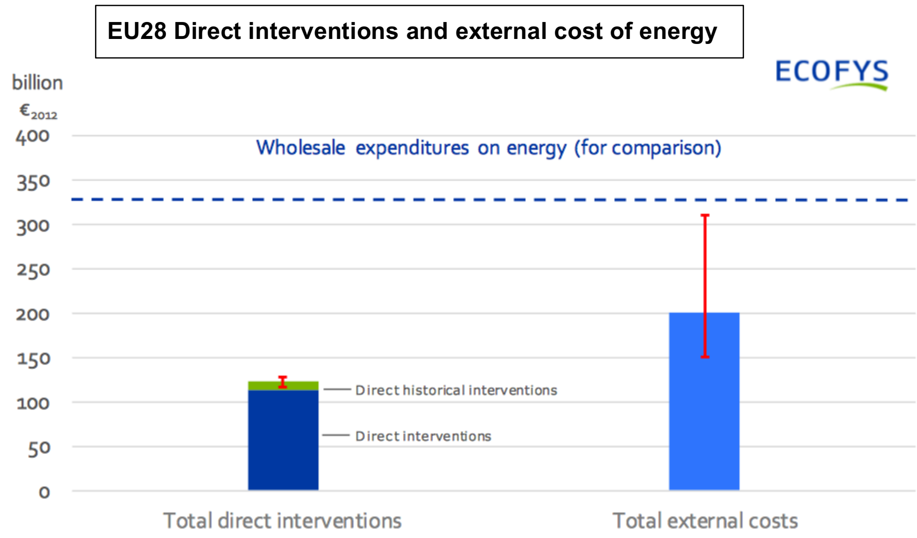


Figure 2-22: EU28 Total direct interventions, external costs and wholesale cost of energy in 2012, Source: Subsidies and costs of EU energy, Ecofys, 2014

The figure 2-22 shows the direct public interventions as well as the external cost not factored into the price as well as the wholesale expenditure on energy. Interventions and subsidies represent EUR 122 billion, external cost are estimated at EUR 200 billion, in total a significant magnitude in the overall expenditure for energy compared to the wholesale cost which reached more than EUR 330 billion in 2012[41].

Base for the increase in renewable energy in Europe is the Renewable Energy Directive (RED). The target of 20% of RES by 2020 is broken down into nationally binding targets for each Member State. Under the Directive various support schemes can be applied:
Direct price support schemes (Feed-in tariffs, premium payments), investment aid, tax refunds, exemptions, reductions, renewable energy obligation support schemes[42].

[40] (European Commission, 2014)
[41] (ECOFYS for the EC, 2014)
[42] (Erbach, 2016)

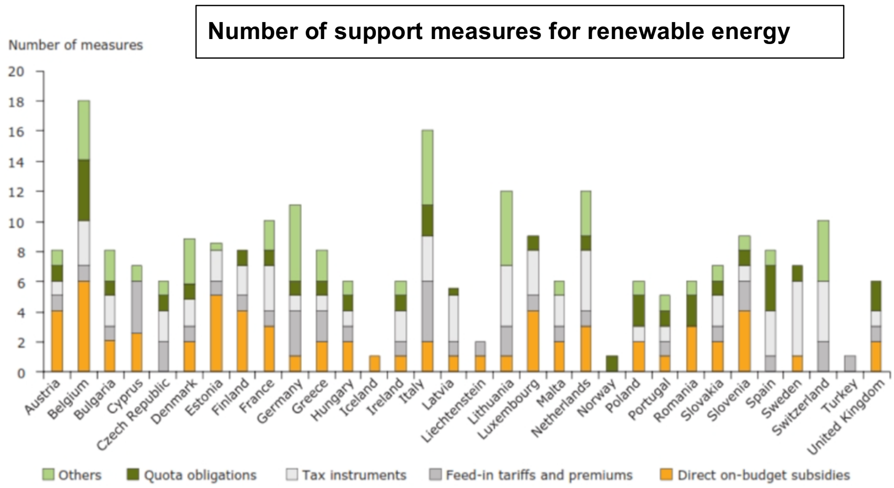


Figure 2-23:Number of support measures for renewable energy in the EU Member States, Source: Erbach Gregor, Promotion of renewable energy sources in the EU, June 2016, p.11

Figure 2-23 shows the number of support measures applied in the EU member states. Direct on budget subsidies are not applied in Czech Republic, Norway and Spain. Feed in tariffs are applied in the majority of countries except Iceland, Norway, Poland, Romania and Sweden.

ENERGY SUBSIDIES/ SUPPORT in 2012 (in Million EUR)

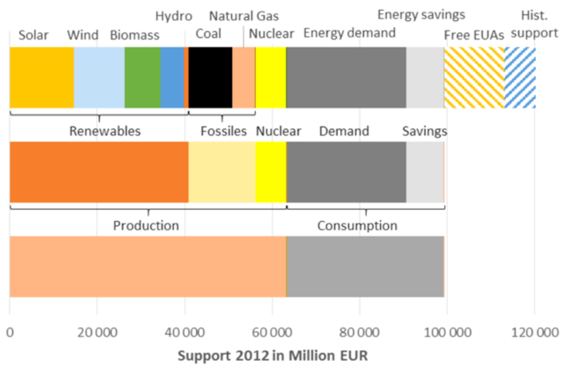


Figure 2-24: EU28 – 2012, Subsidies in the energy sector, Source: Günsberg G. based on Ecofys (2012), http://eeg.tuwien.ac.at/eeg.tuwien.ac.at_pages/events/iewt/iewt2015/uploads/fullpaper/P_252_Bergauer_Bettina_10-Feb-2015_20:56.pdf

The support for energy in the EU28 including free allocations of emission allowances and the current portion of the historical support added up to 120 billion EUR, as shown in Figure 2-24. Support for Renewables represented app. EUR 40 billion[43].

Comparing the subsidies seen above the global investment into green energy is increasing at a fast pace reaching USD 329 billion in 2015, presented in Figure 2-25.

[43] (Bergauer, 2015)

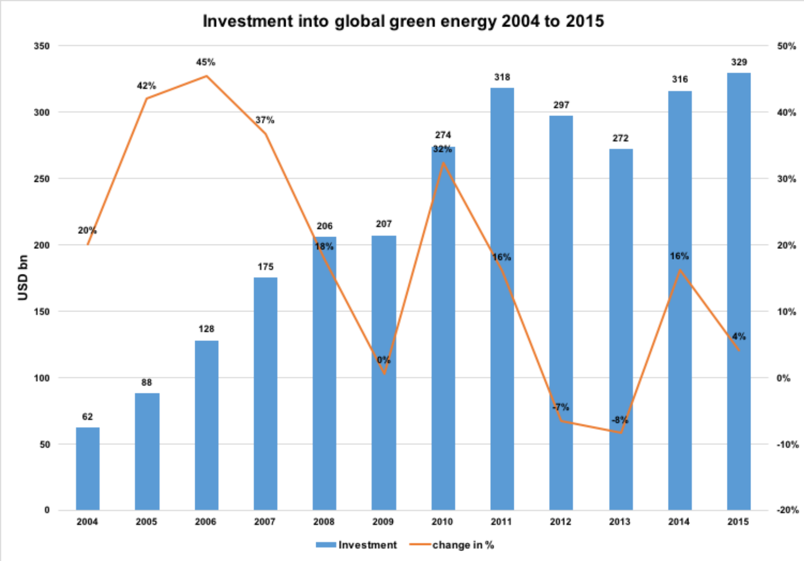


Figure 2-25: Global clean energy investment 2004 – 2015, in USD billions, Source, Bloomberg New Energy Finance, 2016, own graph

2.7 Conclusions

Fossil fuel usage increased tremendously over the last 150 years causing the GHG emissions to grow faster than ever in man´s history. The long lasting doubt about global warming caused by high concentrations of GHG has vanished and international engagement to limit GHG has resulted in the Kyoto protocol aiming at reducing GHG emissions globally. In a joint effort to reach Kyoto targets EU has implemented the EU-ETS as of 2005 and is currently in the third phase aiming to limit CO_2 emissions to a level 20% lower than in 1990, to be reached as of 2020.

The EU-ETS, implemented as a cap and trade systems intended to reduce the GHG emissions in the most cost effective way. The idea behind is that the mitigation or abatement actions which cost less than the certificates would be applied immediately. With reducing the amount of certificates over time, their reduced availability should increase the price of the certificates and more measures to abate CO_2 emissions would be financially attractive to be implemented. Figure 2-26 gives an overview of the key design elements of the EU ETS and the development over time.

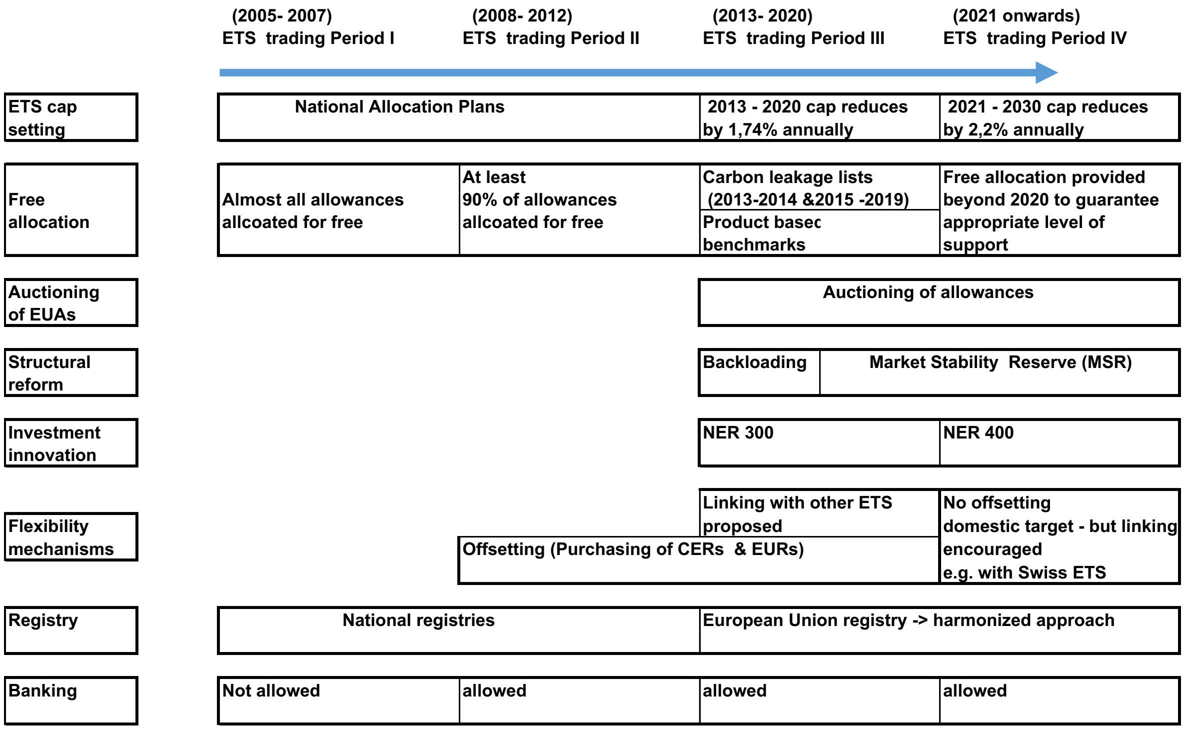


Figure 2-26: Overview of the key design elements of the EU ETS, Source: *(EEA, 2015)*, Annex 1, own summary

Several factors had a detrimental effect on the intended ideal scenario:

1. Over-allocation of allowances from 2005 to 2007 (based on grandfathering)
2. Adding significant amounts of allowances from CDM and JI in phase I 2008 -2012 (as defined in the Kyoto protocol)
3. Global economic crisis starting 2008 and reducing the industrial output significantly. New mechanisms for economic fluctuation and external shocks will be included for the Phase III with backloading and MSR.
4. Auctioning of certificates for electricity producers with high GHG emissions post-poned for EU members joining 2004
5. Free allocation for industrial installations due to carbon leakage -> profits generated within these companies have not been allocated to GHG reduction measures
6. The increase of electricity production with Renewable energy leads to reductions in the CO_2 emissions which is only partially accounted for in the model.
7. External cost has a political and economic dimension, not considered and are ef-fecting global competitiveness, resulting in missing integration. The change of the overall energy system has an impact on all levels of society and will take several generations.

8. Potential losers of the transformation are existing monopolies and oligopolies still connected in strong lobbying/networks and slow down efforts which harm their financial wealth and personal well being.

Measures regarding GHG covered in EU-ETS are well on track to reach the intended level. EU ETS is covering more than 12000 installations and approximately 45% of all GHG emissions in the EU. Even though individual countries will not be able to comply fully, the European Union as a whole will be able to achieve the targets defined for 2020 and 2030.
Measures for segments not included in the EU ETS as there are transportation, heating for private consumers and agriculture will involve behavioral change but also investment into infrastructure (e.g. public transport, isolation of houses, new building standards, loading infrastructure for non fossil fuel cars). As important the implementation of laws to limit emissions might be direct citizen involvement is crucial to make the change happen.

3. Development of GHG emissions in Austria

This chapter will give an overview on the historical development of GHG emissions and future reduction targets for Austria. The development of energy needs as well as the renewable energy status is described as well as the support schemes used for renewable energy. Conclusions including comments on the analyzed measures to reduce CO_2 and GHG and an outlook for the vision 2050 close the chapter.

3.1 Framework for GHG reductions

The targets and their hierarchy are summarized in Figure 3-1 as follows:

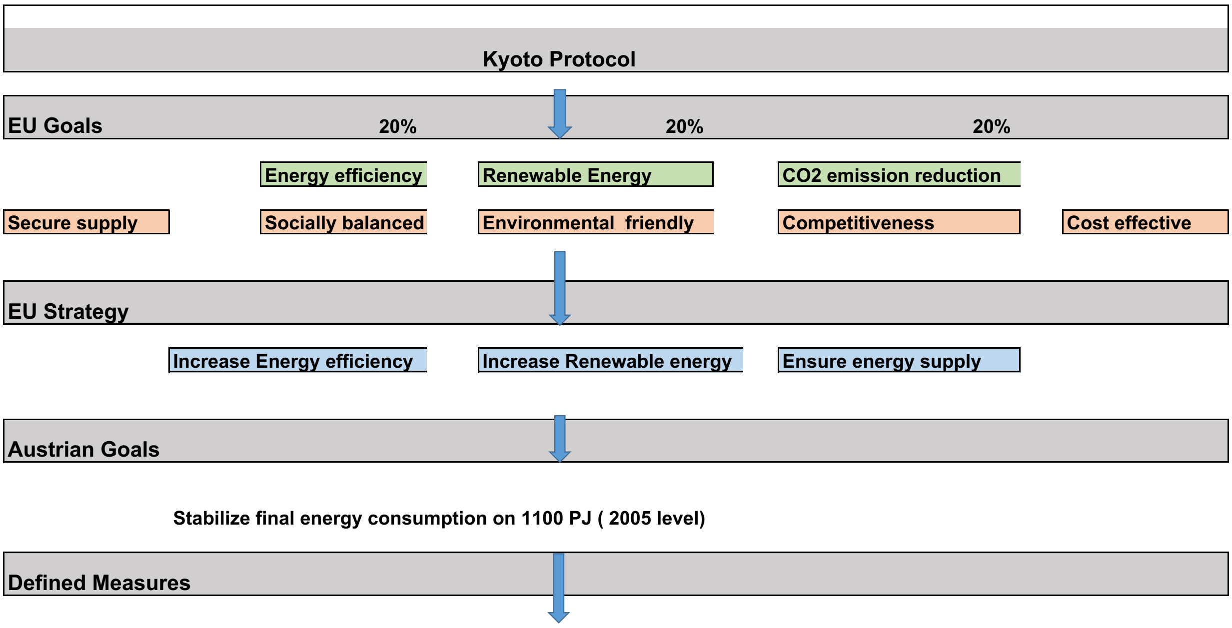


Figure 3-1: Summary of the hierarchy of goals, Source: Energiestrategie Österreich, p.8[44]

EU ratified the UN climate frame convention and committed for the first Kyoto period to an 8% reduction of GHG within the period of 2008 - 2012, compared to base year 1990.
Austria signed the Kyoto protocol in 1992 and ratified it in 2002. Based on the commitment under this agreement Austria accepted a 13% reduction of GHG compared to the base year 1990 for the first Kyoto period 2008 to 2012[45]. This goal has not been achieved.
The EU28 defined reduction goals for CO_2 on an international level and agreed within their member states the distribution on how to achieve this goals. Austria joined the EU in 1995 and

[44] (BMwfj, 2010)
[45] (Lebensministerium, 2013)

is an integral party to the EU 20-20-20 (2020 climate change & energy package) goals, which aim for a CO_2 reduction of 20% compared to 1990, a 20% share of renewable energy in the the net final energy consumption and a 20% energy efficiency improvement by 2020[46].

This 20% reduction of GHG emissions goal is split into two areas:

- Emissions as defined under the EU-ETS are foreseen to be reduced by 21% compared to 2005 -> focusing on big industrial producers as well as on energy industry.
- Non EU-ETS emissions for all EU member states have to be reduced by 10% compared to 2005 and are split between member states according to their individual capabilities -> based on the effort sharing decision[47]
  - for Austria the target is defined with a 16% reduction compared to 2005.

The EU 2020 reduction target foresees in the current Phase III a linear reduction of GHG per year starting from 2013 with 1,74% reduction per year, this pace continuing up to 2020. In Phase IV of the EU-ETS a steeper reduction of 2,2% per year is foreseen[48].

The EU goals aim at energy efficiency, increase of renewable energy and finally at reducing CO_2 emissions. At the same time, it is important to ensure the energy supply at affordable prices, socially balanced and environmentally friendly. In order to keep keep the competitiveness of the European economy all measures need to be implemented in a cost effective way.

For Austria as a results the net energy consumption is targeted at the 2005 level of 1100 PJ in 2020.

As you can see below in Figure 3-2, the development of GHG emissions in Austria did not reach the 13% reduction target for Austria, as originally committed under the Kyoto Protocol and the EU target for the period 2008 to 2012[49]. In 2014 Austria managed emitting 2 Mio tons lower GHG emissions than 1990, reaching 76,3 Mio t.

46 (European Commission, 2014)
47 (European Comission, 2016)
48 (European Commission, 2014)
49 (bmlfuw, 2014)

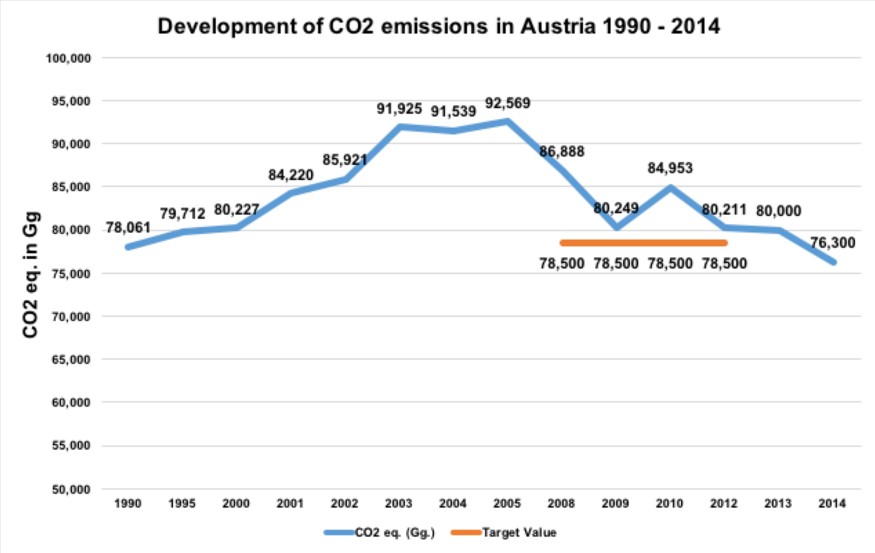


Figure 3-2: Development of GHG emissions in Austria and the Kyoto goal, Umweltbundesamt, Klimaschutzbericht 2015, Umweltbundesamt 2016, own graph

In Table 4 the cumulative result for the GHG emissions for Austria between 2008 and 2012 can be seen. Development in forestry reduced the emission balance by 6,8 Mio tons, the emissions for companies which received allowances were higher by 5 Mio.

Table 4: Kyoto CO2 emissions target and actual results 2008 – 2012, Source: Umweltbundesamt 2013, own summary

Kyoto - balance in Mio t CO2 eq.	2008	2009	2010	2011	2012	Kyoto-Period 2008 - 2012
Total Emissions	86,9	80,1	84,8	82,8	80,1	414,7
Balance from new forrests and deforrestation	-0,9	-1,4	-1,5	-1,5	-1,5	-6,8
EU ETS Installations	-1,2	3,5	0,0	0,3	2,5	5,1
Amount of flexible instruments	-16,0	-13,4	-14,5	-12,8	-12,3	-69,0
Kyoto goal 2008 - 2012	68,8	68,8	68,8	68,8	68,8	344,0

The overshooting of the Kyoto target had to be compensated with 69 Mio allowances purchased. Cost for the Austrian state budget of 500 EUR Mio had been reported[50].

In the following Table 5 the GHG emissions are split in the individual sectors, dominated by the sector Energy & Industry.

[50] (APA, 2014)

Table 5: Austria's greenhouse gas emissions by sector in the base year (1990) and in 2014 as well as their share and trend, Source: Umweltbundesamt 2016, own summary

GHG	1990	2014	Trend 1990 - 2014	1990	2014
	Emissions (Mio t CO2e)			Share (%)	
Total	**78,85**	**76,33**	**-3,2%**	**100,0%**	**100,0%**
Energy & Industry	36,55	33,91	-7,2%	46,4%	44,4%
Transport	13,79	21,73	57,6%	17,5%	28,5%
Buildings	13,13	7,60	-42,1%	16,7%	10,0%
Agriculture	9,44	7,97	-15,6%	12,0%	10,4%
Fluorized gases	1,66	2,02	21,7%	2,1%	2,6%
Waste	4,28	3,10	-27,6%	5,4%	4,1%

GHG emissions from Energy & Industry represent 46,4% in 1990 and 44,4% in 2014, and are mainly covered within the EU-ETS. Transport has increased 57,6% over that period. After a steep increase in the development till 2009, a decrease started over the last 6 years. This sector will need highest attention and effective reduction measures.

The following Table 6 is further detailing the CO_2 emissions into subsectors.

Table 6: CO2 Emissions Austria 1990, 2005, 2012 for all sectors including LULUF and Memo Items, Source Environment Agency Austria, 2014, own summary

Emission Trends CO2 Austria

	1990 in (000) tons	in %	2005 in (000) ton	in %	2012 in (000) ton	in %
TOTAL CO2 emissions incl LULUF	62.692		90.109		91.143	
incl. Memo items						
1. Energy	54.171		70.484		58.689	
Fuel Combustion (Sectoral Approach)	54.069	100%	70.279	100%	58.452	100%
1 Energy Industries	13.792	26%	16.223	23%	12.325	21%
2 Manufacturing Industr and Construction	12.685	23%	16.161	23%	15.565	27%
3 Transport	13.771	25%	24.675	35%	21.418	37%
4 Other Sectors	13.785	25%	13.177	19%	9.097	16%
5 Other Sectors	35		43		47	
Fugitive Emsissions from Fuels	102		205		237	
1 Solid Fuels	-		-		-	
2 Oil& Natural Gas	102		205		237	
2. Industrial Processes	7.540		8.682		9.007	
A Mineral Products	3.274		3.132		2.946	
B Chemical Industry	541		535		587	
C Metal Production	3.725		5.015		5.474	
3. Solvent and Other Product Use	279		213		189	
4. Agriculture						
5. Land Use, LUCaF	- 9.898		- 7.645		- 3.865	
6. Waste	27		12		27	
7. Other						
Memo Items						
International Bunkers	924		2.022		2.118	
CO2 Emissions from Biomass	9.928		16.554		25.167	

Energy Industries reduced their CO_2 emissions by almost 1,4 Mio tons between 1990 and 2012, peaking in 2005 at 16,2 Mio tons. Manufacturing Industries and Construction increased by 3 Mio tons of CO_2 between 1990 and 2012. Transport had the steepest increase for this period namely 7,7 Mio tons, increasing 55% compared to 1990. Other sectors reduced by more than 4,7 Mio tons[51].

The memo items show International Bunkers and emissions from biomass, nearly tripling since 1990. CO_2 emissions from biomass are not accounted for under the European legislation and biomass is considered renewable energy, representing two thirds of renewable energy in the EU28[52]. Looking at this significant number it is important to monitor the sustainability of future increased usage of biomass.

3.2 Development of economic growth, energy consumption and GHG

This section will focus on the development of energy in Austria as well as the composition of energy in fossil as well as renewable energy over the time period 1990 till 2013.

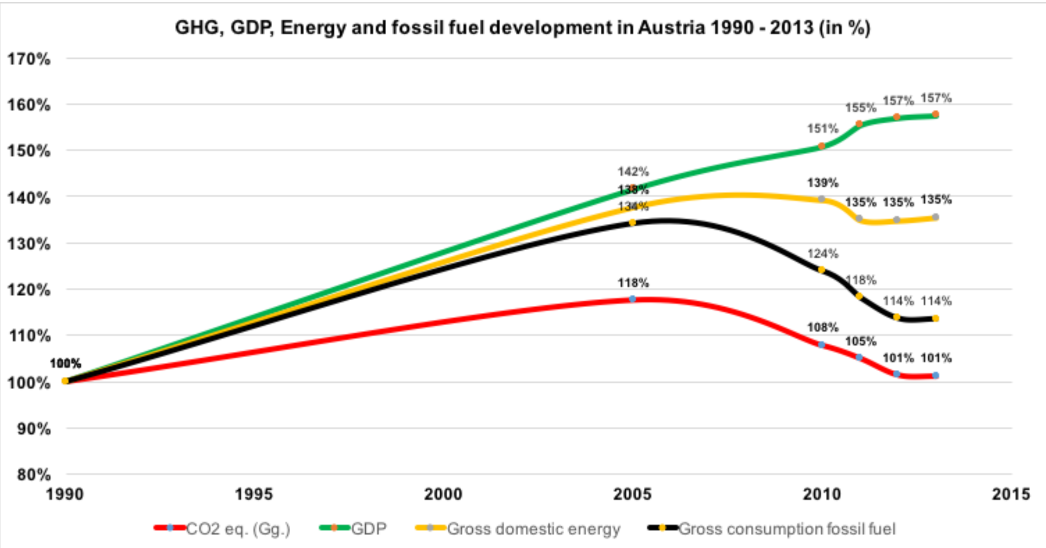


Figure 3-3: GHG emissions compared to GDP, Gross energy consumption of fossil fuels, 1990 - 2013, Source Umweltbundesamt (2015a), Statistik Austria (2014a,b), own graph

For developed economies energy consumption is strongly linked to the GDP development. Also for Austria this is confirmed in the Figure 3-3 shown above. Only in the recent years a decoupling is taking place. Between 2010 and 2013 GDP increases while the Gross domestic energy consumption stabilizes. The usage of fossil fuels has decreased over this period,

[51] (Environment Agency Austria / Umweltbundesamt, 2016)
[52] (Bourguignon, 2015)

since renewable energies could provide a higher share of energy. This is clearly reflected in a downward trend in the GHG emissions.

Table 7 below is showing the absolute values of GHG emissions of domestic energy consumption, fossil energy carriers used to produce energy and the GDP between 1990 and 2014.

Table 7 : Influence of Gross domestic energy consumption, gross domestic fossil fuel consumption and GDP on the GHG emissions in Austria from 1990 to 2014, Source: Umweltbundesamt 2016), own summary

Year	GHG emissions (Mio t CO2e)	Gross domestic energy consumption (PJ)	Gross domestic fossil fuels (PJ)	GDP (bn EUR)
1990	78,8	1.052	835	195
2005	92,8	1.449	1.120	276
2010	84,9	1.465	1.031	295
2014	76,3	1.381	901	307
1990 - 2014	**-3,20%**	**31,20%**	**8,00%**	**57,70%**

It can be concluded that as of 2014 GDP improved by 57,7% compared to 1990, with an energy increase of 31,2%[53]. Fossil fuel was partially replaced by renewable (but also by imports of electricity). This results finally in a reduction of GHG towards 76,3 Mio t or 3,2 % below 1990 levels. The upcoming challenge is a further reduction of CO_2 by 2020.

Table 8: Austria - Gross domestic energy consumption 1990 to 2013, by fuel, Source: *(Bundesministerium für Wissenschaft, Forschung und Wirtschaft, 2015)*, bmwfw, Energiestatus Österreich 2016, own summary

Gross domestic energy consumption Austria													
Year	Coal PJ	%	Fuel PJ	%	Gas PJ	%	Hydro PJ	%	Oth. Ren. Energy PJ	%	Burnable Waste PJ	%	TOTAL PJ
1990	171,5	16,3%	443,9	42,2%	219,2	20,8%	111,8	10,6%	97,7	9,3%	8,1	0,8%	1052,2
2000	152,9	12,5%	513,1	41,9%	275,7	22,5%	145,7	11,9%	126,6	10,3%	10,5	0,9%	1224,5
2005	167,7	11,6%	610,8	42,2%	341,6	23,6%	141,6	9,8%	170,9	11,8%	16,4	1,1%	1449
2010	141,5	9,7%	548,6	37,4%	343,9	23,5%	146,5	10,0%	256,2	17,5%	28,4	1,9%	1465,1
2013	138,4	9,7%	515,6	36,2%	293,6	20,6%	177,3	12,4%	273,3	19,2%	26,7	1,9%	1424,9
2014	129,4	9,4%	508,3	36,8%	271,6	19,7%	173,05	12,5%	269,3	19,5%	29,2	2,1%	1380,8

Table 8 above, gives an overview on how the gross domestic energy consumption increased from 1052 PJ in 1990 to 1381 PJ in 2014. The share of fossil fuel decreased from 80% in 1990

53 (Environment Agency Austria / Umweltbundesamt, 2016)

to 65,9% in 2014. With the increase of energy a significant rise of renewable energy through expansion investments took place as well[54].

Between Gross domestic energy consumption and Final net energy consumption more than one third transformation losses and distribution losses occurred in 1990.

The final net energy consumption developed from 766 PJ in 1990 to 1119 PJ in 2013[55].

In the following chapter the split of energy consumption by sectors and final consumers will be analyzed.

3.3. Analysis of the sectors and their GHG development

In 1990 71% of GHG have been related to energy consumption, in 2012 this increased to 74,6%, as shown in Table 9. Industry related GHG emissions rose in average 8,7% to 10,8 Mio tons of CO_2 eq[56].

Table 9: GHG emissions 1990 and 2012, trend in % as well as the relative share in %., Source: *(Bundesministerium für Wissenschaft, Forschung und Wirtschaft, 2015)*, own summary

GHG	1990	2012	Trend 1990 - 2012	1990	2012
	Emissions (Gg CO2e)			Share (%)	
Total	**78.061**	**80.211**	**2,8%**	**100,0%**	**100,0%**
1 Energy	**55.400**	**59.843**	**8,0%**	**71,0%**	**74,6%**
2 Industry	**10.005**	**10.877**	**8,7%**	**12,8%**	**13,6%**
3 Solvent	**512**	**335**	**-34,6%**	**0,7%**	**0,4%**
4 Agriculture	**8.557**	**7.499**	**-12,4%**	**11,0%**	**9,3%**
5 LULUCF	**-9877**	**-3840**	**-61,1%**	**-**	**-**
6 Waste	**3.587**	**1.657**	**-53,8%**	**4,6%**	**2,1%**

Total emissions without emissions from LULUCF

[54] (Bundesministerium für Wissenschaft, Forschung und Wirtschaft, 2015)
[55] (Bundesministerium für Wissenschaft, Forschung und Wirtschaft, 2015)
[56] (Bundesministerium für Wissenschaft, Forschung und Wirtschaft, 2015)

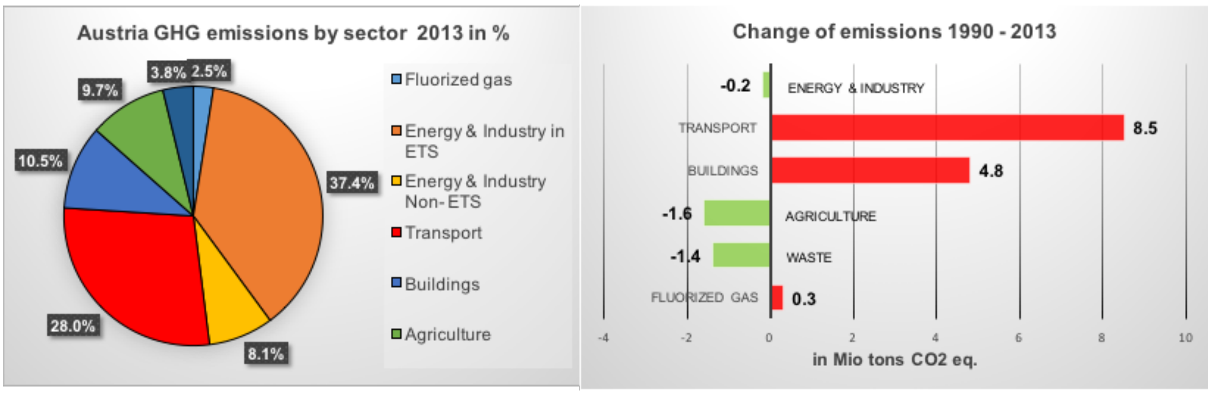


Figure 3-4: Austria, GHG emissions by sectors in 2013 in % , Change of emissions 1990 to 2013 in Mio t CO2 eq, Source: Umweltbundesamt, Klimaschutzbericht 2015, own graph

Figure 3-4 shows the development in the change of emissions for the individual sectors in Austria between 1990 and 2013. Transport increased with 8,5 Mio tons, buildings by 4,8 Mio and fluorized gases by 0,3 Mio t. Reductions could be achieved in energy & industry, agriculture and waste, with a total 3,2 Mio t[57].

In the Table 10 below the absolute values for GHG emissions per sector are visible.

Table 10: GHG emissions 2005 to 2013 an target for 2020, by sector, CO2 eq. in Mio t, Source: Umweltbundesamt 2015a, KSG (BGBl.) I Nr. 128/2015, own summary

	GHG Inventory in Mio t CO2eq.				Target	Target
Sector	2005	2010	2012	2013	2020	2030
Energy & Industry - no	6,5	6,7	6,8	6,4	6,5	
Transport	24,6	22,1	21,2	22,2	21,7	
Buildings	12,6	10,5	8,7	8,3	7,9	
Agriculture	8,0	7,8	7,7	7,7	7,9	
Waste	3,2	3,1	3,1	3,0	2,7	
Fluorized gases	1,8	1,9	2,0	2,0	2,1	
TOTAL non ETS	56,6	52,0	49,5	49,7	48,8	39,9
Total Austria	92,5	84,8	79,8	79,6	77,8	61,1

The targets for 2030 as described in Table 10 have been communicated in July 2016[58]. Acknowledging, that Austria is currently slightly below the 1990 level of GHG emissions, intensified efforts will be needed to reach this targets.

[57] (Environmental Agency of Austria, 2015)
[58] (DerStandard, 2016)

3.3.1 Energy consumption by sectors and final consumers

Gross energy consumption in Austria increased from 1052 PJ in 1990 to 1380,8 PJ in 2014 as summarized in Table 11 below. Starting from a 20,7% share of renewables in 1990 the overall increase of renewables resulted in 33,0% in 2014.

Table 11: Austria, Gross Energy Consumption, 1990 – 2013, Renewable Energy in PJ and in %, Source: (Bundesministerium für Wissenschaft, Forschung und Wirtschaft, 2015), bmwfw: Energiestatus Österreich 2016, own compilation

Gross energy consumption Aus						Net energy consumption Austria											
Year	Fossil PJ	in %	Renewable PJ	in %	TOTAL PJ	Production PJ	in %	Transport PJ	in %	Services PJ	in %	Households PJ	in %	Agriculture PJ	in %	TOTAL PJ
1990	843,1	80%	209,1	20%	1052,2	216,6	28%	208,8	27%	73,1	10%	243,5	32%	24,5	3%	766,5
2000	945,6	77%	278,9	23%	1224,5	253,6	27%	292,7	31%	113,2	12%	259,6	28%	22,2	2%	941,3
2005	1144,0	79%	305,0	21%	1449,0	303,0	27%	379,3	34%	124,7	11%	281,0	25%	22,9	2%	1110,9
2010	1088,0	74%	377,6	26%	1465,6	329,5	29%	366,6	32%	128,2	11%	286,8	25%	23,5	2%	1134,6
2013	1022,5	72%	402,4	28%	1424,9	335,7	30%	370,3	33%	111,4	10%	278,2	25%	23,7	2%	1119,3
2014	981,7	71%	399,1	29%	1380,8	332	31%	365,49	34%	108,95	10%	242,03	23%	22,61	2%	1071,1
2020														Goal		1100,0

Table 11 confirms that in 2014 transport triggered the highest energy consumption, reaching 365,5PJ, which is based more than 90% on fossil fuels, followed by production[59], compared to the situation in 1990 when private households had with 32% the biggest share of net energy consumption.

Looking at the distribution of the energy in final purpose, more than 365PJ are consumed for transport/ 330PJ for heating and hot water, more than 90PJ for steam production/ electricity, 150 PJ for industrial heat, 120 PJ for fixed motors and 30PJ for lighting and IT[60].

For 2020 the goal is to reach 1100 PJ[61] net energy consumption for Austria. This target could be achieved in 2014 first time after 2005.

[59] (Bundesministerium für Wissenschaft, Forschung und Wirtschaft, 2015)
[60] (Bundesministerium für Wissenschaft, Forschung und Wirtschaft, 2015)
[61] (bmwfw, 2010)

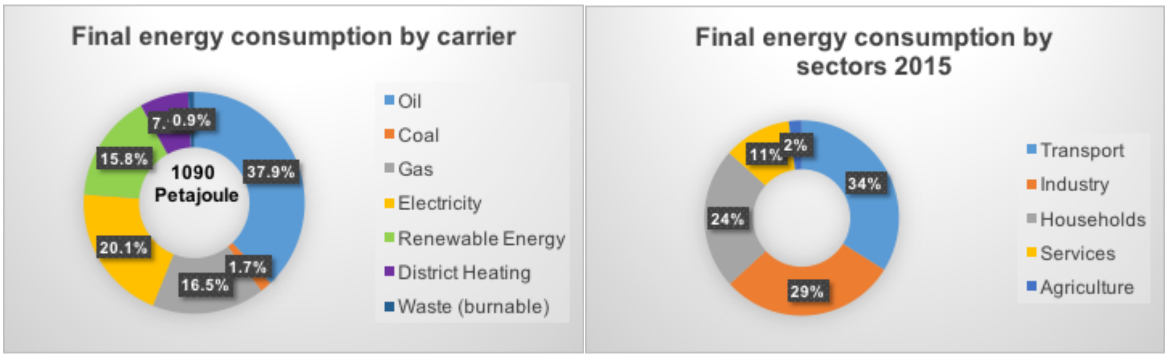


Figure 3-5: Final energy consumption by sectors in Austria 2015, APA, Statistik Austria , own graph

As can be seen in the figure 3-5 transport sector consumed 34% of final energy in 2015, which is more than 90% from petrol and other fossil sources. Renewable energy made up 15,8% and electricity 20,1%. As 79,1% of electricity are produced in renewable way, the total renewable portion for Austria reached 33% of final energy consumption.

The goal for 2020 is defined with 34%, which will be executed with a very high probability by that time.

Figure 3-6 shows the electricity production between 1990 and 2013, which increased from 49TWh to 68TWh[62]. In 2013 14,2 TWh representing 21% of final energy consumed, have been produced with fossil fuel, the bigger share 79% has come from hydro and renewable energy.

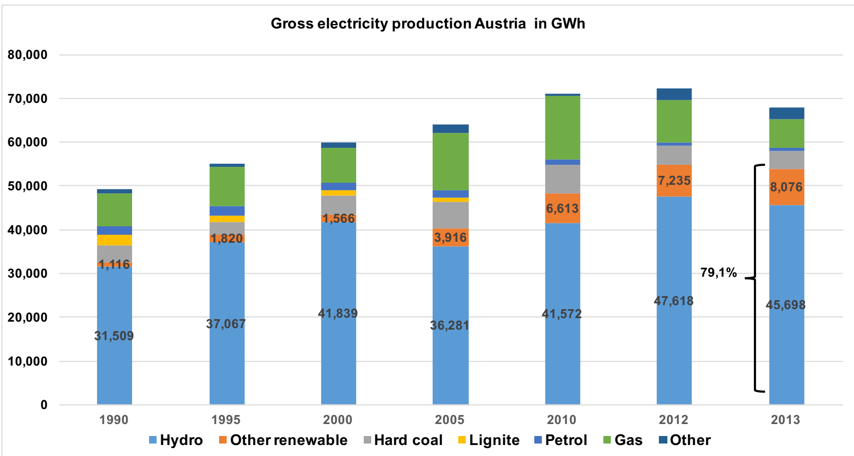


Figure 3-6: Gross electricity production Austria by energy carrier 1990 – 2013 in GWh, Source: (Bundesministerium für Wissenschaft, Forschung und Wirtschaft, 2015), own graph

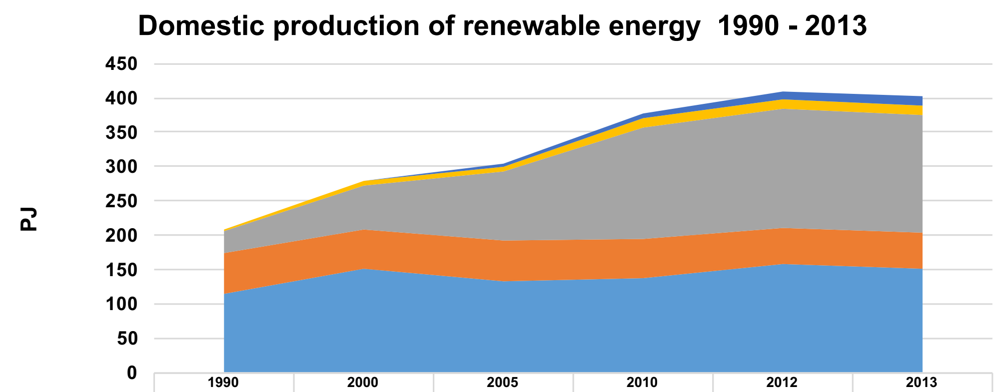
In the following chapter the development of renewable energy in Austria is described.

62 (Bundesministerium für Wissenschaft, Forschung und Wirtschaft, 2015)

3.4. Development of RES in Austria

Due to its geographic location and its natural wealth biomass from wood, as well as hydro energy from its rivers play an important role in Austria´s ecosystem. The engineering and innovation capabilities of Austrian inventors like Viktor Kaplan[63] led to the successful increased usage of rivers for electricity production in the beginning of the 20th century.

In regards to renewables, the burning of wood and burnable waste mainly for heat complemented the energy production needed.



	1990	2000	2005	2010	2012	2013
Wind/PV	0	0.3	4.9	7.7	10.1	13.4
Other renewables	2.1	5.9	7.5	12.7	14.4	15.1
Biofuel	32.2	63.5	100.3	162	174.1	171.4
Wood	61.4	58.6	60.3	57.1	52.8	51.4
Hydro	113.4	150.6	132	138.1	157.7	151.1

Figure 3-7: Austria, Domestic production of renewable energy 1990 – 2013, Source: (Bundesministerium für Wissenschaft, Forschung und Wirtschaft, 2015), own graph

Figure 3-7 shows that renewable energy between 1990 and 2013 nearly doubled from 209PJ to 401PJ. Wood, burnable waste, hydro power and biofuels are dominating that development. Wind, solar energy and heat pumps are still building up their potential[64].

2014 domestic production of renewable energy stayed almost on the same level as 2013, falling from 401 PJ to 399 PJ[65].

Table 12 below is showing the development of the gross domestic energy consumption between 1990 and 2013 as well as the split between fossil and renewable energy. The total amount reached 1380,8 PJ in 2014.

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[63] (austria-forum.org/af/Wissenssammlungen/Biographien/Kaplan,_Viktor, 2013)
[64] (Bointner et al, 2013)
[65] (Statistik Austria, 2016)

Table 12: Austria, Gross Energy Consumption, 1990 – 2013, Renewable Energy in PJ and in %, Source: (Bundesministerium für Wissenschaft, Forschung und Wirtschaft, 2015), Statistik Austria 2016, own summary

Gross energy consumption Austria					
Year	Fossil PJ	in %	Renewable PJ	in %	TOTAL PJ
1990	843,1	80%	209,1	20%	1052,2
2000	945,6	77%	278,9	23%	1224,5
2005	1144,0	79%	305,0	21%	1449,0
2010	1088,0	74%	377,6	26%	1465,6
2013	1022,5	72%	402,4	28%	1424,9
2014	981,7	71%	399,1	29%	1380,8

An important fact is that 90% of energy is imported. More than 8,5% of the value of net imported goods to Austria is related to fossil fuel. In 2013 this represented EUR 11,4 billion[66] . Gross energy consumption from renewable energy reached 402,4 PJ -> 28%.

The EU Renewable Energy Directive 2009/28/EG defined for all EU28 member states goals for renewable energy as part of final energy.
Austria targets a share of 34% by 2020. It can be expected that this goal will be overachieved.

Investments into proven technologies as well into new technologies have been done over the last 30 years. In the following Table 13 the development of the individual renewable energy carriers and the percentage of REN in electricity, transport as well as heating & cooling for 2012 can be seen. For electricity 70%, for transport 8,9% and for heating& cooling 32,6% had been achieved in 2014. It is obvious that transport is the sector needing most attention for future improvements.

[66] (Bundesministerium für Wissenschaft, Forschung und Wirtschaft, 2015)

Table 13: Renewable Energy for electricity, transport and heating6 cooling in Austria 2014 in ktoe and in %, Source:EC-Eurostat, 16.01.2015, http://ec.europa.eu/eurostat/web/energy/data/shares, own summary

	2014
Renewable Electricty	**in ktoe**
Hydro	3.499
Wind	329
Solar	68
Solid biofuels	296
All other REN	78
TOTAL	**4.268**
Electricity generation from all sources	**6.094**
RES E (in %)	**70,0%**
Renewables in transport	
Ren. electricity in road transport	0,8
Non-Ren. electricity in road transport	0,4
Ren. electricity in rail transport	114,7
Non-Ren. electricity in rail transport	57,8
Ren. electricity in all other transport modes	57,0
Non-Ren. electricity in all other transport modes	28,7
Compliant biofuels*	531,9
of which Article 21(2)	0,0
Other renewable energies	0,0
Total (RES-T numerator)	**705,6**
* In period 2004-2010 all consumed biofuels are included in this category; as of 2011 only those compliant with Articles 17 and 18 of Directive 2009/28/EC.	
Fuel used in transport (as defined in Article 3)	
Total (RES-T denominator)	**7.919,0**
Note: Total numerator and total denominator include multiplier 2.5 for electricity in road transport and multiplier 2 for Article 21(2)	
RES-T [%]	**8,91%**
Renewables in heating and cooling	
Final energy consumption	3.240,0
Derived heat	864,0
Heat pumps	169,9
Total (RES-H&C numerator)	**4.274,0**
All fuel consumed for heating and cooling	
Total (RES-H&C denominator)	**13.092,5**
Note: total includes all elements of "gross final consumption of energy" other than electricity and for other pruposes than transport	
RES-H&C [%]	**32,64%**
Total (RES numerator)	**9.074,3**
Article 2 (f): Gross final consumption of energy	
GFCoE	27.269,8
Article 5 (6): Aviation adjustment	
Total before adjustment	27.439,7
Total (RES denominator)	**27.439,7**
RES [%]	**33,07%**
Target 2020	**34%**

3.5. Overview of the support for energy in Austria

The overarching goal for energy is to be sufficiently available, reliably accessible and afforda-ble. This has been and is the premise for industrial growth as well as development of wealth. Energy has been provided for centrally and support and subsidies have been put in place to allow to fulfill the above mentioned goal.

Subsidies for energy can be split into:

- Monetary subsidies/ tax breaks
- State spending for research and development

- External cost not represented in the market price for energy (health damages or environmental damages)

The following pages will describe the subsidies for renewable electricity, renewable heat, energy efficiency and biofuels as well as subsidies for research and innovation.

3.5.1. Subsidies for renewable electricity

Subsidies for renewable energy are based on the Green Electricity Act 2012 (Ökostromgesetz 2012) . They can be divided into:

- Investment subsidies
- Feed in tariff
- Tax reductions and tax exemptions.

The Green Electricity Act defines:
Mandatory takeover for electricity from renewable energy, based on legally defined FIT (feed in tariffs) by the green power settlement agent (OeMAG), limited by the yearly allocated subsidies. Subsidies of 50 Mio/year starting as of 2013 have been agreed, to be reduced by 1 Mio per year over the next 10 years[67].

For the renewable electricity the merit order principle applies. As described in Figure 3-9, the energy carrier with the lowest price will be first in delivering to the network, followed by the next higher variable cost of the energy carrier as long as the total demand is not covered. The last added energy carrier defines the market price for this procedure. As is shown in the Figure 3-8, by adding renewable energy with low/ zero variable cost the overall market price for electricity has been driven down, as more renewable electricity was available for the grid.

If there are lower amounts of renewable energy available, the market price is higher again.

[67] (Federal State of Austria, 2013)

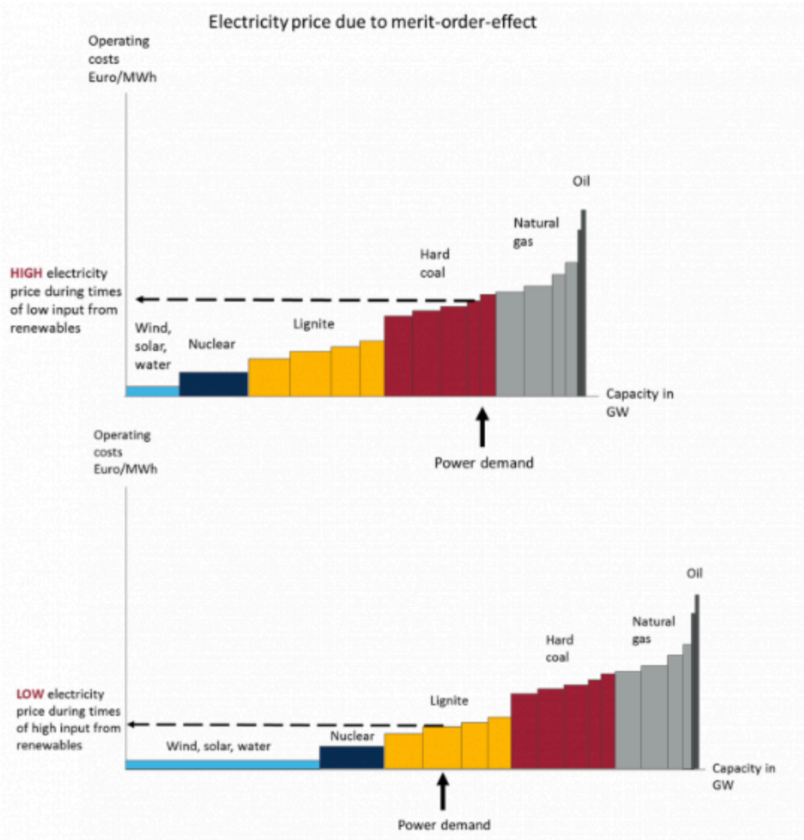

Figure 3-8: Explanation of the merit order principle, Source: https://www.cleanenergywire.org/factsheets/setting-power-price-merit-order-effect

Table 14 shows the investment subsidies for renewable energy sources producing electricity in line with the Green energy law 2012. Starting with EUR 50 Mio, this amount will be reduced every year by EUR 1 Mio. The split gives highest priority to investments in wind energy, second highest to biomass.

Table 14: Subsidies according to the Green Energy law for new installations 2013 to 2023 in Mio EUR, per type of renewable energy source, ÖSG2012, 30.07.2016, own summary

Subsidies for new installations on renewable energy in EUR Mio.											
	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Wind (min)	11,5	11,5	11,5	11,5	11,5	11,5	11,5	11,5	11,5	11,5	11,5
PV	1,8	1,8	1,8	1,8	1,8	1,8	1,8	1,8	1,8	1,8	1,8
Biomass	10	10	10	10	10	10	10	10	10	10	10
Hydropower (min)	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5
Other	19	18	17	16	15	14	13	12	11	10	9
not defined	6,2	6,2	6,2	6,2	6,2	6,2	6,2	6,2	6,2	6,2	6,2
TOTAL	50	49	48	47	46	45	44	43	42	41	40

In addition to this subsidies, which are granted on a first come, first serve basis and have to be published daily on the OeMAG webpage[68] FIT (feed in tariffs) are in place.

This FIT (feed in tariffs) are granted for 15 years in case of renewable sources from raw materials (wood, pellets) and 13 years for PV and wind. The prices are valid for installations granted in 2016 at 9,04 cents/kWh for wind and will be reduced by 1% each following year.

The system is financed by the final electricity consumers. Low income households have a maximum amount of EUR 20/ year, whereas the average customer will pay 103 EUR/ year in 2016[69]. Figure 3-9 shows the development of feed in tariffs from 2003 to 2013[70].

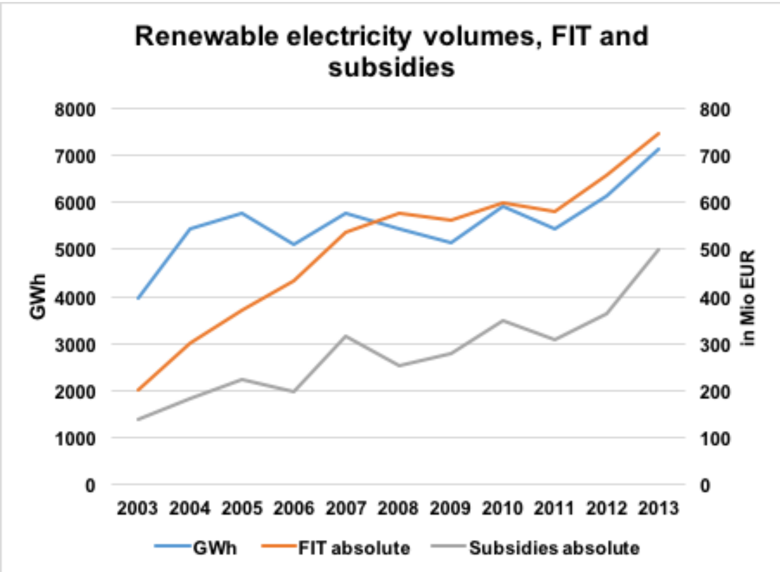

Figure 3-9:Development of renewable electricity volumes and feed in tariffs allocated as well as investment subsidies 2003 to 2012

As shown above, in 2003 4000 GWh of renewable electricity have been supported with EUR 150 Mio in investment and EUR 200 Mio in FIT (average 20 cent/kWh), changing to 7140GWh and EUR 747Mio. For 2014 this increased to 8200 GWh and EUR 846 Mio in FIT (average 10,3 cent/kWh).[71]

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68 (OeMAG, 2016)
69 (AK Wien, 2016)
70 (Energie-Control Austria, 2014)
71 (Energie-Control Austria, 2015)

The percentage of renewable electricity compared to total final consumption between 2003 and 2014, increased from 7,8% to 14,5% over that time period. In absolute GWh it more than doubled from 4000 GWh to 8200 GWh over 11 years[72].

Table 15: Development of support for renewable electricity from 2005 to 2015, Source OeMAG, ÖkoBGV, E Control, own summary

AUSTRIA: Development of support for renewable electricity (in EUR Mio)												
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2005 - 2015
Energy carrier												
Wind	75	71	74	42	49	78	56	83	154	248	320	1.250
Biomass solid	43	87	156	142	160	184	171	179	196	195	222	1.735
Biogas	25	32	51	61	60	63	58	68	65	77	86	646
Biomass liquid	3	5	10	4	3	3	1	-	1	-	-	30
PV	8	8	8	9	11	13	17	32	67	82	86	341
Other REN electrcity	2	1	3	1	1	2	1	-	1	-	1	13
Total REN electrcity	156	204	302	259	284	343	304	362	484	602	715	4.015
Small hydro power plants (OEMAG)	67	- 7	12	- 7	- 4	7	4	1	16	30	36	155
TOTAL support REN electricity	223	197	314	252	280	350	308	363	500	632	751	4.170
Market price cent/kWh	3,79	5,21	5,11	6,43	5,91	4,58	5,35	5,21	4,51	3,68	3,42	

Table 15 shows the development of support for renewable electricity from 2005 to 2014 and an estimate for 2015. More than EUR 4 bn have been funded over that time period, 40% for solid biomass, 30% for wind, 15% for biogas and 8% for PV[73].

The following Figure 3-10 gives an overview on the development of the FIT for the different renewable sources compared with the market price. The FIT for PV reflects the cost reduction in panels but is still high above FIT for wind energy. In comparison to that small hydropower is close to the market price range which is seemingly not triggering additional investments.

[72] (Energie-Control Austria, 2015)
[73] (Energie-Control Austria, 2015)

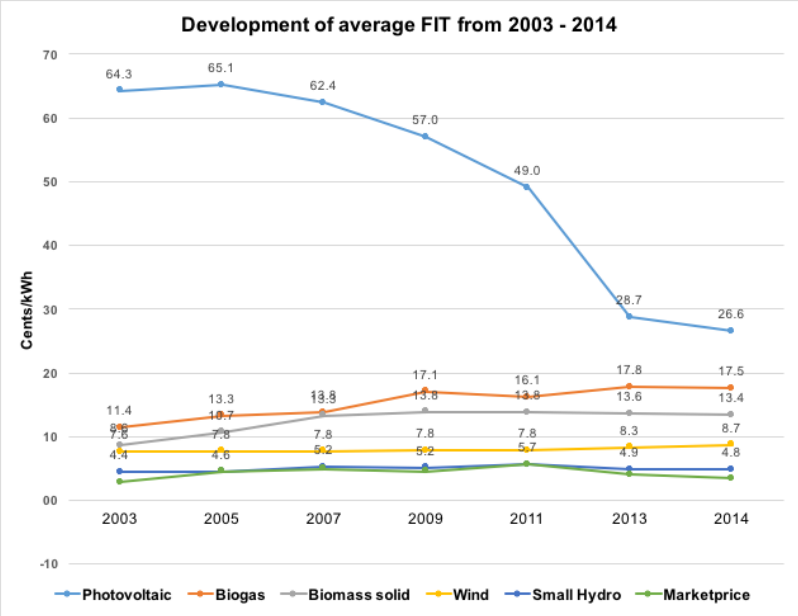


Figure 3-10:Development of average FIT 2003 to 2014 in EUR cent/ kWh, Source: OeMAG,, E-Control, (Energie-Control Austria, 2015), own graph

Figure 3-10 shows the development of the FIT from 2003 to 2014. PV had a strong financial support in 2003, when the investment cost were high and the efficiency of the technology was weak. This has been adjusted according to the technological development and is further reduced over time.

The future development of installations and consequently of support for renewables can be seen in Table 16, with planned doubling of installations for renewables for hydro, wind, biomass and PV for 2015 and 2020 compared to 2010.[74]

Table 16: Expansion of renewable Energy 2015 and 2020 in MW and assumed GWh in addition to 2010, E- Control, own summary

Additional planned installation of renewable energy compared to base year 2010 (ÖSG 2012)				
	Goal 2015		Goal 2020	
	MW	GWh	MW	GWh
Hydro	700	3.500	1.000	4.000
Wind	700	1.500	2.000	4.000
Biomass & biogas	100	600	200	1.300
PV	500	500	1.200	1.200
TOTAL	2.000	6.100	4.400	10.500

[74] (Energie-Control Austria, 2015)

3.5.2. Subsidies for renewable heat

Final energy in form of heat in 2013 has been provided with 580 PJ. This represents 52% of the final energy consumed. Out of the 580 PJ a share of 54% has been produced with fossil fuels, 13% with electricity and 33% with renewable energy. The energy for heat has been used for private households 42%, Production 40%, services 16% and 2% for agriculture.

Several subsidies are in place for this renewable heat.

Renewable energy from biomass:
The law on power and heat coupling provides 12 Mio EUR/ year for those installations[75].

Climate neutral heating systems : A total amount of EUR 5 Mio in 2015 has been provided
Three systems had been supported:

• Exchange of old fossil boilers to renewable with	EUR 2000/boiler/household
• Replacing old biomass boilers	EUR 800/piece/ household
• New pellet burning stove	EUR 500/ stove/ household

The subsidy is valid for the exchange of the fossil boiler if it is older than 15 years and if the new one has a efficiency higher than 85%[76]. This subsidy is only applicable to private persons.

Small solar heating installations for heating water and heating the building:
For 2015 the total budget available was EUR 3 Mio

Solar heating for water	EUR 750/ installation
Solar heating for buildings	EUR 1500/ installation

In addition cost for the solar installation are tax deductible up to max EUR 2920 for the year when it has been installed[77].

[75] (Austrian Federal State Law, 2015)
[76] (Klima- und Energiefonds, 2016)
[77] (Austria Solar, 2016)

Table 17: Overview of subsidies for solar thermal installations in Austria for 2013, Source: Mauthner et al. 2014, own summary

	Investment promotion	Housing subsidies	Building regulations	Tax deductability for private persons companies energy producers	low interest loans annuity subsidies	Subsidies paid 2012 in EUR (000)
Federal	X			X		**38.125**
Burgenland	X	X			X	**904**
Carinthia	X	X			X	**5.639**
Lower Austria	X	X			X	**8.170**
Upper Austria	X	X			X	**7.000**
Salzburg	X	X			X	**835**
Styria	X	X	X		X	**7.621**
Tyrol	X	X			X	**3.974**
Vorarlberg	X	X			X	**3.065**
Vienna	X	X			X	**917**

In Table 17 the overview of subsidies for solar thermal in Austria is described. A combination of tax deductibility of investments, investment subsidies and subsidies for annuities as well as low interest loans[78] is applied. The main subsidies are provided from the federal states in Austria, reaching EU 38 Mio in 2012, as can be seen above[79].

Solar heating has a more than 30 years successful history in Austria. Austria achieving a value of 0,6 m2/capita, has the third highest per capita application on a global scale.

3.5.3. Subsidies for improving energy efficiency of buildings through refurbishment

Between 2011 and 2013 federal state budget provided EUR 286 Million for isolating and refurbishing of buildings older than 20 years. This triggered investments of EUR 3,6 billion[80]. In 2014 EUR 100 Mio, 2015 EUR 80 Mio, 2016 EUR 43 Mio have been reserved in the budget. Looking at the energy consumption related to buildings the speed of refurbishing is important to reach the CO_2 reduction targets. A substantial increase of this subsidy would support a faster implementation process.

[78] (Mauthner et al, 2014)
[79] (C. Fink, 2014)
[80] (WKO, 2015)

3.5.4. Subsidies for biofuels

Based on the EU Directive 2003/30/EU biofuels have been defined to reach a share of 5,75%, calculated in energy value, of all diesel and gasoline fuel used as of 2010. This Directive has been replaced by the Directive on renewable energy 2009/28/EU.
Based on this the substitution of fossil fuel with biofuels has been changed to biofuels substitution of 3,4% for gasoline (adding of 5% bioethanol) and biofuels substitution of 6,3% for diesel (biodiesel included 7% on a general level).
Heading to 2020, renewables are supposed to reach 10%. This includes biofuels first and second generation, hydrogen and electricity.
The usage of biofuels from waste and other non food materials will be counted double in order to reach the target. Electricity produced in renewable way for electric cars will be counted 2,5 fold.
Biofuels will be only accounted for if they are able to demonstrate at least 35% saving of GHG compared to fossil fuel[81]. Vendors of fuel have to reduce GHG by 0,6%/year up to 2020.
The current development of biofuels first generation has stalled, due to the price development of the raw materials, change of legal focus as well as the surpassing of other technologies for personal transport.
The focus of their usage will remain for heavy trucks and agriculture.
Ongoing research on biofuels second generation is heading towards promising results and intensified usage opportunities.

3.5.5. Subsidies in research and innovation

According to KPC (Kommunal Public Consulting) EUR 70 Mio per year are used to support projects to strengthen the environment. In addition, co-financing for EU and federal counties of Austria is added to this amount. Ninety percent of this amount is invested into protection of climate.
Renewable energy projects contributed to savings of 200 000 tons (2/3rds of 294 000 tons) of CO_2 in 2014 and will sum up to 5,5 Mio t of CO_2 over the lifetime of the projects (which is in average 18 years)[82].

The Climate and Energy fund (KLIEN) has been established in 2007 and has since then initiated several programs in research and development of renewable energy, transportation as

[81] (FCIO, Fachverband der Chemischen Industrie Österreich, 2016)
[82] (bmlfuw, 2015)

well as programs on how to disseminate the results of the research into projects. This organization belongs to the BMVIT and has been funded with more than 1 billion EUR to help reduce climate effect in Austria (see Table 18). The activities have been grouped in three main fields:

- Research and development of technology for renewable energy,
- Transportation and
- Market implementation efforts.

Austria is in the middle range if compared with other European countries.

Table 18: Subsidies of the Climate and Energy fund Austria, 2008 – 2016 in EUR Mio, Source: https://www.klimafonds.gv.at/foerderungen/aktuelle-foerderungen/ 2008 - 2016, own graph

Climate and Energy fund Austria 2008 - 2016 Klima und Energiefond										
	Subsidies in EUR Mio									**TOTAL**
Program	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	
Research/ development of technology	**70,7**	**50,6**	**40,5**	**47,4**	**40,5**	**30,5**	**46,0**	**46,6**	**44,2**	**417**
Transportation	**39,3**	**40,5**	**56,5**	**42,8**	**34,8**	**48,0**	**34,3**	**15,0**	**18,3**	**329**
Market implementation efforts	**35,3**	**27,9**	**51,0**	**54,8**	**52,5**	**59,1**	**58,2**	**58,6**	**43,1**	**440**
Administration		**2,0**	**2,1**	**2,4**	**2,2**	**3,0**	**3,0**	**2,8**	**2,7**	**20**
TOTAL	**145,3**	**121,0**	**150,0**	**147,4**	**130,0**	**140,6**	**141,5**	**123,0**	**108,2**	**1.207**

In the last 20 years more than 110.000 projects relevant for the improvement of the environment have been supported, based on the environmental support law (UFG/Umweltförderungsgesetz 1993). The subsidies totaled EUR 6,3 billion. Renewable energy production and energy efficiency related projects represent more than 80% over the last 10 years. This resulted in CO_2 savings of 5,2 Mio ton, as well as significant savings of other GHG. For the lifespan of the projects subsidized 85 Mio ton of CO2 will be avoided[83] .

3.6. Environmental taxes

Environmental taxes amounted to EUR 8,6 billion in 2014. A total of 58% are contributed from energy, 33% from transport, 8% for resources and 1% related to emission allowances.

Income from this source more than doubled since 1995. The source of this tax is energy and transport. Changing the energy system will have an impact on the tax system and has to be

[83] (BMFLFW, 2013)

considered already today in order to avoid conflicting goals for environment and the state budget.

So called “fuel tourism”, meaning non residents of Austria filling their car with cheaper diesel or gasoline on Austrian gas stations is assumed to contribute EUR 1,4 billion/ year.

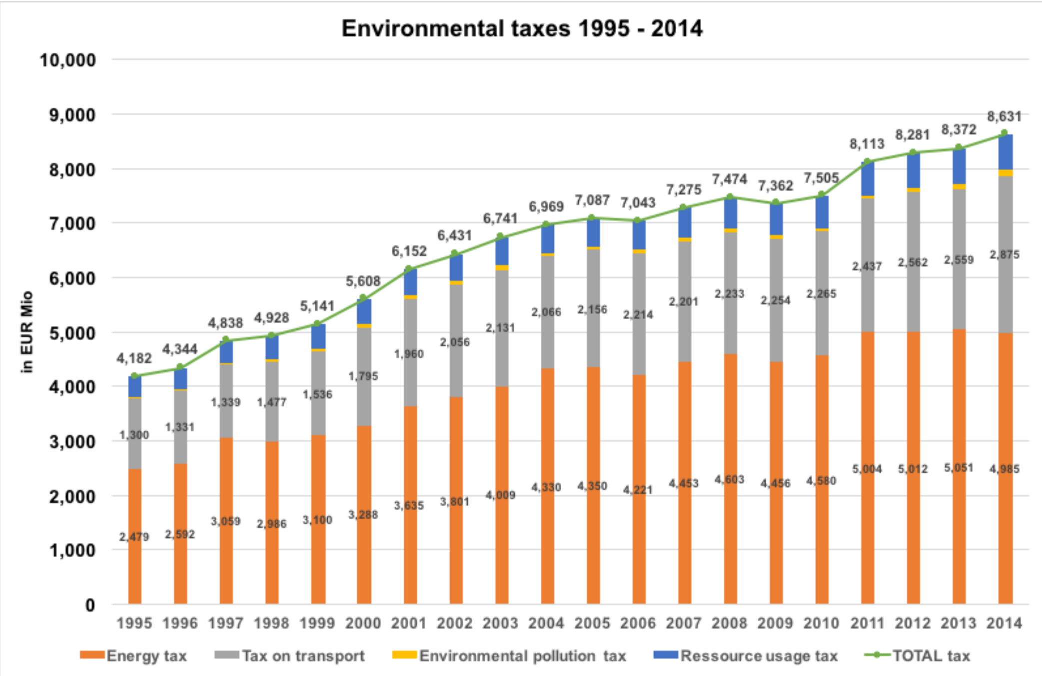


Figure 3-11: Environmental related taxes 1995 to 2014 in Mio EUR, Source: http://www.statistik.at/web_de/statistiken/energie_umwelt_innovation_mobilitaet/energie_und_umwelt/umwelt/oeko-steuern/index.html, own graph

A discussion to align and adjust the existing tax system towards sustainability goals had a fresh start in Austria in 2016.

3.6.1. Environmental contra-productive subsidies

The economic research organization (WIFO) published a report in 2016 pointing at subsidies in Austria which have a negative effect on the environment. Half of it could be influenced within the Austrian legal frame, e.g. changed within the national laws, whereas the other half is connected to international treaties and EU law.

What can be seen as a harmful subsidy ? The following two definitions may give some understanding.

Definition OECD 2005 " A subsidy is harmful to the environment if it leads to higher levels of waste and emissions, including those in the earlier stage of production and consumption, than what would be in the case without the support measure"[84]

Definition EEA 2014: " An energy support measure is a government action that results in (marginal or average private) costs not born by economic agents (producers and consumers) and thus increasing the first order demand or supply for specific energy carriers and /or energy technologies"[85]

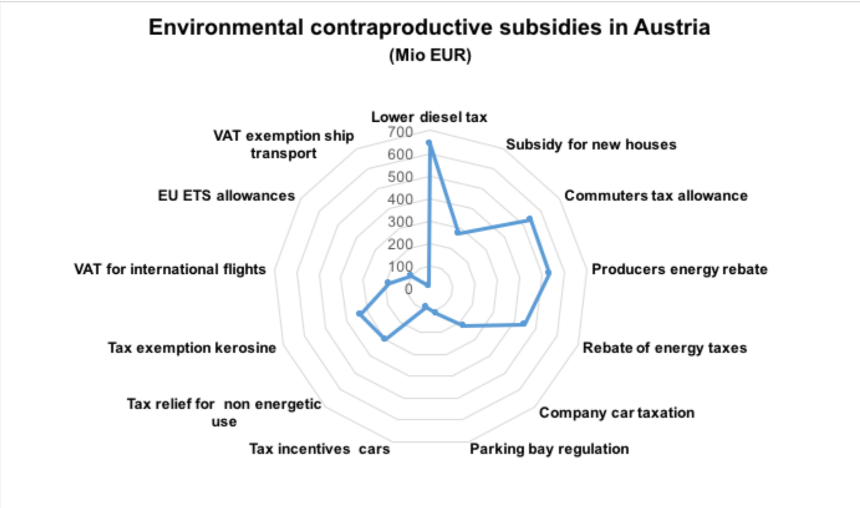


Figure 3-12: Environmental contra productive subsidies in Austria, in Mio EUR, Source WIFO, 2015, own graph

Figure 3-12 shows the subsidies which have been defined as contra-productive for the environment and calculated by WIFO[86].

This analysis has to be taken into consideration when transforming the existing economical and ecological framework and transferring it to a decarbonized one.

The following areas can be decided within the Austrian political framework:

Diesel tax, commuters tax allowance, rebate of energy taxes, company car taxation, parking bay regulation, tax incentives for cars, subsidies for new houses. These areas cover already 60% (EUR 2,4 billion) of the identified amounts.

[84] (WIFO, 2016)
[85] (WIFO, 2016)
[86] (WIFO, 2016)

All transport related subsidies in place could be used to shape the development towards a low carbon economy. This will need a clear vision and a strong political commitment as well as transparent communication with all involved parties.

Austria started a discussion on the energy strategy (Grünbuch) in July 2016, aiming also to adjust the tax system in a way which reduces the load on the labor cost and allows higher spending for activities improving the environment.
The competitiveness of the Austrian industry and sustainability of workplaces must always be in the focus.

3.6.2. Subsidies for fossil fuels

The IMF analyzed the global post tax subsidies under this criteria and calculated a figure of more than 4,9 trillion USD for the global fossil subsidies in 2013[87]. This figure includes external effects and is based on a qualified estimate.

In contrary to IMF World Energy Outlook from the IEA, presents USD 490 billion in 2014 as the amount of subsidies for fossil fuels. The difference of domestic consumers price with the international market price is the calculation criteria. No external effects are included[88].

For Austria the post tax subsidies amounted to 3,82 billion USD or 0,85% of GDP.
On a per capita basis this represents 446 USD (app. EUR 400)[89]
This figure includes the monetary as well as the estimated external cost of fossil fuel.

For Austria historically a network of subsidies applied for fossil fuels:

- Tax for diesel is 8,5 EUR cent lower than for petrol
- Diesel for agriculture has been additionally subsidized till 2012
- Compensation for companies which paid energy taxes for green electricity
- Tax brakes for energy intensive industries
- Tax exemption for diesel in trains and gas for public transport till 2012
- Tax exemption for kerosene used for air transport
- No VAT for international flights

All subsidies added up to app. EUR 2,2 billion /year. This represents EUR 260/ capita excluding external cost of fossil fuel.

[87] (Coady, 2015)
[88] (IEA International Energy Agency, 2016)
[89] (Coady, 2015)

The higher value from the IMF considers also external cost for health and environment not calculated for in the 260 EUR/ capita.

3.7. Results of the subsidies and the change towards renewables

Austria could avoid more than 28 Mio tons of CO_2 by applying renewable energy for the sectors electricity, heat and transport, as is shown in Figure 3-13[90].

The important environmental effect is followed by:

1.) Reduction of GHG as committed to in the Kyoto protocol.
2.) Reduction of money spent for energy imports (EUR 11,4 billion or 11,3% of imports in 2013)[91].
3.) Improvement of the industries own value creation through energy saving and increasing attractiveness of Austria for tourism and living (research).
4.) Creating jobs connected to renewable energy and expanding Austria´s export industry (especially to the important German market - e.g. boilers, pellets, renewable technology for storage, smart network solutions)

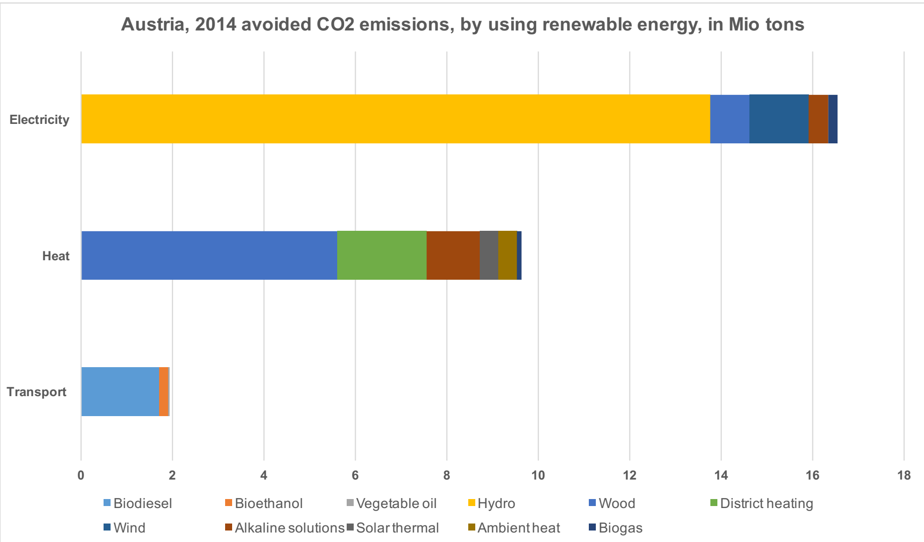


Figure 3-13:Austria, 2014 avoided CO2 emissions, by using renewable energy in the sectors electricity, heat, transport, Source: Biermayr Peter, Erneuerbare Energie in Zahlen 2015, own graph

[90] (Biermayr, 2015)
[91] (Bundesministerium für Wissenschaft, Forschung und Wirtschaft, 2015)

3.8. Conclusions

Austria is privileged due to its rich availability of rivers, resulting in a more than 50% coverage of hydropower as well as in the high amount of woods and their responsible and sustainable foresting and utilization. Biomass has a long tradition in Austria mainly for heating.
Austria has pioneered in the development of solar heating over the last 30 years and could develop a significant percentage installed. Austria started with using 20% of renewable sources in electricity in 1990, developed steadily over time to reach almost 80% of final electricity supplied in renewable way.

Transport and households consume today 60% of the final energy. These sectors must be fully involved in order to achieve the reduction target for 2030. These sectors are not included in the EU-ETS, a significant change has to be triggered by other tools and support measures in each country. Research, taxes and subsidies have proven a successful mix in this field.

Table 19: Development of CO2eq emissions in EU, Austria, 1990 – 2013, and goals 2020, 2030, 2050, *Source: European Commissions, http://ec.europa.eu/clima/policies/strategies/2020/index_en.htm, http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/145397.pdf, https://ec.europa.eu/energy/sites/ener/files/documents/2012_energy_roadmap_2050_en_0.pdf, September30th,* Statistic Austria 2015b *own summary*

Development of GHG emissions in Mio tons of CO2 eq							
	EU		A		A ETS	A non ETS	
1990	5.735	100%	78,0	100%			
2000	5.284	92%	80,2	103%			
2005	5.347	93%	92,6	119%	35,9	56,7	100%
2012	4.691	82%	80,2	103%			
2013	4.602	80%	80,0	103%			
2014	4.419	77%	76,3	98%	28,2	48,1	
Target 2020	4.588	80%	70,5	90%	22,93	47,59	-16%
Target 2030	3.441	60%	54,1	69%	17,87	36,26	-36%
Vision 2050	1.147	20%	15,6	20%			
Vision 2050	287	5%	3,9	5%			

Table 19 shows the GHG emissions trend since 1990. First time in 2014 a value 2 Mio tons below 1990 has been achieved. The goals for 2020 and 2030 have been communicated by the EU, based on 2005 emitted GHG in the non ETS sector.
Having in mind the achievements from 2014, it will be challenging to achieve the defined goals for 2020 and 2030. Intensified joint efforts all over the society will be needed to do so.

The need for energy in form of electricity and heat will persist and even increase in the future.

Stabilizing the need for heat asks for a refurbishment of existing buildings towards passive house or even zero energy standard, as has been successfully shown with the TU-Vienna, (Getreidemarkt) building[92].
Today almost 80% of the final electricity consumption is from renewables, putting the existing grid infrastructure to its limits. Micro-grids and storage solutions, currently under development, will be needed in order to satisfy the increase in electricity consumption and allow their safe and affordable distribution.

The transport sector has started to use renewable energy, adding biofuels. The EU targets have been adjusted with accounting rules for 2 fold or 2,5 fold counting of biofuel and renewable electricity for cars. Accounting alone will not solve the GHG emissions increase.
For transport similar programs as for renewable energy transformation have to be developed together with the industry involved. Changing energy needs from petrol to electricity or other renewable carriers will set free high amounts of money needed for importing fossil fuels (EUR 11,4 billion in 2013)

GHG reductions cannot be solved by the Ministry of Environment on its own. It is cross-cutting through all levels of society and it effects environment, economy, health, finance (taxes) as well as education, research and innovation.
Fossil fuel tax has to be replaced with other sources of income and will be a tool for driving the change towards decarbonization.

Having in mind, that the long term goal is the decarbonization, this has to be communicated publicly in a convincing way, involving schools and the general public. All involved working together and supporting each other, can achieve this challenging task.
The Austrian knowledge in the field of renewable energy solutions has to be used as the economic driver for a strong export industry and will contribute to a stable domestic wealth.
Exporting and implementing this knowledge in other countries will as well contribute to GHG reductions in those areas.

[92] (TU Vienna, 2014)

4. Development of GHG emissions in Germany

This section will give an overview on the historical development of GHG emissions and valid reduction targets for Germany. The development of energy needs and the status of renewable energy in the country is described. Support schemes for renewable electricity, renewable heat, biofuels, improving energy efficiency, as well as for research and innovations are included. Conclusions including comments on the analyzed measures to reduce CO_2 and GHG close the chapter.

4.1. Framework for GHG reductions

Germany signed together with 191 countries the Kyoto protocol in 1997. This has foreseen an obligation for all signatories to reduce the GHG emissions in the first reduction period 2008 – 2012 by 5%. All EU member states are participants of this treaty. First results have been achieved in this period.
The EU agreed to a 20% reduction of CO_2 compared to 1990 in 2020.

Being one of the six founding members of the European Coal and Steel Community which developed towards todays EU, Germany has accepted the responsibility to reduce GHG emissions even more progressively than other countries.
With a leading industrial sector and an excellent developed transportation infrastructure Germany has been, and still is, a high energy consumer and has highest per capita GHG emissions in Europe. Germany as of 2014 is the fifth largest economy, measured in GDP on a global level[93].
The efforts bundled in the "Energiewende" and "Energie Effizienz Gesetz" show already significant improvements and the recently defined measures for achieving 40% GHG reduction in 2030 compared to 1990 show the boldness of Germany in approaching the topic.

[93] (PWC, Price Waterhouse Coopers, 2015)

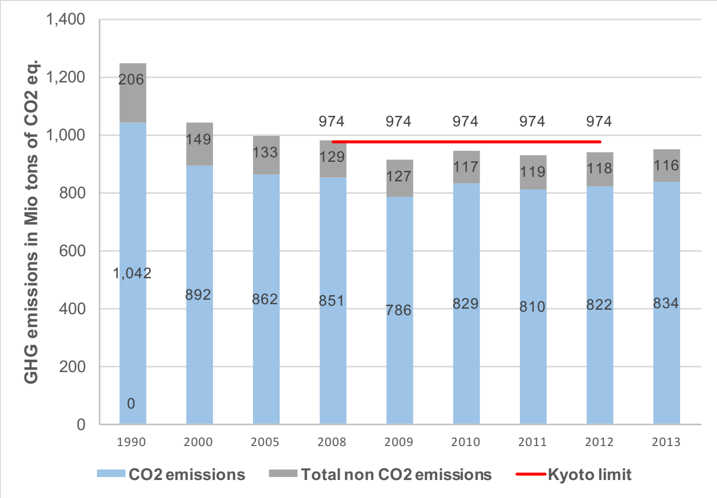


Figure 4-1: GHG emissions 1990 to 2013 in million tons of CO2 eq., Source: BMUB, The German Government´s Climate Action Plan 2020, Berlin 2014, own graph

As shown in the figure 4-1 Germany could, as of 2013, reduce the GHG by 23,7% compared to 1990, reaching 951 Mio t of CO_2 equivalents[94].

4.2. Development of economic growth, energy consumption and GHG

The German reunification was followed by an unprecedented industrial restructuring, mainly in the eastern part. Significant reduction of the usage of lignite for electricity production as well as energy efficiency improvements due to change of the overall industry structure lead to a CO_2 saving of 105 Mio tons[95] (Wall fall profit).

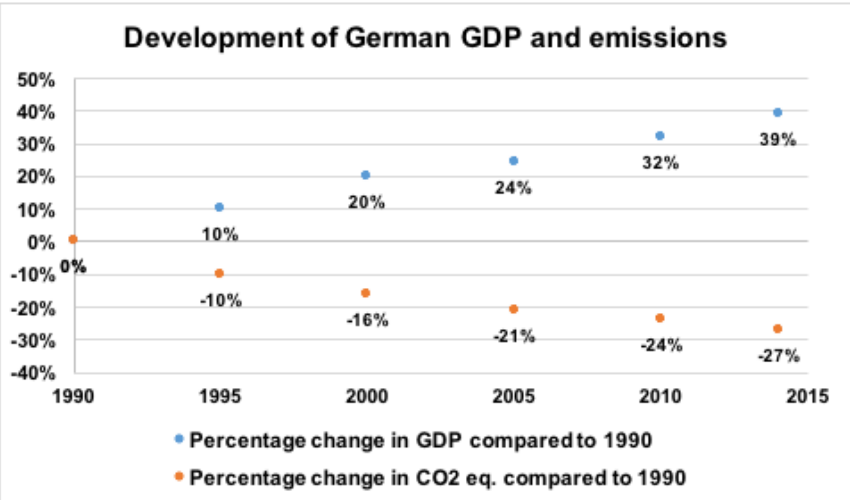


Figure 4-2:Decoupling economic growth from greenhouse gas emissions, Source: Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, Climate Action in Figures, 2015 edition, own graph

94 (Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, 2014)
95 (DIW, Hans.J. Ziesing &al., 2001)

GDP growth and energy development could be decoupled in Germany already in the 1990ties. As can be seen in the Figure 4-2 GDP development for Germany increased more than 39% since 1990, while CO_2 equivalents have been reduced by 27% over that time period[96].

4.3. Goals for GHG emission reductions in Germany

Starting with 1250 Million tons of CO_2 equivalent in 1990, Germany aims at a reduction of 500 Million tons of CO_2 equivalents to achieve 750 Million tons in 2020[97] . This development can be seen in Figure 4-3.

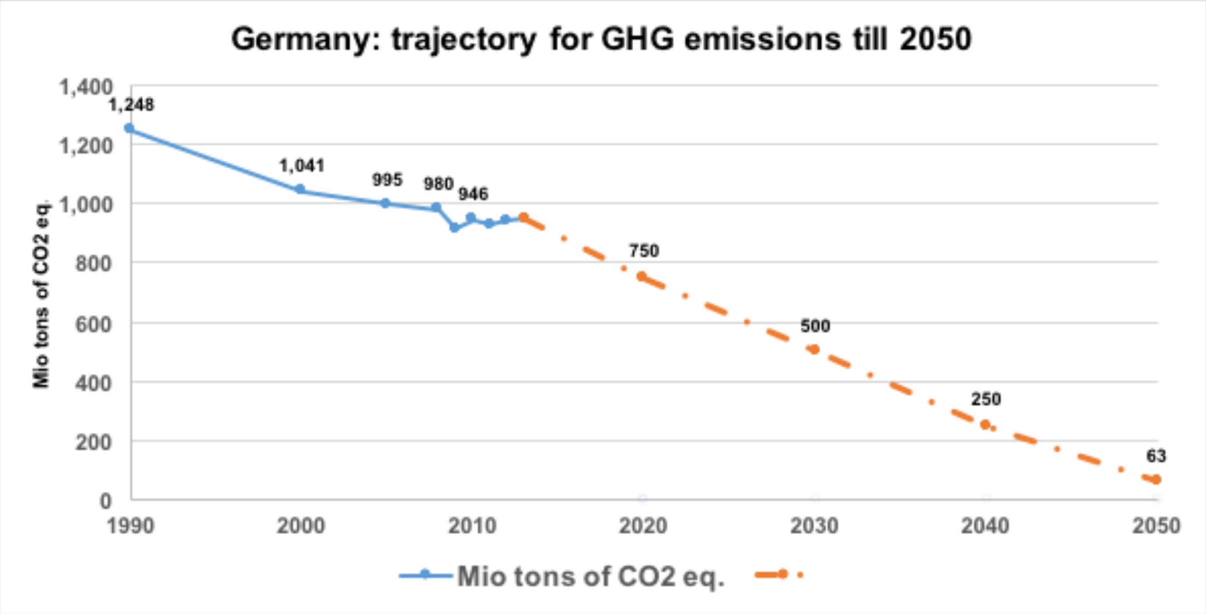


Figure 4-3:Trajectory for GHG emissions up to 2050, Source: Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, Climate Action in Figures, 2015 edition, own graph

In the following Table 20 the current climate and energy targets for Germany are shown. Germany is quite on track to reach the 2020 goals. These energy policy targets have been designed under the coalition agreement 2013 aiming also to ensure the competitiveness of the industry and of the country. Basis for the climate actions are as well the affordability, supply security of energy and environmental and climate compatibility of actions[98].

[96] (Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, 2014)
[97] (Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, 2015)
[98] (Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, 2015)

Table 20: Current climate action and energy targets, Source: Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, Climate Action in Figures, 2015 edition

		2013	2014	2020	2030	2040	2050
GHG emissions absolut	**in Mio t**	**953**	**913**	**750**	**563**	**375**	**250**
Greenhouse gas emissions compared to 1990	**in %**	**-23,80%**	**-27%**	**-40%**	**-55%**	**-70%**	**-80%**
Growth of proportion of REN within energy consumption							
Proportion within gross final energy consumption		**12,40%**		**18%**	**30%**	**45%**	**60%**
Proportion within gross electrcity consumptior		**25,40%**	**27,80%**	**35%**	**50%**	**65%**	**80%**
Proportion within heat consumption		**9,90%**	**9,90%**	**14%**			
Proportion within transport sector		**5,50%**	**5,40%**				
Reduction in energy consumption and increase in energy efficiency							
Primary energy consumption in comparison to 2008		**-3,80%**		**-20%**			**-50%**
Final energy productivity		**0,20% annually**		**2,10% annually**	**->**	**->**	**->**
Gross energy consumption in comparison to 2008		**-3,20%**		**-10%**	**->**	**->**	**-25%**
Heating demand in comparison to 2008		**0,80%**		**-20%**			
Final energy needs in transport sector in comparison to 2005		**1%**		**-10%**			**-40%**

Table 21 shows the split of the goals to the individual sectors. All sectors except Transport show double digit improvements between 1990 and 2012. Industry and Energy Industry are part of the EU-ETS and could reduce their emissions significantly.

Table 21: Trends in GHG emissions in Germany by sector and projections up to 2020, , Source: Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, The German Government´s Climate Action Programme 2020

Sector	Emissions 2012 CO2 eq. Mio tons	Change between 1990 and 2012 in percent	Projection 2020 CO2 eq. Mio tons	Projection 2020 reduction in % compared to 1990
Energy industry	**377**	**-17,7**	**306**	**-33**
Industry	**185**	**-33**	**183**	**-34**
Households	**94**	**-28,2**	**80**	**-39**
Transport	**151**	**-5,6**	**151**	**-6**
Commerce/trade/ services	**42**	**-48,1**	**35**	**-57**
Agriculture	**76**	**-23,2**	**72**	**-27**
Other	**15**	**-67,4**	**10**	**-77**
TOTAL	**940**	**-24,7**	**837**	**-33**

Summarizing the projection provided by the Federal Ministry of the Environment, Germany will fall short by 7% to the 40% goal for CO2 emissions planned for 2020. Transport might have some potential to close the gap.

German development of CO2 eq. emissions

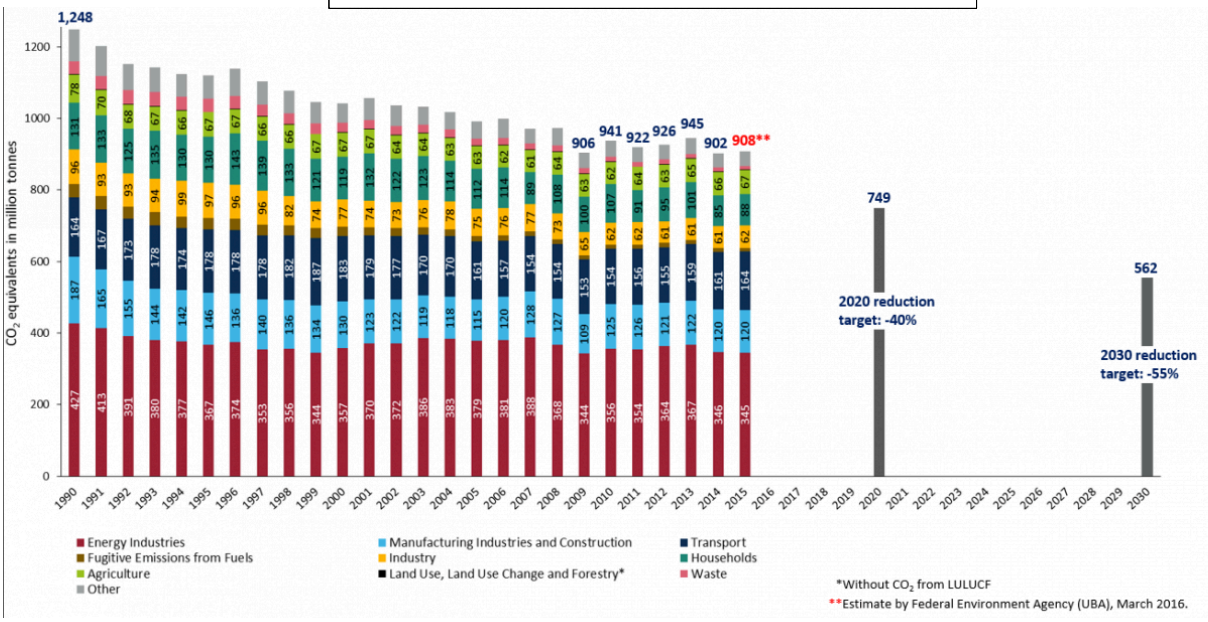


Figure 4-4: German development of CO2 eq. emissions 1990 to 2014 and estimation 2015, by sectors, Source: https://www.cleanenergywire.org/factsheets/germanys-greenhouse-gas-emissions-and-climate-targets, June25, 2016

In Figure 4-4 can be seen, that Energy industry reduced 25% of CO_2 emissions, Industry 30%, whereas transport stayed on the level of 1990. Big efforts in all this sectors are expected to achieve the 2020 goal of 750 Mio tons of CO_2 eq.

4.4. Total energy production and consumption by sectors and final consumers

Germany has been rich on lignite and hard coal, as shown in their primary energy contribution of 36,9% in 1990. With 42% electricity produced from coal these energy carriers still today dominate this sector[99]. Hard coal industry is under restructuring processes for several decades and 90% of hard coal used is imported today[100]. Petroleum and gas contributed 50% to the primary energy consumption in 1990. Renewable energy started in 1990 with nearly unnoticed at a 4,0% share[101].

Table 22 shows the development of the primary energy consumption in Germany, where a steeper increase in renewable energy is visible as of 2005.

[99] (Bundesministerium für Wirtschaft und Energie, 2016)
[100] (Bundesministerium für Wirtschaft und Energie, 2016)
[101] (Arbeitsgemeinschaft Energiebilanzen, DIW , 2015)

Table 22: Germany, primary energy consumption by energy carrier in PJ, Source: http://www.ag-energiebilanzen.de/10-0-Auswertungstabellen.html, own summary

	Primary energy consumption in PJ									
Energy carrier	1990	2000	2005	2008	2009	2010	2011	2012	2013	2014
Hard coal	2.306	2.021	1.808	1.800	1.496	1.714	1.715	1.725	1.840	1.724
Lignite	3.201	1.550	1.596	1.554	1.507	1.512	1.564	1.645	1.629	1.574
Petrol	5.228	5.499	5.166	4.904	4.635	4.684	4.525	4.527	4.628	4.516
Gas	2.304	2.996	3.261	3.231	3.047	3.181	2.923	2.933	3.074	2.688
Nuclear energy	1.668	1.851	1.779	1.623	1.472	1.533	1.178	1.085	1.061	1.059
Renewable energy	196	417	769	1.147	1.201	1.413	1.463	1.385	1.499	1.486
Other	-	56	211	202	224	243	255	231	208	207
Balance for electric	3	11	-31	-81	-52	-64	-23	-83	-116	-122
TOTAL	14.906	14.401	14.559	14.380	13.530	14.216	13.600	13.448	13.823	13.132

Figure 4-5 below shows the development from hard coal and lignite dominated indigenous primary energy production towards an increase in renewable sources. Germany can currently cover only 30% of its energy need with own sources.

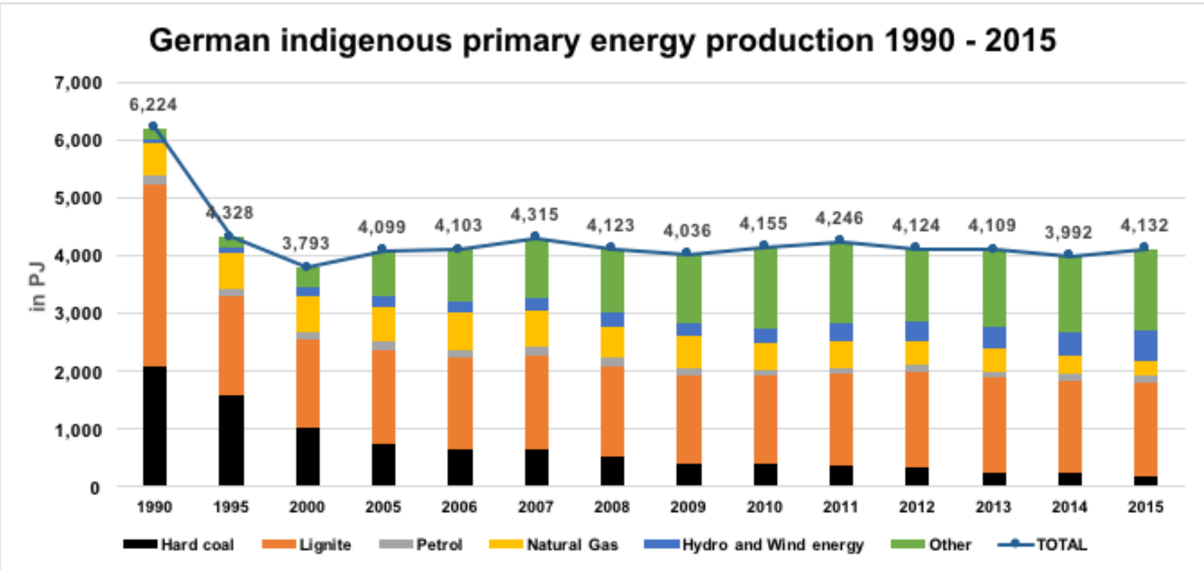


Figure 4-5: German primary energy production 1990 – 2015 in PJ, Source: http://www.bmwi.de/DE/Themen/Energie/Energiedaten-und-analysen/Energiedaten/energiegewinnung-energieverbrauch.html, July 2016, own graph

Germany is for more than 69% of its energy production dependent on imports.
Import of hard coal is 86%, Petrol 97,7%, natural gas 87,4% and uranium for nuclear energy 100%. Lignite is available for all domestic energy needed and is even exported.
In 2013 Germany spent EUR 91 billion for fossil fuel imports (app. 3,4% of the GDP or in average EUR 1135/citizen). For the period 2000 – 2013 this adds up to EUR 833 billion.

This amounts have to be taken in mind in order to compare the cost to decarbonize the economy and to invest into renewable energy[102].

In the following Figure 4-6, the primary energy consumption for Germany 2014 in PJ is shown on the left side of the figure, giving more details on renewables on the right side of the figure.

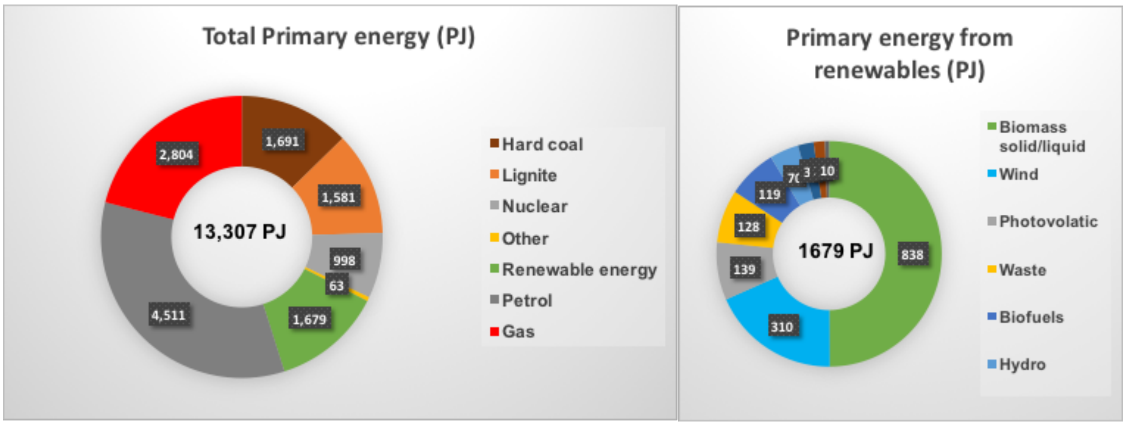


Figure 4-6:Split of Primary energy consumption by energy carriers in PJ, detailed split of renewable energies by carrier in PJ, Source: http://www.bmwi.de/DE/Themen/Energie/Energiedaten-und-analysen/Energiedaten/energiegewinnung-energieverbrauch.html , own graph

In renewable energy. biomass has the biggest share in Germany, reaching 838 PJ in 2014, followed by wind energy with 310 PJ, PV 139 PJ and Waste 128 PJ. Biofuels could contribute 119 PJ, Hydro 310 PJ, Heat pump 38PJ, Solar thermal 27PJ and Geo-Thermal 10PJ.

In fossil energy there is a strong domination of petrol with 4511 PJ making up more than one third of the final energy consumed. Nuclear, which has been decided to phase out in 2022 represents today 7,5% of all energy consumed. If it would be replaced with renewables, only this change will ask for a 50% increase in the renewables energy capacity.

Table 23: Final energy consumption 1990 to 2014, Source: Arbeitsgemeinschaft Energiebilanzen, Evaluation Tables of the Energy Balance for Germany 1990 to 2014, August 2015, Berlin

Total final energy consumption by energy carrier								
	1.990		2000		2012		2014	
	in PJ	in %	in PJ	in %	in PJ	in %	in PJ	in %
Hard Coal	571	6,0%	432	4,7%	340	3,8%	346	4,0%
Lignite	975	10,3%	82	0,9%	92	1,0%	87	1,0%
Petroleum	4.061	42,9%	4.148	44,9%	3.331	37,4%	3.340	38,6%
Gases	1.789	18,9%	2.328	25,2%	2.186	24,5%	2.026	23,4%
Electricity	1.638	17,3%	1.780	19,3%	1.884	21,1%	1.833	21,2%
District heating	383	4,0%	265	2,9%	431	4,8%	390	4,5%
Renewable Energy	54	0,6%	201	2,2%	572	6,4%	567	6,6%
Other energy carriers	-		-		82	0,9%	60	0,7%
TOTAL	9.471	100,0%	9.236	100,0%	8.918	100,0%	8.649	100,0%

102 (Energy Comment - Internationale Energiemärkte, 2013)

Table 23 shows the individual share of the energy carriers in the final energy consumption between 1990 and 2014. More than one third of losses in transformation and distribution have to be accounted for between primary energy production and final energy consumption.
Figure 4-7 shows the final energy consumption is distributed between households, trade, commerce and services, reaching 40,6% in 2014, Transport consuming 30,4% and Other mining and manufacturing industry at 29%. Primary energy consumption of 13132 PJ end up at 8648 PJ final energy consumption in 2014.

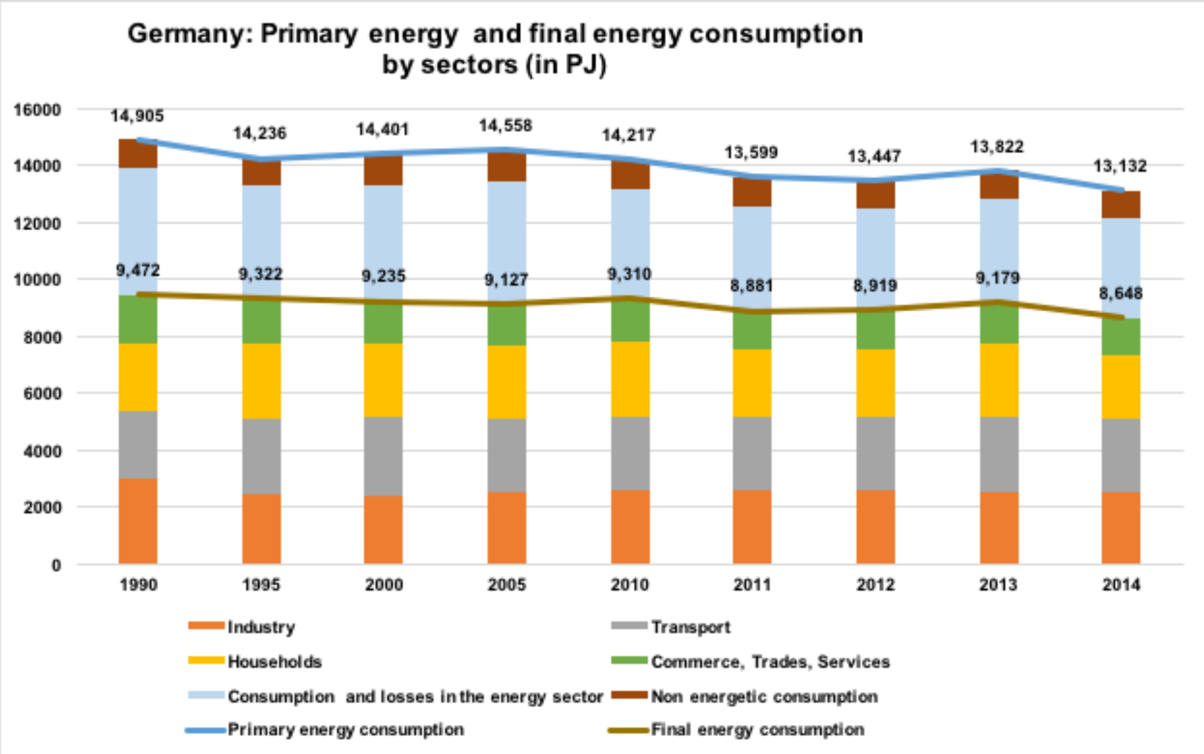


Figure 4-7: Development of energy consumption by sectors 1990 – 2014 in PJ, Source: http://www.bmwi.de/DE/Themen/Energie/Energiedaten-und-analysen/Energiedaten/energiegewinnung-energieverbrauch.html, own graph

The conversion losses from the energy sector as well as the non-energy consumption add up to 34,1 %.
In the following overview the final energy usage for the individual services can be seen.

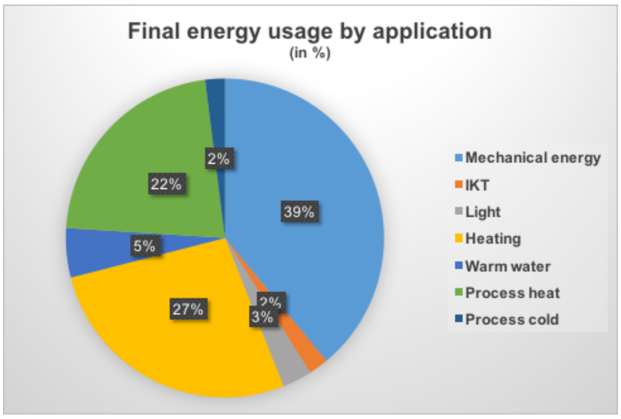


Figure 4-8: Usage of final energy according to their application, Source: http://www.bmwi.de/DE/Themen/Energie/Energiedaten-und-analysen/Energiedaten/energiegewinnung-energieverbrauch.html, own graph

Figure 4-8 shows the usage of final energy for applications in Germany in 2014. The total of 8648PJ has been consumed for mechanical energy with a share of 39%, heating 27% and process heat 22%, these three sectors adding up to almost 90 % of the whole amount.

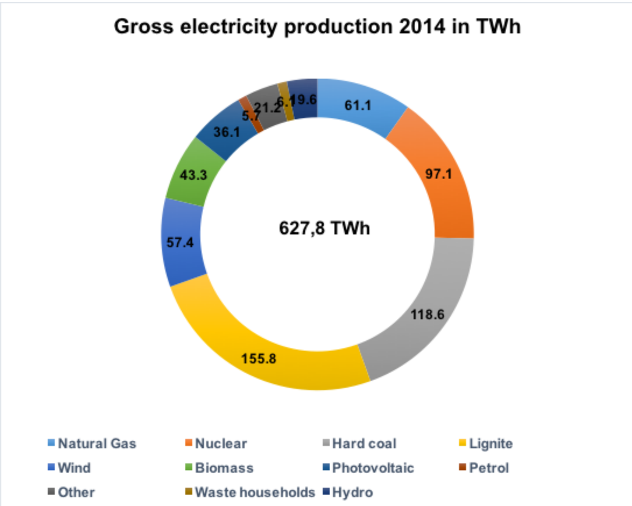


Figure 4-9: Composition of the net electricity production mix in 2014/ 2013 ?, Source: http://www.bmwi.de/DE/Themen/Energie/Strommarkt-der-Zukunft/zahlen-fakten.html, July 22 , own graph

Figure 4-9 shows the gross electricity production in 2014 in TWh. More than 20% have been produced with renewable sources.

4.5. Development of RES in Germany

Starting from 2% of renewable energy in total final energy consumption, Germany reached 12,4% in 2014 approaching the goal of 18% for 2020. As shown in Table 24 electricity supply had the steepest increase by supporting renewables in wind, PV and biomass over the last years, within the program “Energiewende” and reached 27,8% in 2014, well on track for the 35% goal to be achieved by 2020.

Renewable energy sources for heating achieved 9,9% and renewable energy in transport 5,4%. Measures in place for transport seem not sufficient to get to the 10% final energy goal to be supplied with renewables in this sector[103].

Table 24: Proportion of renewable energy sources in energy supply, 2000-2014 and 2020 goal, Source: Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, Climate Action in Figures, 2015 edition

	Electricity Supply	Final energy heating	Final energy transport	Primary energy consumption	Final energy consumption
Goal 2020	35,0%	14,0%	10,0%		18,0%
2014	27,8%	9,9%	5,4%	11,1%	12,4%
1990	3,4%	2,1%	0,1%	1,3%	2,0%

Table 25 shows the development of primary energy consumption by energy carriers for renewable energy. From 1990 with 197 PJ this increased more than 7fold to 1485 PJ in 2014. The biggest share is with biomass (882 PJ), followed by wind energy (206PJ) and waste from renewables (132 PJ) before PV (126 PJ). Due to geographical limitations hydro is comparably small. Solar thermal and heat pumps offer still a big growth potential.

Table 25: German primary energy consumption from renewable energies, 1990 – 2014 in PJ, Source: AGEB, Evaluation Tables of the Energy Balance for Germany 1990- 2014, August 2015, section 3.1. , own graph

Renewable energy	1990	2000	2005	2008	2009	2010	2011	2012	2013	2014
Primary energy consumption in PJ										
Hydro	58	92	70	74	69	75	64	78	83	71
Wind	-	35	98	146	139	136	176	182	186	206
Photovoltaic	-	-	5	16	24	42	70	95	112	126
Biomass	59	242	492	778	836	1.014	1.000	856	929	882
included biofuels		12	77	127	115	121	117	121	113	116
Waste from renewables	80	39	88	102	99	106	110	114	127	132
Geothermal	-	-	-	1	1	1	1	7	6	7
Solar thermal	-	4	10	15	17	19	20	24	24	26
Heat pumps	-	5	6	16	17	19	22	29	31	35
TOTAL	197	417	769	1.148	1.202	1.412	1.463	1.385	1.498	1.485

The usage of renewable energies in Germany resulted in avoiding in 2014 151 Mio tons of CO_2eq, of which for electricity 110 Mio tons of CO_2eq., heat 36,1 Mio tons and transport 5,2 Mio tons CO_2eq.

[103] (Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, 2015)

The change in energy policy (Energiewende) is based on the energy efficiency law (EEG, newest version 08.07.2016, EEG 2017), the law for the electricity market (Strommarktgesetz), and the law on digitalization (measuring electricity digitally). It has been summarized in a program comprising ten main points[104]:

- Renewable Energy to be tendered and better coordinated with the grid extension
- European Emission Trading Scheme and EU goals
- Competitive design of the electricity market
- Regional cooperation within EU
- Improving the transport grid infrastructure with earth DC cables
- Modernization of the distribution grid, connection of smart grid, smart meter, smart home
- NAPE, National Action Plan on Energy Efficiency
- Energy Efficiency for buildings -> goal to be CO_2 neutral by 2050
- Gas supply strategy, for the important current and future supply
- Transparent and strict monitoring process including all groups of society.

4.6. Framework for energy support including renewables

With sufficient own reserves for hard coal as well as for lignite Germany built the energy system around these major energy carriers. In the 1960ties also nuclear fission has been added. Subsidies for these energy carriers can be seen in the Figure 4-10. Hard coal received the highest amount of 327 bn. EUR, nuclear energy 219 bn EUR, lignite 95 bn EUR and renewable energy for all carriers 102 bn EUR.

[104] (Bundesministerium für Wirtschaft und Energie, 2016)

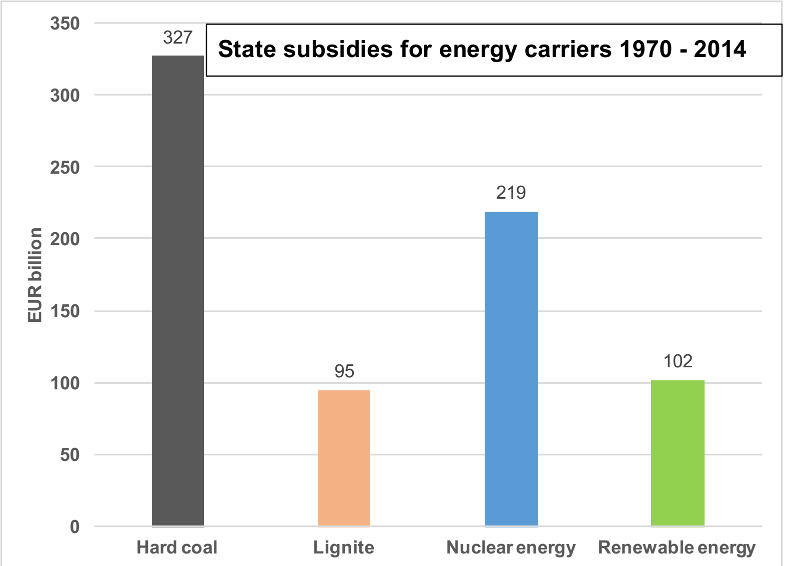


Figure 4-10:State subsidies for energy carriers 1970 – 2014, Source: Greenpeace-energy, Was Strom wirklich kostet(http://www.greenpeace-energy.de/uploads/media/Greenpeace_Energy_Was_Strom_wirklich_kostet_2015.pdf, 2015, own graph

The German Parliament (Bundestag) decided on exiting nuclear power for electricity production in 2022. Another EUR 48 bn[105] is foreseen for dismantling the installations and save storage of the nuclear waste material. Estimates for the dismantling of the power plants and save storage of the nuclear waste add up to EUR 169 billion by the end of this century. Potential new technology in the area of nuclear fusion is under research in Europe, solutions are expected within the next decades.

Lignite has been subsidized with EUR 95bn in the period 1970 to 2014. This does not include external cost of app. EUR 13,2bn for GHG emissions, particulate matter and mercury identified[106]. If those external cost would be added to the electricity price an increase for EUR-cent 8,8/kWh would result.

The energy efficiency law is the base for the implementation and support of renewable energy (Energie Effizienz Gesetz/EEG)

The main goals are:

- Sustainable development of energy supply
- Consider and reduce the long term external cost of energy supply for the economy

[105] (Trittin, 2015)
[106] (R. Wronski, 2015)

- Reserve fossil energy resources
- Support the development of technologies for renewables

The main key parameters are:

- Feed in tariff : guaranteed for 20 years, which gives a long term stability for the investor. FIT is reduced yearly, monthly (photovoltaic) or quarterly (wind).

- Net operators have the obligation to connect and to accept energy produced from renewable sources (merit order principle). Payment for feed in electricity in line with market prices base on the stock exchange Leipzig.

- EEG includes hydro, wind, solar (photovoltaic), geothermic, and energy from biological material (wood), biogas, biomethan, landfill gas, biological waste.

4.6.1. Subsidies for renewable electricity

Subsidies for renewable electricity are based on the renewable energy law, (EEG 2000). The last adjustment has been agreed July 8th, 2016. Goal of this law is the speeding up of the implementation of renewable energy in Germany[107]. Eligible producers of renewable electricity have been supported with a FIT (feed in tariff) for 20 years, depending on location of the installation, size of the production and type of energy carrier (e.g. wind, solar, biomass,..).
Renewable electricity has priority in the existing distribution grid, as well as in the connection to the existing grid. The prioritization is in line with the so called merit order principle, already explained in chapter 3.5.1 for Austria.
The system is based on the apportionment procedure, which means that the cost for the FIT, not covered by the market price achievable on the electricity stock exchange is covered by the consumers of the electricity.
Figure 4-11 shows the development of the EEG apportionment and the total amount spend for the FIT between 2000 and 2014.

[107] (Schwarzwald-Energy, 2015)

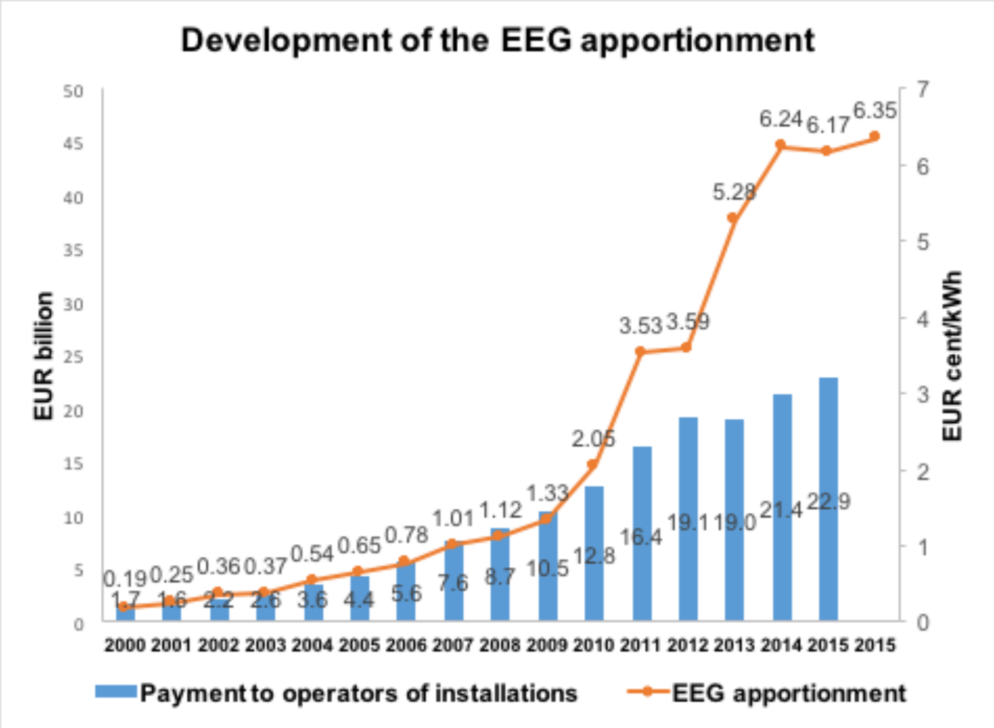


Figure 4-11: Development of the EEG apportionment and total amount spent for subsidies between 2000 and 2015 in bn. EUR, Source: https://www.ise.fraunhofer.de/de/downloads/pdf-files/data-nivc-/kurzstudie-zur-historischen-entwicklung-der-eeg-umlage.pdf, BMWi, BNetzA, own graph

In 2016 an amendment to the EEG has taken place and future renewable energy installations will have to compete between each other. The FIT has been decreasing already in the recent past and is expected to decrease further, based on the increased competitiveness of investment cost and operational cost of the renewable energy installations.

The relevant key points are following:

- Tender for all installations > 750 kW
- Photovoltaic
  - increase of 2500 MW/ year (600 MW for big PV areas)
  - Roof areas < 750kW , the old EEG 2014 is in place, bigger installations will be tendered

  Three times per year will be started the tender process (01.02. /01.06. /01.10.)
- Biogas installations
  - All installations bigger than 150kW will be tendered
  - The first three years 150MW/ year/ the following 3 years 200 MW/ year increase

- Wind turbines
    - Offshore: new rules from 2021 – 800 MW/ year, reaching 15GW in 2030
    - Onshore: in 2017 three tenders, as of 2018 4 tenders, 2800 MW between 2017 and 2019, and another capacity of 2900 MW from 2020 are foreseen
    - Maximum 60% of the new capacities can be build in Northern Germany to avoid bottlenecks in transmission.

For Geothermic the EEG 2014 continuous to be the valid base[108].

4.6.2. Subsidies for renewable heat

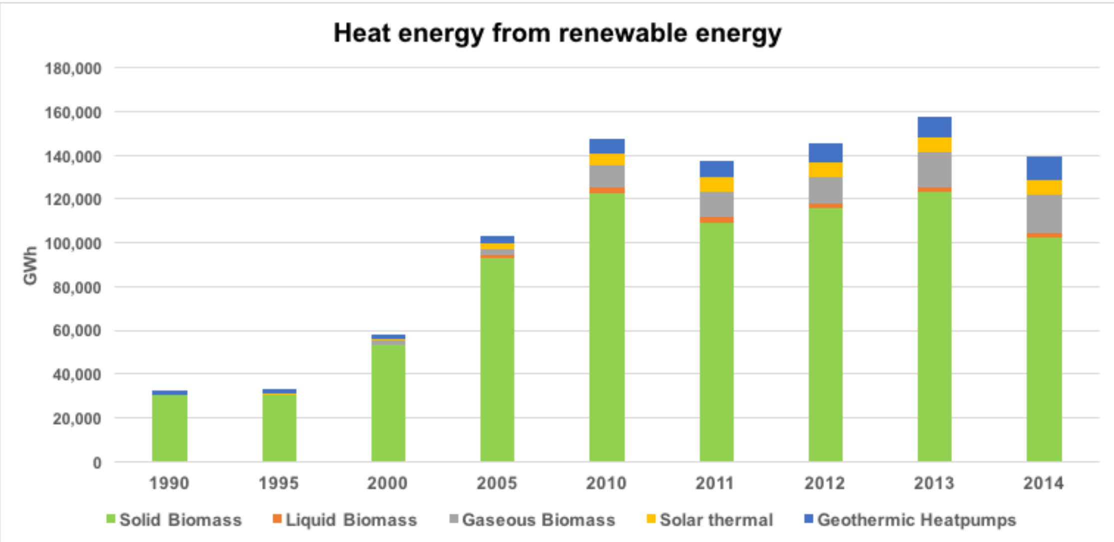


Figure 4-12: Heat energy from renewable energy 1990 to 2014 in GWh, Source:BMWI, Erneuerbare Energie in Zahlen, 2014, Berlin, own graph

Figure 4-12 shows the development of heat provided from renewable energy between 1990 (2,1%) and 2014 (12,2%). The main providers of heat are still coal and gas.

Support and subsidies for renewable heat is regulated in the MAP (Marktanreizprogramm), the market incentive program. It has been started already as early as 1993. Since 2009 it is part of the Renewable Energy Thermal law (EEWärmeG. 2009/9). The target for renewable energy in the thermal energy is 14% as of 2020, whereas 12,2% have been achieved in

108 (UDI, 2016)

2014. New buildings are obliged to have a minimum standard for renewable energy for heating and cooling.

MAP includes two support elements:

- Investment grants for small installations in existing buildings (single or two family houses)
- Low interest loans with redemption grants for multifamily buildings as well as for district heating and heat storage systems

Table 26: Overview of MAP relevant installations and investment grants between 2000 and 2014, Bundesministerium für Wirtschaft und Energie, Erneuerbare Energie in Zahlen, 2014

	Period 2000 - 2014 Nr. of installations	Grants in Mio EUR	Investments associated in Mio EUR	Average Investment in EUR
Solar thermal	**1.140.000**	**1.330**	**9.900**	**8.684**
Heating with biomass	**366.000**	**660**	**5.300**	**14.481**

As shown in Table 26 almost 2 bn EUR for grants have been given which triggered 15,5 bn EUR investment in heating installations with renewable energy.

The second support element of MAP has been realized with a total of 19.031 low interest loans for bigger solar thermal projects, biomass installations and deep reaching geothermal installations, with redemption grants. The overall volume of this loans reached EUR 3 bn between 2000 and 2014. The redemption grants summed up to 720 Mio[109].

4.6.3. Subsidies for improving energy efficiency

Efficiency first is the clear priority for the energy efficiency strategy for buildings, as has been formally decided on November 2015[110].

The measures developed can be divided into

- Strategy
- Consulting

109 (Bundesministerium für Wirtschaft und Energie, 2015)
110 (Bundesministerium für Wirtschaft und Energie, 2016)

- Financial support
- Monitoring

For all areas detailed programs have been developed and partially put in place since more than a decade, but have been refined and adjusted to the actual situation as well as to the goals for CO_2 reduction defined for 2020 and further on. Communities, as well as, small and medium business and private households are the main target groups of these programs.

Strategy puts the improvement of the efficiency on top of the program, which will trickle down to energy savings and sub sequential CO_2 savings.

Consulting is the key program to inform the interested communities. This includes the individual investor into refurbishing or building of flats, houses, commercial buildings, as well as the procurement of energy efficient installations and appliances.

Financial Support is provided via different programs: Energy efficiency for buildings, MAP, APEE, STEP up!, Contracting for energy savings, changing of lights to LED as well as waste heat recuperation for industrial processes.

Very important is the **Monitoring** part which supports activities to measure the actual consumption of each single installation/ appliance used, labels heating installations (average age more than 17 years) and finally enforces regular energy audits[111]. These shall support CO_2 savings of 3,4 Mio tons till 2020.

The following Figure 4-13 is summarizing all activities identified in a more detailed overview.

CO2 Buildings renovation program	**Market incentive program for renewable energy**	**Initiative energy efficient nets**	**Obligatory energy audit for big companies**	**Strategy energy efficiency buildings**
Energy Consulting	**Using waste heat**	**extent KfW energy efficiency programs**	**Competitve tendering for energy efficiency electricity**	**Incentive program energy efficiency**
National Top-Runner-Initiative	**Support market surveillance**	**New EU energy label**	**Pilot savings counter**	**National efficiency label heating installations**

Figure 4-13: German activities for EEG, NAPE meter ,Source: http://www.bmwi.de/DE/Themen/Energie/Energieeffizienz/NAPE/infografik-nape.html, 15.07.2016, own summary

[111] (Bundesministerium für Wirtschaft und Energie, 2016)

		Communities	Companies	Private Households	Mio EUR	Time period	How
STRATEGY	Efficiency first	x	x	x			strategy for energy efficent buildings / CO2 neutral 2050
CONSULTING							
	Energy consulting	x	x	x		ongoing	For private consumers max 400/800/1100 EUR / measure
	including waste water installations						
	Energy efficiency manager	x	x				
	regional						
	Service center "energy efficiency"		x				Information and consulting for companies
							information for consumers shall trigger an efficiency change
	Top Runner Initiative		x	x			promote the energy efficiency at the sales point
FINANCIAL SUPPORT	Energy efficiency for buildings						Grants
	4,2 Mio flats since 2006						low interest loans
	triggererd 239 bn EUR investment	x	x	x	2.000	2016 - 2018	repayment grants
	Residential buildings	x	x	x			75.000 EUR / Building
	Renovation/ new building		x	x	1.200	2016 - 2018	low interest loans (900 in 2015)
	MAP /renewable heating	x	x	x	300 per year		
	APEE						
	Incentivized Energy efficiency program	x	x	x	165 per year	2016 - 2018	Grants (10% to 15% of total cost)
	Heating and Airconditioning						low interest loans
							repayment grants
	Competition on	x	x	x	300	2016 - 2018	
	electrcity efficiency						maximum electricity savings / EUR granted
	STEP up !						
	Contracting		x				min. 25% energy savings
	for Energy savings						trigger a guarantee for up to 2 Mio EUR
							for the loan/ 10 years
	Waste heat recuperation		x		300	2016 - 2020	Grant and low interest loans
	lighting changed to LED				158		mainly LED projects
MONITORING	Measuring per unit		x	x			Companies offering the service of measuring EE for each
							installations will be supported
	Labelling of electrical appliances		x				improve labeling to A-G and enable easy
	Energy audits		x				big companies obliged since April 2015
	Labelling of old heating installations	x	x	x		2016 -	obligatory as of 2017

Figure 4-14:Summary of energy efficiency measures in Germany, Source: (Bundesministerium für Wirtschaft und Energie, 2016), own compilation

The impact of all measures as presented in Figure 4-14 are planned to result in saving of the primary energy consumption of 390 – 460 PJ and reduce the CO_2 emissions for 25 to 30 Mio tons till 2020[112]. The cost of this program adds up to approximately EUR 250/ ton of CO_2 avoided by 2020. Measures in place will have a longer lasting effect, beyond 2020.

4.6.4. Subsidies for biofuels

Based on the EU Directive 2003/30/EU biofuels have been defined to reach a share of 5,75%, calculated in energy value, of all diesel and gasoline fuel used as of 2010. This Directive has been replaced by the Directive on renewable energy 2009/28/EU.

Based on this the substitution of fossil fuel with biofuels has been changed to

[112] (BMWi, 2015)

biofuels substitution of 3,4% for gasoline (adding of 5% bioethanol)
biofuels substitution of 6,3% for diesel (biodiesel included 7% on a general level)

Heading towards 2020, renewables in fuels are supposed to reach 10%. This includes biofuels first and second generation, hydrogen and electricity.
The usage of biofuels from waste and other non food materials will be counted double in order to reach the target. Electricity produced in renewable way for electric cars will be counted 2,5 fold.
As of 2015 the industry for refining petrol has to reduce their GHG emissions by 3,5%, this value increase 2017 to 4% and 2020 to 6%. GHG emissions of biofuels from waste are at 17%, from rapeseed 40% and from bioethanol 45% compared to GHG from fossil fuel. The newly introduced system will need a strict monitoring and controls in order to verify the calculated savings.
It can be seen from the development of the biodiesel volumes – Figure 4-15, that tax incentives and support for this product pushed the volumes till 2007, change of legislation reduced this segment, stagnating at 2 Mio tons/ year[113].

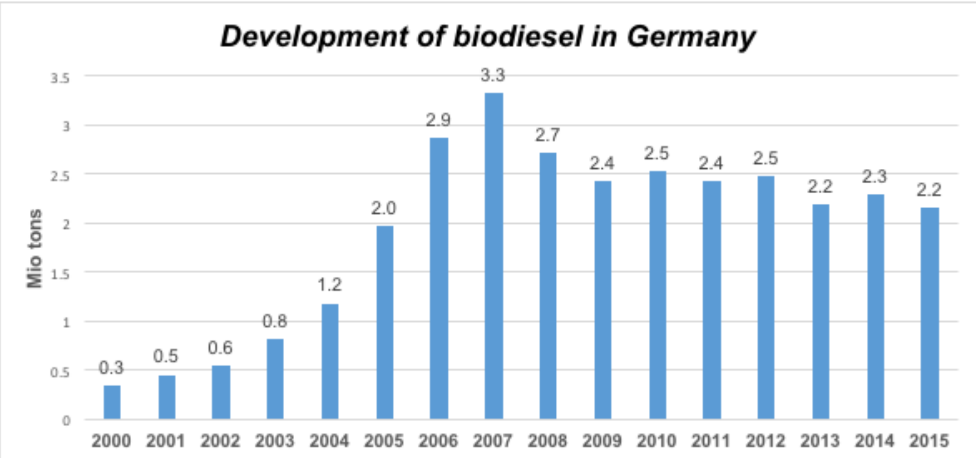


Figure 4-15: Development of biodiesel in Germany 2000 to 2015, Source: http://www.biokraftstoffverband.de/index.php/absatzzahlen.html, July 2016, own graph

The focus of usage of biofuels will remain on heavy trucks and agriculture.

4.6.5. Subsidies in research and innovation

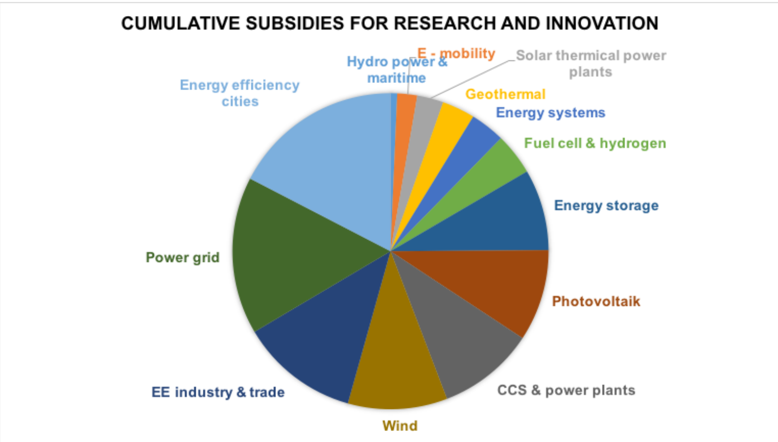
Research in renewable energies has a strong history in Germany.
The goals of the support of research in the energy sector are defined as follows:

[113] (Biokraftstoff Verband, 2015)

- Expand the usage of renewable energy in line with the climate and energy policy of the government
- Achieve significant cost reductions for renewable heat and renewable electricity
- Strengthen the international competitiveness of German companies and research institutes – finally create sustainable jobs.

Increasing the share of renewable energies needs a constant optimization of the energy system as a whole, guarantee a fast knowledge transfer from research to the market, ensure environmental friendly expansion of renewable technologies[114]

The Federal Ministry for Economy and Energy has summarized the amounts spent over the last years. EUR 2,8bn have been invested in research on how to improve renewable energy for the German and the international markets. In Figure 4-16 the percentage split and the absolute amounts for the individual areas cumulative as of 2015[115] can be seen.



	in %	Mio EUR
Hydro power & maritime	0,7%	19
E - mobility	2,0%	57
Solar thermical power pla	2,7%	75
Geothermal	3,4%	94
Energy systems	3,5%	99
Fuel cell & hydrogen	4,3%	119
Energy storage	8,3%	232
Photovoltaik	9,4%	262
CCS & power plants	9,9%	277
Wind	10,2%	284
EE industry & trade	12,1%	339
Power grid	16,1%	450
Energy efficiency cities	17,4%	486
TOTAL	100,0%	2.793

Figure 4-16:Cumulative subsidies for research and innovation as of 2015, Source: BMWE, Innovation durch Forschung, 2015, own summary

Most financial support for research has been put into energy efficient cities, the power grid and energy efficiency for industry, commerce and trade. The future of e-mobility has been partially covered with the fuel cell topic as well. Wind, photovoltaic and energy storage range at similar levels. CCS (Carbon capture and storage) and improvements for power plant technology is important for existing energy installations.

[114] (Bundesministerium für Wirtschaft und Energie, 2016)
[115] (Federal Ministry of Economy and Energy, 2016)

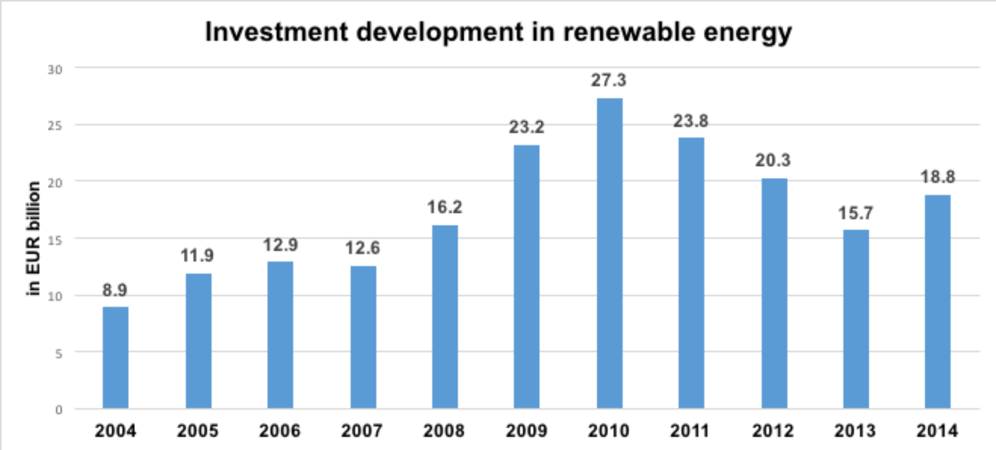


Figure 4-17: Investment development in renewable energy 2004 – 2014, Source: (Bundesministerium für Wirtschaft und Energie, 2015) , p. 23, own graph

As can be seen in Figure 4-17 investments into renewable energy have more than tripled in the period 2004 to 2010, and reduced to EUR 18,8 billion in 2014. 84,6% of the investment flows into installation for electricity production[116].

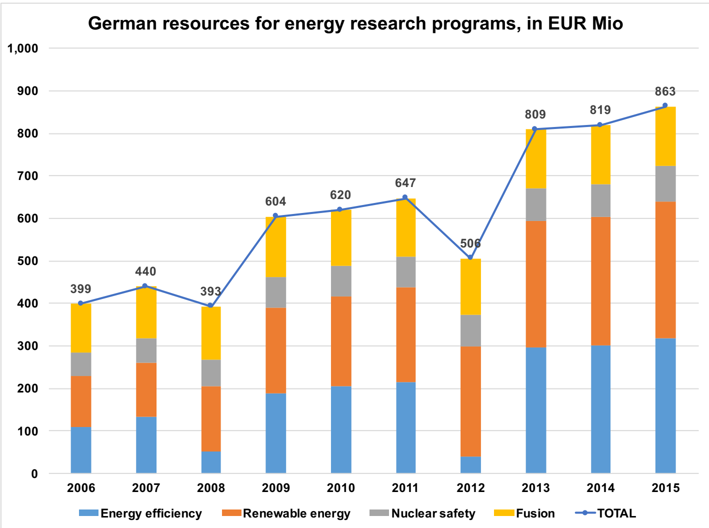


Figure 4-18: German resources for energy research programs, 2006 – 2015, Source: (Bundesministerium für Wirtschaft und Energie, 2016), own graph

Energy research received EUR 863 Mio in 2015, split between energy efficiency, renewable energy, nuclear safety and fusion, as visible in the Figure 4-18 above.

[116] (Bundesministerium für Wirtschaft und Energie, 2015)

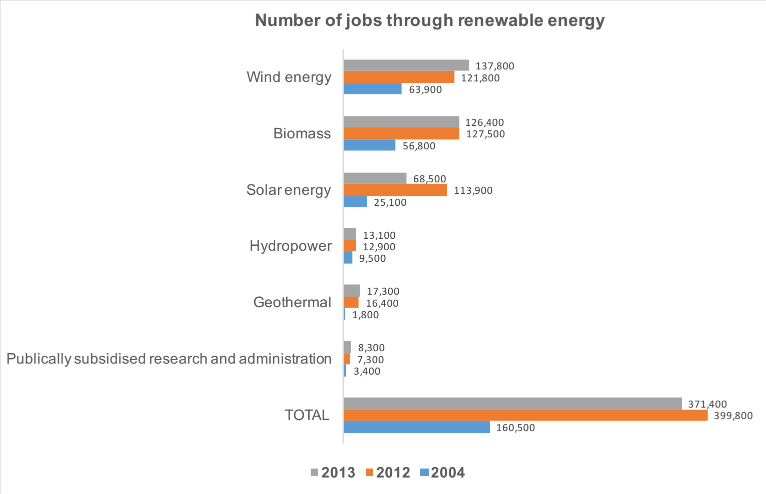


Figure 4-19: Development of jobs through renewable energy 2004 – 2013, Source, Federal Ministry for Economic Affairs and Energy, Gross employment from renewable energy in Germany in 2013 – a first estimate – as of: May 2014, own graph

Research and investment into renewables and the resulting expansion had also significant effects on the employment in this sector.

As described in Figure 4-19 jobs created in renewable energies more than doubled between 2004 and 2013. Gaining know-how and being able to implement it locally as well as to export it regionally and globally represents another serious potential for improving the overall effect of the decarbonization of the economy in Germany.

4.7. Conclusions

Risks related to the usage of fossil fuel have been visible in the last years: reduced availability, geopolitical risks, economic risks through international oligopolies, cartels, exchange rate risks, technological and ecological risks of mining the resources.

Since 2000 when the law on energy efficiency (EEG) has been implemented the first time, Germany followed a strict path towards decarbonization of the society. The German reunion in 1989 and the following restructuring of industries and electricity production in the eastern federal states (Neue Bundesländer) resulted in an 105 Mio ton CO_2 saving ("wall fall profit"). Industry with a share of 21% in GHG emissions reduced them since 1990 from 283 Mio tons CO_2 eq. to 187 Mio tons in 2014. In the last ten years no significant improvements have been made.

Whereas there is a focus on energy efficiency in buildings and to supply the energy needed with renewables is followed along with the strategy developed, a lot of effort has to be taken to convince still the majority of citizens as well as companies to follow this path.

The most challenging sector in the German strategy is the transport, responsible for 18% of the emissions. Out of the 164 Mio tons of CO_2 61% (100 Mio tons) are from passenger transport, 35% or 57 Mio tons CO_2eq from commercial vehicles and the remainder from rail shipping and domestic air transport.

Valid as of July 1st 2016 electric cars, fuel cell cars and plug in hybrids are subsidized with EUR 2000/car respectively EUR 1500/car from the German state, and with the same amount from the car distributor[117]. This program is aiming to motivate as much participants as possible to come closer to the vision of one million e-cars in Germany by 2020. Additional effort is needed in providing the infrastructure of e-loading stations for the future increased amount of e-cars.

Table 27: Development of CO2eq emissions in EU and Germany, 1990 – 2013, and goals 2020, 2030, 2050, Source: European Commissions, http://ec.europa.eu/clima/policies/strategies/2020/index_en.htm, http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/145397.pdf, https://ec.europa.eu/energy/sites/ener/files/documents/2012_energy_roadmap_2050_en_0.pdf, http://www.umweltbundesamt.de/daten/klimawandel/treibhausgas-emissionen-in-deutschland, http://www.bmub.bund.de/themen/klima-energie/klimaschutz/nationale-klimapolitik/, http://www.bmub.bund.de/fileadmin/Daten_BMU/Download_PDF/Klimaschutz/klimaschutzplan_2050_entwurf_bf.pdf
September30th, own summary

Development of GHG emissions in Mio tons of CO2 eq				
	EU		D	
1990	5.735	100%	1.248	100%
2000	5.284	92%	1.041	83%
2005	5.347	93%	995	80%
2012	4.691	82%	940	75%
2013	4.602	80%	950	76%
2014	4.419	77%	902	72%
Target 2020	4.588	80%	750	60%
Target 2030	3.441	60%	562	45%
Vision 2050	1.147	20%	250	20%
Vision 2050	287	5%	62	5%

Table 27 summarizes the development of GHG emissions in Germany since 1990. As of 2014 a reduction of 28% has been realized. According to German estimates the 2020 goal of 40% will not be reached, but further efforts towards the ambitious 2030 goals are visible on all levels.

[117] (BAFA, 2016)

The structured approach from strategy to measures to monitoring and a consequent involvement of the public as well as educational efforts, supported with a financial model on how to improve renewables is showing a successful model of changing the society to a low carbon one !

German politics in implementing renewable energy is very structured, goal oriented and has a transparent monitoring in place.

Germany is a high emitter but also the leader in improvements and is pushing new developments in research, industry, behavior and is finally benefitting from improvements in ecological and economical results!

5. Scenario for the development of CO_2 in passenger transport in India, China, Japan, US, EU till 2050, based on Kaya formula

As outlined above, CO_2 emissions increased over time with increasing population, increased energy need and growing GDP. As todays economy is based on fossil fuels the CO_2 emissions are linked to the energy needed for an increased service level.

5.1. KAYA equation

This observed principle has been summarized into a formula by Prof. Yoichi Kaya[118] in 1990 and is presented under the KAYA equation:

Global CO_2 emissions= Population x (GDP/Population) x (Energy use/ Unit of GDP) x (Carbon emissions/Energy unit)

This chapter will focus on the potential development of CO_2 emissions based on the GDP growth, population growth as well as service level for passenger transport for China, India, EU, Japan and US. A comparison of CO_2 development under the current known efficiency limits, as well as for technically feasible limits will be shown.

5.2. Development of passenger transport and GDP growth in the EU

From 1990 to 2002 GPD growth and growth of passenger transport had a very strong correlation in the EU15 countries, as can be seen in Figure 5-1. For Portugal, Spain and Greece the growth of GDP and the growth of passenger transport strongly correlated over that time period. Germany and Austria showed a rather weak correlation for that time period.

[118] (Manicore, 2014)

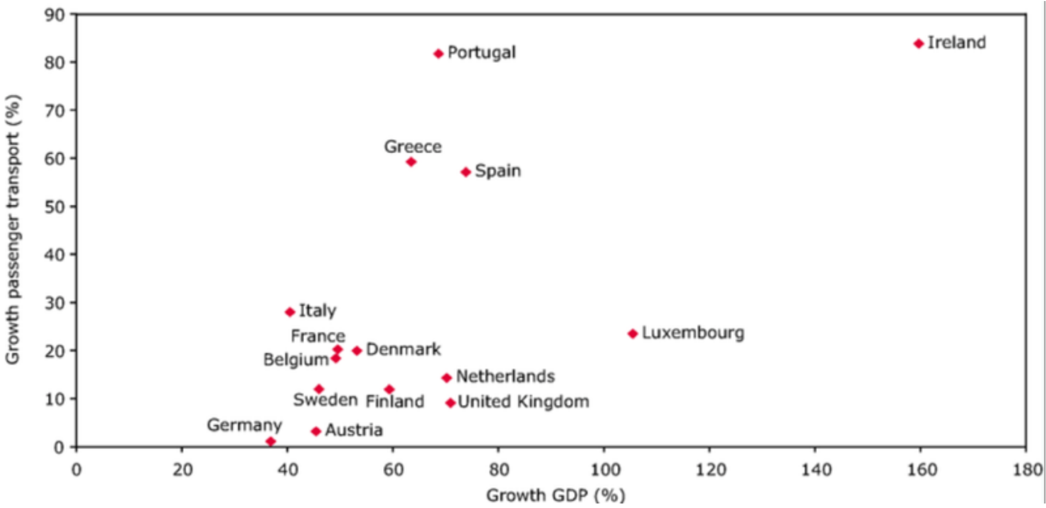


Figure 5-1: EU 15 1991 to 2002 , GDP growth and Growth in Passenger Transport, http://www.eea.europa.eu/downloads/F25DF79E-F29B-4502-A94B-9A96925D9612/1354185495/correlation-in-growth-of-passenger-transport-vs-gdp-growth.pdf

5.3. Global passenger transport emissions and agreed emission limits for fast growing economies

Transportation caused 23% of global GHG emissions in 2010[119], as can be seen in Figure 5-2, and has been increasing substantially over the last decades. Especially road transport has been contributing over-proportionally to the CO_2 growth over that period and is continuing to do so . The share for light vehicles for passenger transport adds up to 9,1 % or 3,5 Gt.

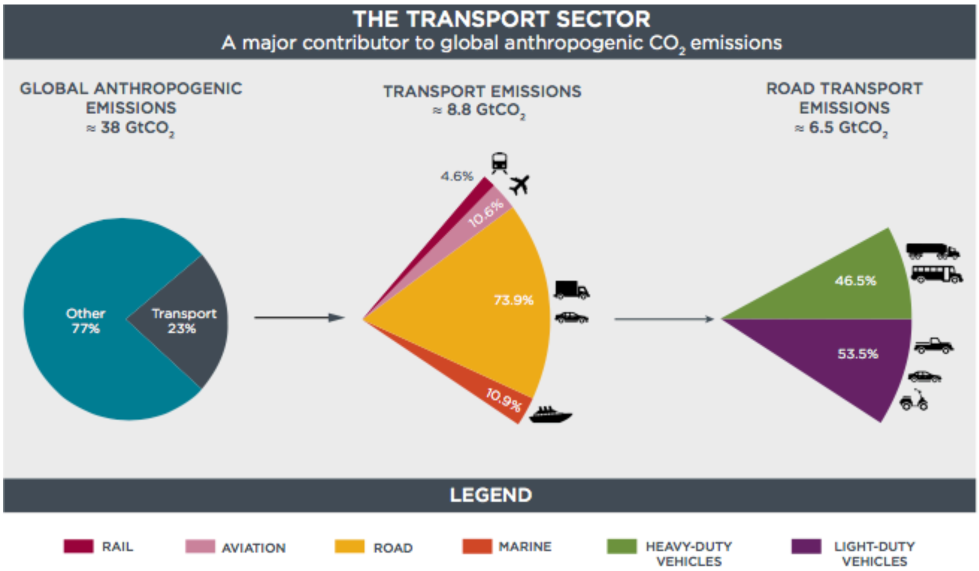


Figure 5-2: Global share of CO2 emissions in transport 2010, Source: ICCT, "a synthesis of vehicle and fuel policy developments, 2014

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119 (ICCT, Joshua D. Miller & C. Facanha, 2014)

Accepting the fact, that especially in Asia population growth is happening and that with an increase in GDP growth also a need for the increase in the service level regarding transport will take place, a comparison of two scenarios will be presented:

1. *Business as usual for an increase of the transport service level in China, India, EU, Japan and the US at current energy consumption levels*

2. *Emission reduction scenario based on todays knowledge of the individual countries reduction targets up to 2030, extrapolating them to 2050*

Based on the ICCT (International Council on Clean Transportation) historical analysis of consumption of fuel/ km as well as related CO_2 emissions achieved and targets defined the calculation for total CO_2 emissions from passenger cars up to 2050 has been used and calculated.

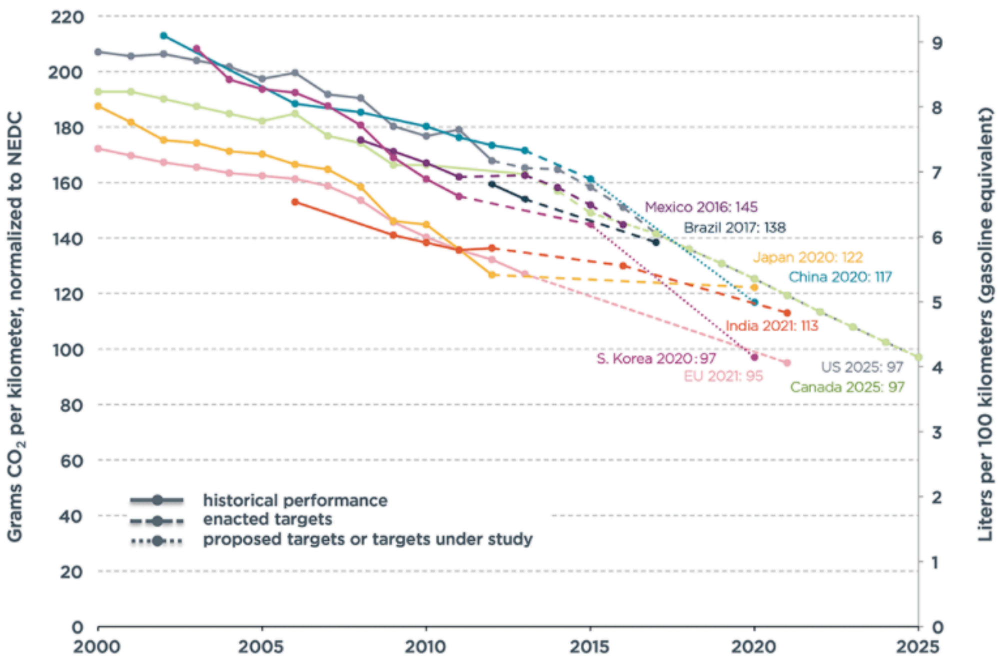

Figure 5-3: Historical performance of light duty vehicles and consumption goals set for Mexico, Brazil, Japan, China, India, US, S. Korea and the EU, Source: http://www.theicct.org/blogs/staff/improving-conversions-between-passenger-vehicle-efficiency-standards, July 2016

As shown in Figure 5-3 CO_2 emissions based on fossil fuels will be reduced by more than half from the year 2000 from values above 200 g CO_2 /km to 100g CO_2 /km planned for 2020[120].

5.4. Results for CO_2 emissions in case of business as usual (BAU) scenario

In the following graph the development of CO_2 emissions for China, India, EU, Japan and US can be seen. GDP growth for all involved countries/regions has been anticipated[121].
Population stabilizes for China till 2050, India will still grow significantly, EU and US moderately and Japan, with an aging population and almost no migration into the country, will reduce its population during that time period. Based on the actual passenger km driven, following the Kaya equation, it has been assumed that km driven will increase with the GDP development and the population increase.

Table 28: Development of CO2 emissions for personnel transport in China, India, EU, Japan and USA 2014 and 2050, Source: JAMA[122], UNEP[123], http://www.theicct.org/blogs/staff/improving-conversions-between-passenger-vehicle-efficiency-standards, July 2016, own graph

	2014 GDP USD bn	2050 GDP growth in %	2014 Population in Mio	2050 Population growth in %	2014 GDP/ capita in USD	2014 Transport Service km/person	2050 Transport Service growth in %	2014 Consumption l/100km	2014 Emissions g CO2/km	2014 - 2050 Consumption l/100km	2014 - 2050 Emissions g CO2/km	2014 CO2 emissions Mio t	2050 CO2 emissions Mio t
China	17.632	3,4	1.382	0	12.758	2.229	3,5%	6,9	167	6,9	167	563	1.950
India	7.277	4,9	1.326	0,7	5.488	557	4,3%	5,1	135	5,1	135	100	579
EU	18.486	1,0	500	0,5%	36.972	11.900	0,5%	6,0	159	6,0	159	946	1.354
Japan	4.788	1,4	126	-0,4	38.000	5.920	1,8%	6,0	158	6,0	158	118	194
US	17.416	2,4	324	0,73	53.753	21.550	1,7%	6,5	158	6,5	158	1.091	2.585
												2.818	**6.661**

In Table 28 the development of emissions from passenger transport for China, India, EU, Japan and USA can be seen. Due to the GDP growth and the population growth the service need for transport will increase over that period and without changing the consumption over the time horizon it will more than double the total CO_2 emissions from 2,8 Gt to 6,7 Gt.

The following figure 5-4 shows the CO_2 emission increase for the BAU (business as usual) scenario, the US, EU and China leading the big CO_2 emissions related to transport over that period, due to the expected GDP growth and the increased service level in transport.

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[120] (ICCT, 2014)
[121] (PWC, Price Waterhouse Coopers, 2015)
[122] (JAMA, Japan Automobile Manufacturers Association, MAY 2015)
[123] (UNEP, 2015)

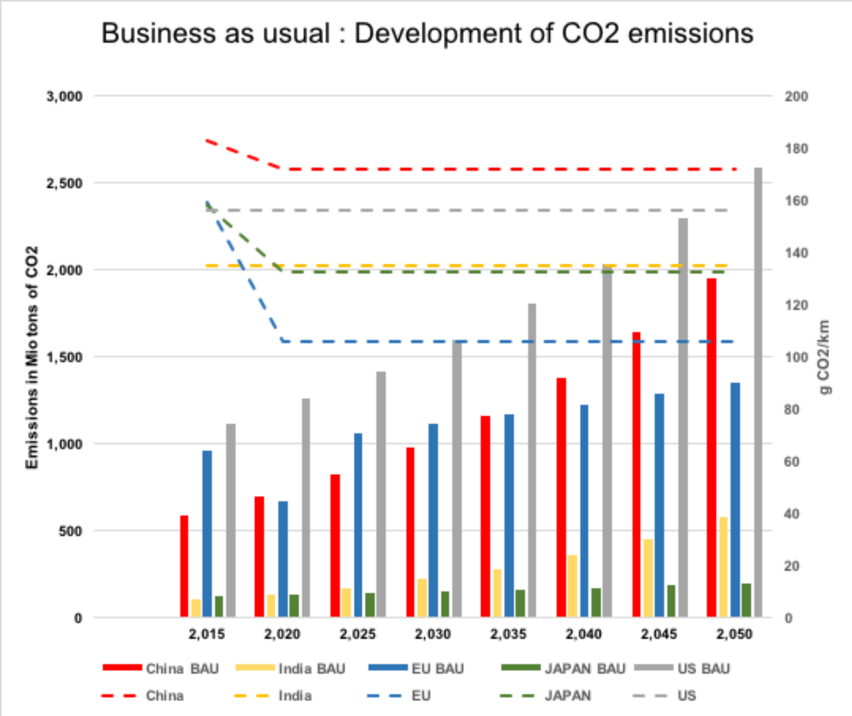

Figure 5-4: Development of CO2 emission for China, India, EU, Japan and USA for passenger transport from 2015 to 2050, Source: JAMA[124], UNEP[125], http://www.theicct.org/blogs/staff/improving-conversions-between-passenger-vehicle-efficiency-standards, July 2016, own graph

5.5. Results for reduced emissions growth

In Table 29 the effect of reduction of consumption due to technological improvements as well due to changes towards renewable technology can be seen. Even under the assumption of a continuous growth of service level, the CO_2 emissions can be reduced by more than 63% compared to 2014.

Table 29: : Development of CO2 emissions for personnel transport implementing technological improvements in China, India, EU, Japan and USA 2014 and 2050, Source: JAMA[126], UNEP[127], http://www.theicct.org/blogs/staff/improving-conversions-between-passenger-vehicle-efficiency-standards, July 2016, own graph

	2014 GDP USD bn	2050 GDP growth in %	2014 Population in Mio	2050 Population growth in %	2014 GDP/ capita in USD	2014 Transport Service km/person	2050 Transport Service growth in %	2014 Consumption l/100km	2014 Emissions g CO2/km	2050 Consumption l/100km	2050 Emissions g CO2/km	2014 CO2 emissions Mio t	2050 optimized CO2 emissions Mio t
China	17.632	3,4%	1.382	0,0%	12.758	2.229	3,5%	6,9	167	1,0	27	563	283
India	7.277	4,9%	1.326	0,7%	5.488	557	4,3%	5,1	135	1,0	27	100	113
EU	18.486	1,0%	500	0,5%	36.972	11.900	0,5%	6,0	159	1,0	27	946	226
Japan	4.788	1,4%	126	-0,4%	38.000	5.920	1,8%	6,0	158	1,0	27	118	33
US	17.416	2,4%	324	0,1%	53.753	21.550	1,7%	6,5	158	1,0	24	1.091	398
												2.818	1.052
													-63%
										BAU-Scenario		2.818	6.661

124 (JAMA, Japan Automobile Manufacturers Association, MAY 2015)
125 (UNEP, 2015)
126 (JAMA, Japan Automobile Manufacturers Association, MAY 2015)
127 (UNEP, 2015)

Figure 5-5 shows the development of the second scenario of optimized technology from 2015 to 2050. With a CO_2 intensity for passenger transport dropping from 167 gCO_2 /km to 27 gCO_2 /km over time, even under the scenario of a service level increase for passenger transport a reduction of CO_2 emissions for 63% can be expected.

This result is based on the precondition, that vehicles can use no more than 1liter of diesel/ gasoline, respectively EVs and with fuel cell operated cars will be the future main choice for transport and energy needed for that purpose will be produced in a renewable way.

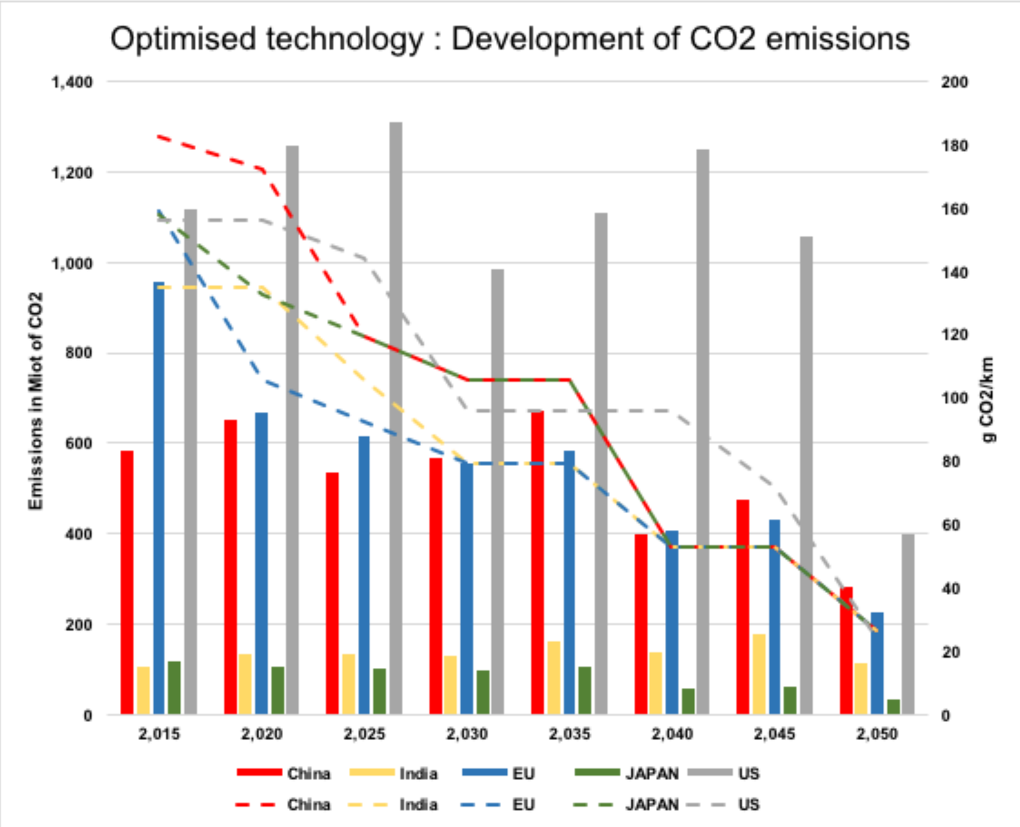

Figure 5-5: *Development of CO2 emission for China, India, EU, Japan and USA for passenger transport from 2015 to 2050, Source: JAMA*[128]*, UNEP*[129]*, <u>http://www.theicct.org/blogs/staff/improving-conversions-between-passenger-vehicle-efficiency-standards</u>, July 2016, own graph*

5.6. Conclusion on future scenarios

The Kaya equation is showing one potential future scenario, based on GDP growth, population growth, service level and CO_2 intensity. The main future levers will be the service level

[128] (JAMA, Japan Automobile Manufacturers Association, MAY 2015)
[129] (UNEP, 2015)

and the CO_2 intensity of the service provided in order to limit CO_2 emissions to an acceptable level. As can be seen in the comparison of the the BAU scenario and the scenario with usage of optimized technology, even a higher service level will not result in higher CO_2 emissions, but even allows to reduce the CO_2 emissions over the time horizon.

Having in mind, that already now legislation exists to limit the individual emissions for the cars entering the market into the next 5 years, it will be highly important to tighten the limits further and implement the readily available new technologies with low CO_2 emission values.

As this is technologically feasible already today, this is a huge opportunity for countries not yet invested in existing technology for their car park. It allows them to leapfrog technical developments todays higher developed countries have gone through. Similar as it happened with land line phones and mobile phones, or main frame computers and mobile computer equipment. This offers a big opportunity for a fast transition towards clean transport.

6. Conclusions

Coming back to the core objectives of the Thesis after the research and analysis done during the process of preparing this document it can be concluded following :

1. What lessons can be taken from the first 10 years of its execution?

The EU ETS has been instrumental in aligning the EU member states toward actions to reduce CO_2 emissions. Looking at the mere figures of CO_2 emissions development since 1990, the 20% achieved compared to 1990 is a success. The price mechanism for the CO_2 allowances did not materialize as foreseen before implementation of the EU ETS -the originally forecasted price for CO_2 allowances has been in the range of EUR 20/t to EUR 30/t. Roots causes for that are:

1. Over-allocation of allowances from 2005 to 2007 (based on grandfathering) – resulted in low CO_2 prices end of trading Period I
2. Adding significant amounts of allowances from CDM and JI in trading Period II 2008 -2012 (as defined in the Kyoto protocol) -> resulted in low CO_2 prices in trading Period II.
3. Global economic crisis starting 2008 and reducing the industrial output significantly. -> resulted in low CO_2 prices trading Period II II. New mechanisms for economic fluctuation and external shocks are included for the trading Period III with backloading and MSR (market stability reserve).
4. Auctioning of certificates for electricity producers with high GHG emissions postponed for EU members joining 2004 and thus postponing improvements in these installations (biggest Poland)
5. Free allocation for industrial installations due to carbon leakage -> profits generated within these companies have not been allocated to GHG reduction measures
6. The increase of electricity production with renewable energy leads to reductions in the CO_2 emissions which is only partially accounted for in the model
7. External cost has a political and economic dimension, generally not considered and are effecting global competitiveness, resulting in missing integration.
8. Potential losers of the transformation are existing monopolies and oligopolies still connected in strong lobbying/networks and slow down efforts which harm their economic success or personal well being

Table 30: : Development of CO2eq emissions in EU, Austria and Germany, 1990 – 2013, and goals 2020, 2030, 2050, Source: European Commissions, http://ec.europa.eu/clima/policies/strategies/2020/index_en.htm, http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/145397.pdf, https://ec.europa.eu/energy/sites/ener/files/documents/2012_energy_roadmap_2050_en_0.pdf, Statistic Austria 2015b, http://www.umweltbundesamt.de/daten/klimawandel/treibhausgas-emissionen-in-deutschland, http://www.bmub.bund.de/themen/klima-energie/klimaschutz/nationale-klimapolitik/, http://www.bmub.bund.de/fileadmin/Daten_BMU/Download_PDF/Klimaschutz/klimaschutzplan_2050_entwurf_bf.pdf, September30th, own summary*,*

Development of GHG emissions in Mio tons of CO2 eq									
	EU		A		A ETS	A non ETS		D	
1990	5.735	100%	78,0	100%				1.248	100%
2000	5.284	92%	80,2	103%				1.041	83%
2005	5.347	93%	92,6	119%	35,9	56,7	100%	995	80%
2012	4.691	82%	80,2	103%				940	75%
2013	4.602	80%	80,0	103%				950	76%
2014	4.419	77%	76,3	98%	28,2	48,1		902	72%
Target 2020	4.588	80%	77,8	100%	22,93	47,59	-16%	750	60%
Target 2030	3.441	60%	54,1	69%	17,87	36,26	-36%	562	45%
Vision 2050	1.147	20%	15,6	20%				250	20%
Vision 2050	287	5%	3,9	5%				62	5%

Table 30 shows that the EU overall , as well as Germany, as one of the main contributors to that development could reduce GHG emissions significantly. Austria will have to increase efforts to reach the 2030 goals.

Further CO_2 reduction success depends heavily on the involvement of sectors in the non EU ETS as there are transport, small commerce, households and agriculture.

2. How are the support systems for renewable energy aligned with the ambition to reduce GHG by 40 % by 2030 compared to the base year 1990 for A, D, EU?

Germany , strongly industrialized, based its energy on domestic hard coal and lignite and imports of gas and petroleum, starting with 2% of renewables in 1990. As of 2014 already 12,4% of the gross final energy are renewable, based on the ENERGIEWENDE, and the EEG, which is pushing the electricity sector towards solar, wind and biomass. The exit from nuclear power in 2022 and the foreseeable exit from the lignite mining and lignite based electricity production after 2030 will need further strong changes towards renewable energy, as well as increased energy efficiency.

The car industry is one of the backbones of the German economy. The transfer of successful research into commercial viable products and service solutions for transport is one of the biggest challenge for Germany. Mobility is an industrial advantage and has to be based on renewal energy for Germany to keep its role on the top of the pack of industrial producers.

The successful realization will only be possible if all citizens can be convinced about the necessity and the advantage for the individual and for the society as a whole.

Austria started from a good base in 1990 with a high percentage of hydro energy for electricity and biomass for heating is on a good track to reach renewable goals defined by the EU for 2020. For 2014 an absolute CO_2 reductions of 2 Mio tons, reaching 76,3 Mio tons of CO_2 emissions have been achieved. Further effort is needed for emission reductions in the transport sector and households which increased their service level significantly and added 13,5 Mio tons of CO2 outnumbering any savings in other sectors.

Transport emissions increased due to higher service levels but also, due to cheaper diesel, which is bought from individuals and transport companies of neighboring countries (tank tourism).
From the analysis it can be concluded that the support systems in place could be improved by a more focused approach based on a clearly defined strategy, aligned with the goals defined for 2030 but aiming at the decarbonization of the economy after 2050.
Whereas this strategy must be agreed on country level, the execution and measuring of improvements must be in the responsibility of the federal states and the communities which are closest to the citizens. Without a broad citizen involvement no sustainable success can be achieved.
Further research would be interesting regarding the cost and the efficiency of measures.
Potential additional KPIs considered could be:

- EUR/ ton of CO2 avoided over the life time of the investment
- Speed of implementation versus long term sustainability of the measures.
- Price tag of external cost / liter fossil fuel

3. Which sectors have to be focused on and which activities are the most urgent reaching the 40% GHG reduction target as a milestone on the path towards decarbonization?

The whole building stock in Austria, Germany and EU has to be refurbished and rebuilt to reach passive house standards (except historical buildings). Accepting the megatrends mentioned earlier, the whole transport sector has to be decarbonized.
The megatrends include:
People moving towards cities, aging generations, improving public transport, using of railway for transporting goods, increasing use of bikes in the cities, use of cars with EV and methane and hydrogene produced with renewables. In Germany the electricity production has still a big challenge ahead, as nuclear will phase out in 2022 and lignite and hard coal production should start this process after 2030.
Looking at the available data, still a lot of subsidies are not in line with the goals ahead of us Reducing and phasing out fossil fuel will need ongoing strong financial support from all parties involved. The cost of restructuring the whole energy system has to be balanced in a way that all citizens are sharing the burden in a balanced way.

Long term sustainability can be achieved only if economy, ecology and social needs are in balance and based on ethical rules.

There is an interesting future ahead of us !

“We have more ability than will power, and it is often an excuse to ourselves that we imagine that things are impossible.” François de la Rochefoucauld

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List of abbreviations and symbols

BMVIT	Federal Ministry for Transport, Innovation and Technology
CCS	Carbon Capture and Storage
CDM	Clean Development Mechanism
CEE	Central and Eastern Europe
CER	Certificates of Emission Reductions
CO2	Carbon Dioxide
COP21	Conference of the Parties number 21
EBRD	European Bank for Reconstruction and Development
EEX	Emission Exchange Leipzig
ERU	Emission Reduction Units
EU	European Union
EUA	European Union Allowance (CO2)
ETS	Emission Trading System
EUR	Euro
FIT	Feed in Tariff
GDP	Gross Domestic Product
GHG	Green House Gas
GW	Giga Watt
ICCT	International Council on Clean Transportation
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
JI	Joint Implementation
LULUCF	Land Use, Land Use Change and Forestry
MAP	Markt Anreiz Programm / Market incentive Program
MSR	Market Stability Reserve
NAPE	National Action Plan on Energy Efficiency
NAP	National Allocation Plan
NER	New Entrance Reserve
PV	Photovoltaic
RE	Renewable Energy

RED	Renewables Energy Directive
RES	Renewable Energy Sources
PJ	Peta Joule
TOE	Ton Oil Equivalent
UNFCCC	United Nation Framework Convention on Climate Change
USD	US Dollar

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