CECILIA 2050
OPTIMAL EU CLIMATE POLICY

Choosing Efficient Combinations of Policy Instruments for Low-carbon development and Innovation to Achieve Europe's 2050 climate targets

Assessing interaction between instruments and the 'optimality' of the current instrument mix

Funded by the European Union

This project has received funding from the European Union's Seventh Programme for Research, Technological Development and Demonstration under Grant Agreement no. 308680.

AUTHOR(S)

Dr Luis Rey, Basque Centre for Climate Change (BC3).

Professor Anil Markandya, Basque Centre for Climate Change (BC3).

Dr Mikel González-Eguino, Basque Centre for Climate Change (BC3).

Paul Drummond, University College London.

With contributions by:

Benjamin Görlach, Ecologic Institute

With thanks to:

Gjalt Huppes

Project coordination and editing provided by Ecologic Institute.

Document title	Assessing interaction between instruments and the 'optimality' of the current instrument mix
Work Package	WP1
Document Type	
Date	20 November 2013
Document Status	Final
Please Cite As	Rey, Luis; Markandya, Anil; Gonzáles-Egiuno, Mikel; Drummond, Paul, 2013. Assessing Interaction between instruments and the 'optimality' of the current instrument mix. CECILIA2050 WP1 Deliverable 1.3. Bilbao: Basque Centre for Climate Change (BC3), London: University College London (UCL).

ACKNOWLEDGEMENT & DISCLAIMER

The research leading to these results has received funding from the European Union FP7 ENV.2012.6.1-4: Exploiting the full potential of economic instruments to achieve the EU's key greenhouse gas emissions reductions targets for 2020 and 2050 under the grant agreement n° 308680.

Table of Contents

LIST OF ABBREVIATIONS

CDM	Clean Development Mechanism
CER	Certified Emissions Reduction
EC	European Commission
ERU	Emissions Reduction Units
EU	European Union
EU ETS	European Union Emissions Trading System
GHG	Greenhouse Gas
JI	Joint Implementation
IPPC	Integrated Pollution Prevention and Control
PV	Photovoltaic
RES	Renewable Energy Sources
RES-E	Electricity from Renewable Energy Sources
UK	United Kingdom
WP	Work Package

1 Executive summary

The European Union faces the challenge to reduce its greenhouse gas emissions by 80% below 1990 levels by 2050 while maintaining its economic competitiveness on global markets. This requires finding the most effective policy instrument mix that can meet this objective. In order to define potential pathways towards 2050, the CECILIA2050 project is initially assessing the ‘optimality’ of the current instrument mix. The optimality assessment covers three criteria: environmental effectiveness, cost-effectiveness and feasibility. This document focuses on the instrument mix implemented at the EU level, and in a representative set of eight EU Member States: the Czech Republic, France, Germany, Italy, the Netherlands, Poland, Spain and the UK.

The EU Emissions Trading System (EU ETS) is the main instrument of the European Union’s policy to combat climate change. It covers power and heat generation, energy-intensive industries and, since 2013, commercial aviation. In total, these sectors account for around 45% of total EU emissions. The EU ETS is a ‘cap and trade’ system which ensures a certain emission reduction[1], but not a carbon price level. Since 2008, the economic recession has reduced the demand for allowances and, hence, the carbon price has slumped. Low carbon prices do not imply that the EU ETS is not achieving a reduction in GHG emissions in a cost-effective manner, at least in the short-run. However, the price signal is not in line with the expected role of the EU ETS in the transition to a low-carbon economy. A low carbon price suggests that the emission reduction target has become easier to meet and a more ambitious target might be desirable. A low carbon price also hinders the dynamic efficiency of the scheme and may induce a technological lock-in. The empirical evidence suggests that the low and uncertain carbon price of the EU ETS did not incentivise innovation in low-carbon technology.

The interaction of the EU ETS and other policy instruments may be beneficial in improving the design of the scheme, while also correcting for market failures and meeting other policy instruments (Sijm, 2005). RES-E support schemes, for instance, have been the major incentive to deploy renewables in electricity generation. Moreover, some instruments, such as the feed-in tariff, have had a positive impact on innovation, particularly in the less mature technologies. In the promotion of energy efficiency measures, the carbon price set by the EU ETS may not encourage the adoption of cost-effective measures due to market failures (e.g. principal-agent problem, capital market imperfections). Non-market based instruments (e.g. energy efficiency standards) are beneficial to implement those measures with an abatement cost lower than the carbon price of the EU ETS.

[1] The EU ETS establishes an annual linear reduction of 1.74% which should be reviewed no later than 2025.

On the other hand, the interaction of the EU ETS with other instruments is affecting the functioning of the scheme. Although, when the EU ETS cap was set, the effects of other policy instruments were considered, they inevitably introduced an element of uncertainty, because the success of other policies could not be predicted. The overachievement on their targets did not result in lower emissions, but in a lower EU ETS price.

Through the promotion of renewable sources of energy, the current instrument mix has been successful in increasing the share of renewables[2]. The carbon price generated by the EU ETS was not high enough to promote renewable sources of energy in electricity generation (del Río, 2009). RES-E support schemes were the major incentive to spur renewables in the EU[3], especially feed-in tariff schemes (e.g. Spain, Germany), which have been more effective than quota obligations (e.g. UK) (Steinhilber et al, 2011). In 2011, the share of renewable energy in gross final energy consumption was 13%, which is above the EU interim target for 2011/2012 (10.7%). Despite this, the economic crisis has affected the reliability of the current instrument mix and, therefore, further efforts will be needed to reach the 2020 target (ECOFYS et al, 2012). From the static efficiency perspective, the promotion of RES-E is far from optimal. RES-E schemes have generated very high abatement costs, well above the EU ETS price, affecting the static efficiency of the instrument mix. Besides, the different abatement costs across countries and technologies highlight the economic inefficiency in the promotion of RES-E.

The instruments implemented to reduce energy consumption and improve energy efficiency have mainly focused on the building and transport sectors. Over the period 2005-2010 primary energy consumption decreased by 3.6% in the EU, which implies energy savings of 5.4%[4]. EC (2011) estimates that under the current scenario, which includes those policies implemented by December 2009, the reduction in the energy consumption (with respect to the baseline scenario) would be only about 8.9% in 2020. Further efforts therefore will be necessary, particularly in the transport sector, which accounts for around 20% of total GHG emissions and where, unlike other sectors, emissions have not decreased since 1990. Current instrument mix has been successful in improving the efficiency of vehicles (e.g. efficiency standards for new cars, energy labelling, CO_2-based vehicle registration tax), but the potential for additional energy savings is still significant, especially in the modal shift, which current policy mix has failed to improve. From the economic efficiency perspective, taxes on transport fuels are not optimal. Although the carbon content of diesel is higher than of

[2] The EU aims to get 20% of its energy from renewable sources by 2020.

[3] It can be argued that RES-E support schemes reduced the demand of the emission permits and thus their price. This may have avoided generating high enough carbon prices to incentive the promotion of renewables.

[4] Energy savings are accounted as the difference between actual energy consumption and projected consumption.

gasoline, the implicit carbon price[5] for diesel is lower in all Member States. In the Netherlands, for instances, the implicit carbon price of diesel is half of gasoline.

Energy efficiency has also improved in buildings, where direct GHG emissions declined by 15.7% from 2000 to 2011. As in the transport sector, energy efficiency gains might not lead to proportional energy reductions, because of rebound effects. Energy efficiency can lead to lower energy demand and, thus, to lower energy prices, resulting in price and income effects. This causes an increase in energy demand again. Rebound effects are larger when energy prices are not high enough. Hence, this could be particularly important in countries such as the Czech Republic, Poland, Spain and the UK, where the implicit carbon price of electricity and natural gas for households is zero or nearly zero.

In relation to non-CO_2 emissions, the current instrument mix has been more successful in reducing emissions in waste and industry than in agriculture. Some instruments such as landfill taxes and the ban of landfilling untreated waste have been effective in reducing CH_4 emissions. In agriculture, the decline of non-CO_2 emissions have been caused by the reallocation of agricultural production, the increase in animal productivity and the lower use of organic and mineral nitrogen fertilizers (Fellmann et al, 2013). Despite the decline in emissions, generally non-CO_2 GHG emissions receive little attention by the current instrument mix.

From the dynamic efficiency perspective, as mentioned above, the existing literature suggests that the EU ETS has not been able to spur innovation in new low-carbon technologies by itself (del Río, 2009; Egenhofer, 2011). The low and uncertain carbon price did not provide a sufficiently strong signal to invest in clean technology. The implementation of non-market based instruments (e.g. feed-in tariff) in the promotion of RES-E has had a positive impact on innovation, particularly in the less mature technologies (Johnstone et al, 2010). In the industrial and transport sector, the empirical evidence shows that those Member States with higher energy taxes encourage more innovation in energy-efficient technologies (Aghion et al, 2012). In buildings, it seems that energy prices have not been high enough to promote innovation and, thus, energy efficiency standards (e.g. Energy Performance of Buildings Directive) have been the main drivers of innovation (Noailly, 2012). The literature also suggests that public R&D financing plays an important role in innovation as compensation for underinvestment in the private sector (Popp, 2010).

Finally, the feasibility of the current instrument mix is generally high. Although the EU ETS has been criticized because of the 'windfall profits' and the 'over-allocation' problems, there is little political or public resistance to this instrument. There is no empirical evidence that the EU ETS led businesses to reduce their competitiveness and transfer production to other countries ('carbon leakage'), partly aided by the low carbon price of the EU ETS. The economic recession has reminded us of the fact that an ETS controls absolute quantities, and

[5] The implicit carbon price for energy sources is as the amount of excise tax levied per unit of energy product divided by the $C0_2$-eq emissions per unit.

is not designed to deliver a certain price. The EU ETS is not flexible enough to alter the intra-phase emission cap and keep carbon price high under a new economic scenario or lower abatement costs. This is not necessary a failure of the scheme, which has been designed to deliver a pre-defined amount of absolute emissions in a given year, not to deliver a certain minimum carbon price. On the one hand, the countercyclical effect of the EU ETS relieves the burden on companies in a time of crisis. On the other hand, as mentioned above, a low carbon price is not in line with the expected role of the EU ETS in the transition to a low-carbon economy.

The public acceptance of energy taxes – and comparable measures like feed-in tariffs – is lower than that of other instruments considered. While energy-intensive industries are generally exempted, a small share of the total energy consumption has to bear the majority of the cost burden, and might generate a disproportionate burden on low income households. The subsidies to improve energy efficiency and reduce energy consumption (e.g. financial support for refurbishment of buildings and financial support for replacing inefficient cars) are more accepted by both consumers and producers. They may achieve cost reductions in the energy bill for some consumers and have a positive impact on the economic activity of some sectors[6]. These instruments are, however, subject to a constant uncertainty about the amount of available public funding. The rise of public debts and the increasing burden on taxpayers may reduce their feasibility. The support for renewable sources of energy by the general public is also high. The promotion of renewables has contributed to reduce energy dependence, the development of a highly dynamic sector, job creation and the improvement in local air quality. However, there is an increasing debate about the costs. In Spain and Germany, where the financial support for the RES-E has been high, electricity consumers are facing a rise in their final price. This can gradually reduce the support by the general public for renewable energy. Finally, in most Member States, non-CO_2 GHG emissions receive little attention, especially in the agriculture sector. Probably this is not due to a low public acceptance, but to the high transaction costs related to their compliance and enforcement, which increase the administrative burden.

2 Introduction

The European Union (EU) faces the challenge to move to a competitive low-carbon economy by 2050. This means that the EU should cut its greenhouse gas (GHG) emissions to 80% below 1990 levels and ensure its economic competitiveness on global markets. The European Commission (EC) is looking at cost-effective pathways to meet this objective. The CECILIA2050 project has set out to identify an 'optimal' policy instrument mix for achieving the necessary GHG emissions reduction by 2050. The first step of the project is to understand

[6] Although it is questionable their effect on the overall economy.

the existing European climate policy instrument mix with its effects and limitations. Therefore, the objective of this report is to provide an initial and qualitative assessment of the current instrument mix. The analysis is focused on the EU27 itself, and on a representative set of eight EU Member States: the Czech Republic, France, Germany, Italy, the Netherlands, Poland, Spain and the UK.

The optimality of the instrument mix is assessed according to the criteria developed under Task 1.1 of CECEILIA2050[7]. The optimality assessment covers three dimensions: environmental effectiveness, cost-effectiveness and feasibility. The environmental effectiveness values whether the instrument mix is able to bring about the necessary emission reduction. The cost-effectiveness measures the cost associated to the emission reduction. This criterion includes the capacity to reduce emissions at least cost now (static efficiency) and over time (dynamic efficiency). The latter refers to the instrument mix potential to lower abatement costs in the future. The feasibility criterion indicates the risk that the policy fails to be adopted as planned and/or to deliver as expected. The CECILIA2050 project will follow a multicriteria-type assessment. Thus, all criteria and their trade-offs are assessed, but there is not an absolute hierarchy among them, this depends on the values and political priorities involved.

Based on the dimensions of the optimality criteria, the document is organised as follows. Firstly, the key instruments implemented at the EU level are presented[8]. They are divided into four policy landscapes: carbon pricing, energy efficiency and energy consumption, promotion of renewable sources of energy and non-carbon dioxide greenhouse gases. It is discussed how the current instruments overlap and how well they are integrated in each landscape and in the overall instrument mix.

In section 4, we assess the environmental effectiveness of the current instrument mix. Similarly to the previous section, the analysis is initially divided into the four landscapes. Thus, we examine the contribution of the EU Emissions Trading System (EU ETS) scheme, the key instrument of the carbon pricing landscape, to the emissions reduction. Then, it is assessed how the current instrument mix has contributed to increase energy efficiency and reduce energy consumption. It is also evaluated the promotion of renewable sources of energy and the reduction of non-carbon dioxide greenhouse gases. Finally, it is assessed the interaction of the overall instrument mix and its contribution to reduce GHG emissions, focusing on four key sectors: electricity generation, industry, transport and buildings.

Section 5 analyses the economic efficiency of the current instrument mix from the point of view of both the static and the dynamic efficiency. The static efficiency is assessed in terms of how successful the current policy mix is in generating unified carbon prices. We calculate the

[7] "Defining the concept of optimality, including political and legal framework conditions".

[8] Please refer to the "Taking stock of the existing instrument mix in Europe", developed under Task 1.2 of CECILIA2050, for a full description of the instruments.

implicit carbon price emerged from the excise tax on the main energy sources (e.g. electricity, natural gas, gasoline) and the abatement costs implied by the promotion of renewables (e.g. hydro, wind, photovoltaic). We compare the results with the carbon price generated in the EU ETS scheme to evaluate the effectiveness of the policy mix. Then, we analyse how the interaction between the EU ETS and other instruments induces the innovation in low-carbon technologies which can reduce abatement costs in the future (dynamic efficiency).

Finally, the feasibility criterion is analysed in Section 6. In addition to the EU ETS, we assess the feasibility of the current instrument mix in the promotion of energy efficiency, renewables and the reduction of non-CO_2 emissions. The assessment includes aspects such as the political, legal and administrative feasibility.

3 Current instrument mix and its interactions

3.1 Carbon Pricing

The two instruments in this landscape are the EU ETS and the Energy Taxation Directive (ETD). The explicit objective of the EU ETS is the reduction of GHG emissions (primarily CO_2) through an EU-wide, multi-sectoral cap-and-trade scheme. The primary objective of the ETD is to improve the functioning of the internal market, with secondary objectives of ensuring greater respect for the environment (although not explicitly through the reduction of GHG emissions), and to encourage employment through switching taxation from labour to energy products. It sets minimum tax rates on energy products used in transport, the production of heat and on the consumption of electricity. As such, the objectives of the instruments do not directly align, although a proposed revision of the ETD would correct this.

The EU ETS is directly linked to CO_2 emissions (with limited coverage of N_2O and perfluorocarbons from certain sectors), whereas the ETD is linked only indirectly to CO_2. Both instruments have wide sectoral coverage. The EU ETS applies to the large-scale production of electricity and heat, and a range of other energy-intensive industry sectors, as well as aviation. The ETD applies economy-wide to the consumption of electricity and motor fuels, and energy products used in the generation of heat (with exemptions). Products used for the production of electricity are exempt, alongside possible exemptions for heating in energy-intensive industry and domestic use, and all energy products used in the agriculture and international aviation sectors. There is relatively little direct target group overlap between the two instruments. Although, energy-intensive industry is subject to both instruments, as the ETD concerns direct fuel combustion and electricity consumption, whilst the EU-ETS concerns direct fuel combustion and process emissions.

The EU ETS and ETD have a conflicted relationship. Whilst the EU ETS directly incentivises emissions mitigation, the ETD, through the differential rates it applies to different energy products, favours the use of carbon-intensive fuel (especially coal). Whilst this does not cause direct conflict in the production of electricity, for example, it causes conflict economy-wide as a reduction in the use of coal for electricity production may be counteracted by its incentivised use for heating in other sectors. The EU ETS, by discriminating against CO_2, encourages the development and use of low-carbon electricity. However, the ETD does not discriminate between high and low carbon generation. Whilst this does not directly counteract the objectives of the ETS, it does not actively support it. The overlapping scope of the instruments, discussed above, also places double carbon costs on electricity end users and other selected sectors.

3.2 Energy Efficiency and Energy Consumption

The three key instruments in this landscape are the EU ETS, the Effort Sharing Decision ('ESD' – which places annual caps on non-ETS GHG emissions on each Member State between 2013 and 2020), and the Energy Efficiency Directive ('EED' – which implements binding measures to achieve a 20% improvement in energy efficiency in 2020, compared to 'Business as Usual').

These three instruments have a mutually supportive relationship. The EU ETS and ESD complement each other by capping emissions from different sectors of the economy, to obligate almost all sectors (except Land Use, Land Use Change And Forestry (LULUCF), and international shipping), to produce emissions savings. The EED promotes and mandates energy efficiency measures for energy generators, suppliers and end users across all Member States, contributing to the goals of both the EU ETS and ESD. Although, the extent to which these instruments drive efficiency depends on energy demand in a counterfactual scenario, greatly impacted by the financial crisis. Whilst the EU ETS is a 'self-contained' instrument, the ESD provides a 'framework', which must employ other instruments (such as the EED), to achieve its aims and targets. The remainder of the key instruments identified in this landscape work to achieve this through encouraging energy efficiency and emission mitigation in the following sectors:

- **Buildings** – The Energy Performance of Buildings Directive (EPBD) contains various provisions on minimum energy performance standards, energy labelling and the promotion of renewables in new and existing buildings.
- **Energy-Related Products** – These are products that directly consume energy (e.g. boilers, white goods), or influence the consumption of energy (e.g. windows and shower heads). The Ecodesign Directive sets minimum performance standards for such products. The Energy Labelling Directive mandates energy labelling of these products, to allow the consumer to make an informed choice.
- **Transport** – The CO_2 Emission Standards for Passenger Cars regulation places an obligation on car manufacturers to achieve a tailpipe emission intensity of 130gCO_2/km by 2015, and 90gCO_2/km by 2020. The CO_2 Labelling for Passenger Cars regulation obliges suppliers to display the specific CO_2 intensity of a vehicle at the point of sale, to inform consumer choice.

However, it must be noted that this this is not exclusive, but based simply on key instruments assessed as part of the CECILIA2050 project. The industrial sector, for example, is subject to the Integrated Pollution Prevention and Control (IPPC) Directive, which places energy efficiency standards on a number of industrial sectors. The Ecodesign and Energy Labelling Directives and CO_2 Emission Standards and CO_2 Labelling for Passenger Cars, are mutually supportive in their respective target groups. All work to increase the market share of energy-efficient products, and ensure the effective functioning of the internal market. The Ecodesign Directive and CO_2 Emission Standards seek to 'push' towards higher efficiency using minimum standards, eliminating the least efficient products from the market, whilst the Energy Labelling Directive and CO_2 Labelling for Passenger Cars regulation attempts to 'pull' the market to higher efficiency through awareness raising and information provision, encouraging purchases of units at the highest end of the energy efficiency spectrum. The EPBD provides both drivers for buildings, through different provisions.

The ESD is the only instrument discussed which explicitly concerns all six GHGs highlighted in the Kyoto Protocol (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride), in the sectors it concerns. The EU-ETS concerns primarily CO_2, but also N_2O and perfluorocarbons to a limited extent, whilst the instruments for CO_2 emission standards and labelling for passenger cars impose a direct link to CO_2 only. The remaining five instruments – the ETD, Energy EED, EPBD, Ecodesign Directive and Energy Labelling Directive, concern the use of energy and energy efficiency directly, with a CO_2 emission mitigation a desired policy impact, but an indirect one.

3.3 Promotion of Renewable Sources of Energy

This policy landscape overlaps significantly with the Energy Efficiency and Energy Consumption landscape. The key instrument is the Renewable Energy Directive ('RED'), which seeks to achieve a 20% penetration of renewable energy into the EU's final energy consumption by 2020. It works to achieve this through setting differentiated renewable energy targets for each Member State, and a number of provisions to help achieve them. The RED operates alongside the EU ETS and ESD, which set the contextual framework).

As with the EED, the RED holds an economy-wide target and therefore impacts both EU ETS and ESD sectors, and does so in a largely supportive manner. Whilst both the EU ETS and RED encourage centralised renewable electricity generation (depending on the Member State and implementation approaches and mechanisms), the RED also encourages decentralised generation under the scope of the ESD (through reducing building-related emissions, for example). However, the promotion of renewables through the RED does not produce additional emissions abatement than is delivered through the EU ETS and ESD alone (however, the expected impact of the RED was considered in the cap-setting of these instruments).

The RED has a mutually supportive relationship with the EPBD, the CO_2 Emission Standards for Passenger Cars and passenger car labelling requirements. The EPBD requires that the cost-effective use of renewables must be assessed for all new buildings, and is encouraged for use in renovations. The RED also requires that efforts should be made to consider the use of renewables when planning and building residential and industrial buildings and areas, but by 31st December 2014, Member States should require a minimum level of energy from renewables in all new buildings (and existing buildings subject to major renovation), and implement mechanisms to allow this to be achieved. The EPBD 'Nearly-Zero Energy Buildings' provisions support and build upon this minimum renewables criterion. It requires that all new buildings owned and occupied by public authorities by 31st December 2018, and by 31st December 2020 for all new-build private buildings, require 'nearly zero' energy, with the remainder covered 'very significantly' by renewables The regulation for CO_2 emission standards for passenger cars aims to promote the use of biofuels in transport that meet the biofuel sustainability requirements of the RED.

3.4 Non-CO_2 GHG Emissions

Again, the key instrument in this landscape is the ESD, with the four key instruments acting to fulfil its targets, as follows:

- **F-Gas Regulations** – aims to contain, prevent and reduce emissions of man-made f-gases listed in Annex A of the Kyoto Protocol through monitoring and reporting requirements, and the banning of its use in certain products.
- **Landfill Directive** – aims to prevent damage to human health and the environment (including the greenhouse effect), from the landfilling of waste. Landfills must meet prescribed technical standards, and Member States must reduce the levels of methane-producing biodegradable waste in line with stated targets.
- **Nitrates Directive** – aims at protecting water quality by limiting the use of fertilisers from agricultural sources through the promotion of good farming practices. Fertilisers contain nitrates, which oxidise to form N_2O.
- **LULUCF Accounting Rules** – Biomass in natural and agricultural landscapes are a significant GHG sink. Prior to this instrument, emission balances in the Land Use, Land Use Change and Forestry sector were not accounted for in a standardised manner. This instrument provides a standardised monitoring and reporting framework in the EU based on the international standard developed through the UNFCCC, as a precursor to inclusion of the net emissions from this sector in overarching emission reduction targets.

The EU-ETS also plays a marginal role for this landscape by capping N_2O emissions from nitric, adipic and glyoxalic acid production, and perfluorocarbons from aluminium production. However, the effect of this on the overall policy landscape is negligible. The instruments in this landscape experience generally neutral relationships, due to their specific sectoral and GHG scopes.

However, the LULUCF Accounting Rules supports and is supported by this Nitrates Directive, as N_2O emissions from land under grazing and crop management (along with CO_2 and CH_4), must be accounted at the national level. Once LULUCF emissions are considered in overarching emission reduction targets, this relationship is likely to strengthen. The Nitrates Directive also experiences a weakly supportive relationship with the Landfill Directive, with the latter encouraging the diversion of biodegradable municipal waste from landfill to other end uses, including compost. This compost is often used in agricultural purposes, reducing the use of synthetic nitrate fertilisers, helping to meet the requirements of the former.

3.5 Policy Landscape Interactions

The two instruments in the Carbon Pricing landscape also fall within the EE&EC landscape. Broadly speaking, a price on carbon provided by the former landscape provides incentive for carbon and energy efficiency in the second (however, there are many caveats to this – such as non-financial barriers to already cost-effective measures). This is generally true with the EU ETS and its relationship with other instruments in the EE&EC landscape, but the current design of the ETD produces a conflicting relationship. This description also holds between the Carbon Pricing and Promotion of Renewables landscape, although the extent to which a carbon price supports the deployment of renewables depends on the design of specific renewable promotion instruments (e.g. feed-in tariffs). Whilst the relationship is relatively neutral regarding the production of renewable electricity (renewable and fossil fuel sources electricity have the same minimum rates under the ETD), the use of renewables in other sectors – such as transport and heating - are discriminated against. Biodiesel, for example, typically holds a lower energy density than diesel. As the ETD currently taxes both commodities at the same rate, based on volume, biodiesel experiences a higher tax burden per unit of energy.

The functioning of the instruments in the EE&EC and Promotion of Renewables landscapes are highly supportive, due to interactions which have been discussed. Additionally however, national Renewable Energy Action Plans under the RED must consider planned and pre-existing energy efficiency measures – including those introduced under the EED (enacted in 2012 – after the RED in 2009). This support is reciprocal; the EED requires the installation of smart meters in new buildings and those undergoing significant refurbishment (also 'encouraged' under the EPBD), which enable microgenerators to supply power to the grid. This has obvious benefits for the RED, which also provides guaranteed access to the grid for renewable installations, alongside mandating the development of transmissions and intelligent grid infrastructure to enable the management of increasing centralised and distributed renewable electricity generation.

There is a largely neutral relationship between the EE&EC and Non-CO_2 GHG landscapes. Aside from the overlap with other landscapes delivered by the EU ETS and ESD however, a key relationship is between the Ecodesign and Energy Labelling Directives, and F-Gas Regulations. Key products, such as air-conditioners and refrigeration equipment, are regulated by all three instruments – and are supportive in reducing the environmental impact of these products. Proposed amendments to the F-Gas Regulation include additional bans on the use of f-gasses in certain products, beginning with domestic refrigerators and freezers in 2015, followed by commercial refrigerators and freezers and movable room air-conditioning appliances by 2020. The proposals may alter the energy consumption profile of the market for these products, altering the premise upon which the Ecodesign and Energy Labelling Directive regulations for these products are based.

Whilst there is an almost entirely neutral relationship between the Carbon Pricing and Non-CO_2 landscapes (aside from the EU-ETS and ESD overlap), there is a generally supportive relationship between the latter policy landscape and the Promotion of Renewables instruments. The use of agricultural waste for the production of energy (e.g. biogas) is incentivised by the RED and the Landfill Directive, with the latter doing so indirectly through the disincentivising landfilling. However, there is also a conflict between these two instruments, as the latter encourages the reduction of biodegradable waste in landfills, reducing the production of landfill gas that is incentivised through the RED. The LULUCF Accounting Rules is supportive of any instrument that encourages the use of biomass or biofuels (particularly the RED, and CO_2 emission standards and labelling of cars, but also the EU ETS, ESD and EPBD, and in future possibly the ETD). Full accounting of the emissions involved in the production of biomass would be considered (although only for domestically produced biomass), allowing for a more comprehensive of biomass sustainability and potential elimination of accounting the use of biomass as zero-emissions.

Only six of the fifteen policy instruments described have direct coverage of GHG emissions – the ESD, EU ETS, CO_2 Emission Standards and Labelling for Passenger Cars, F-Gas Regulations and LULUCF Accounting Rules. The ESD concerns all six Kyoto GHGs, whilst the subsequent three concern principally CO_2, with the EU-ETS also covering N_2O and perfluorocarbons to a limited extent. The LULUCF Accounting Rules also cover N_2O and perfluorocarbons (alongside CO_2) whilst F-Gas Regulations concern hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride. A seventh instrument, the CCS Directive, may also be considered directly concerned with CO_2 emissions, but it is not directly concerned with its mitigation. The remaining instruments impact GHG emissions indirectly. Six of the remaining eight instruments focus on CO_2 (ETD, EPBD, Ecodesign Directive, Energy Labelling Directive, EED and the RED), whilst the remaining two – Nitrates Directive and Landfill Directive – focus indirectly on N_2O and CH_4, respectively.

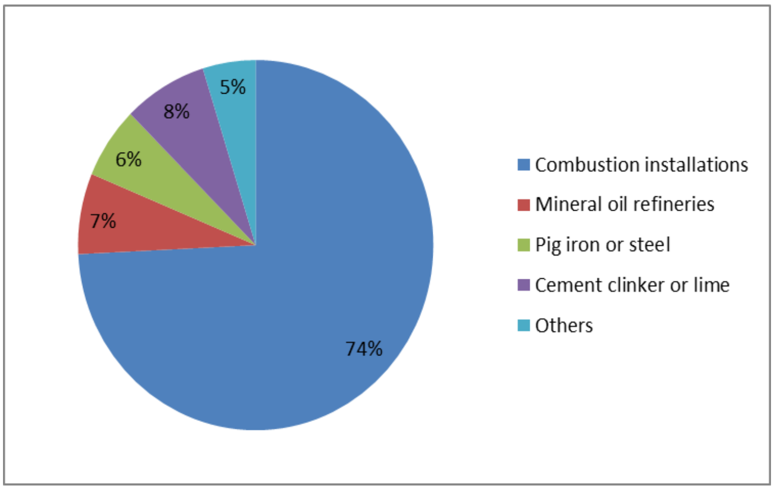
4 Environmental effectiveness

4.1 Carbon Pricing

The EU Emissions Trading System (EU ETS) is the main instrument of the EU's policy to combat climate change. In 2012, the EU ETS sectors accounted for 1.9 Gt CO_2-eq which represented around 40% of the EU's GHG emissions[9]. Since its start in 2005, the EU ETS has covered power and heat generation and the main energy-intensive industry sectors. Currently, the EU ETS is in its third phase (2013-2020) and has incorporated the commercial aviation. The system operates in the 28 EU Member States plus Iceland, Liechtenstein and Norway. In total, more than 11,000 installations are covered. Regarding greenhouse gases, not only CO_2 is included in the system, but also N_2O from the production of certain acids and PFCs from aluminium production.

In 2012 around 74% of the GHG emissions took place in power and heat generation (see figure 1). Among the energy-intensive industry sectors, oil refineries (7%), cement (8%), steel works and production of iron (6%) has the most significant weight in the EU ETS.

Figure 1. Distribution of GHG emissions by sector in the EU27 (2012)



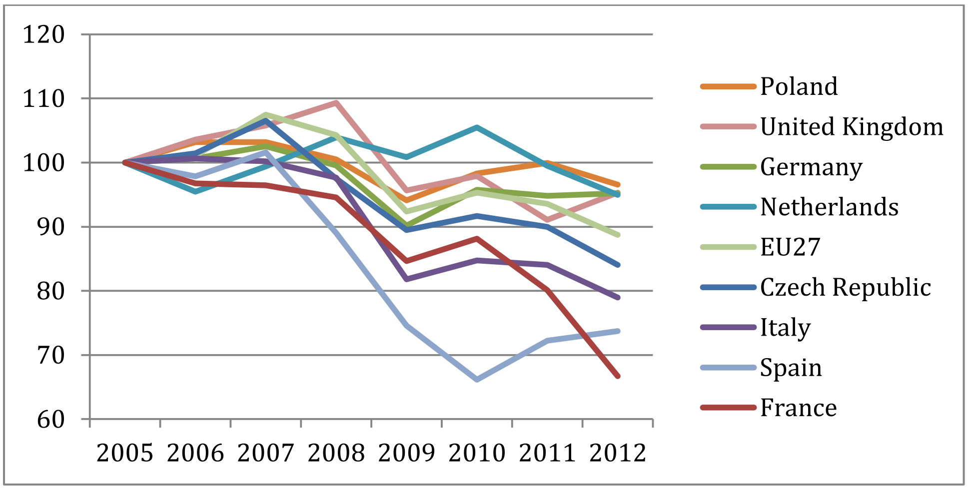
Source: EEA

Figure 2 shows how EU ETS emissions have evolved from 2005 (when the EU ETS was launched) to 2012. In the EU27 the emissions have been reduced by 11% in this period. The emissions have declined in all eight countries analysed in this document. Nevertheless, there are significant differences between countries. In France, Spain and Italy emissions have decreased more than 20%, while in the Czech Republic, the Netherlands and the UK the decline has been around 5%.

Given the weight of power generation in the EU ETS, emissions path has been mainly driven by this sector. From 2005 to 2012 power generators have decreased their emissions by around 9%. A deeper decline has been observed in energy-intensive industry sectors. The steel and iron sector has reduced its emissions by 13% in this period, while in oil refineries and the cement sector emissions have decreased by 17% and 23% respectively.

[9] Currently, after the inclusion of the commercial aviation in 2013, the EU ETS covers around 45% of total EU emissions.

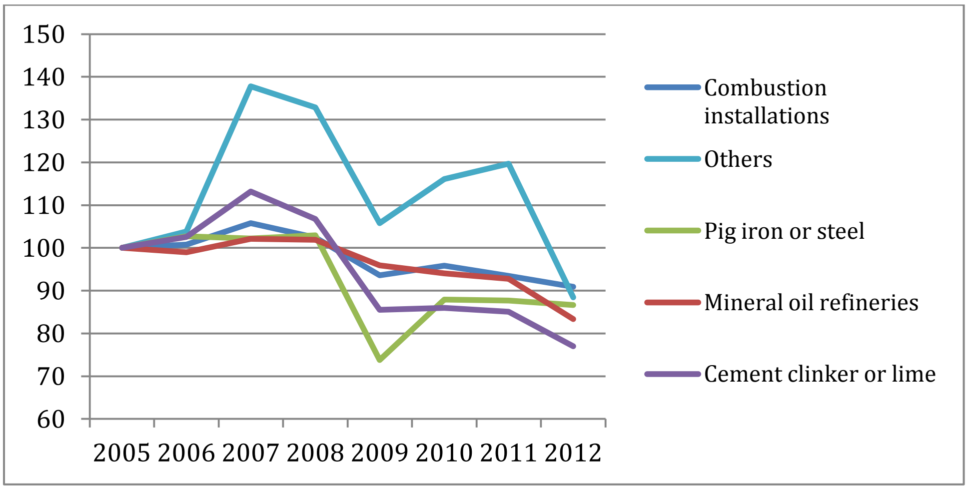
Figure 2. Evolution of GHG emissions in the EU ETS by country (2005-2012)



Source: EEA

The drop in emissions has been more pronounced since 2008, when the financial crisis affected the economic activity. This is particularly true for those countries and sectors which were more affected by the economic recession. In France, Italy and Spain, EU ETS emissions remained constant until 2008; however, since then, emissions have plummeted. The cement industry, which is very dependent on the construction sector, has also been affected by the economic crisis, since 2007 emissions have declined more than 30% (see figure 3).

Figure 3. Evolution of GHG emissions by EU ETS sectors (2005-2012)

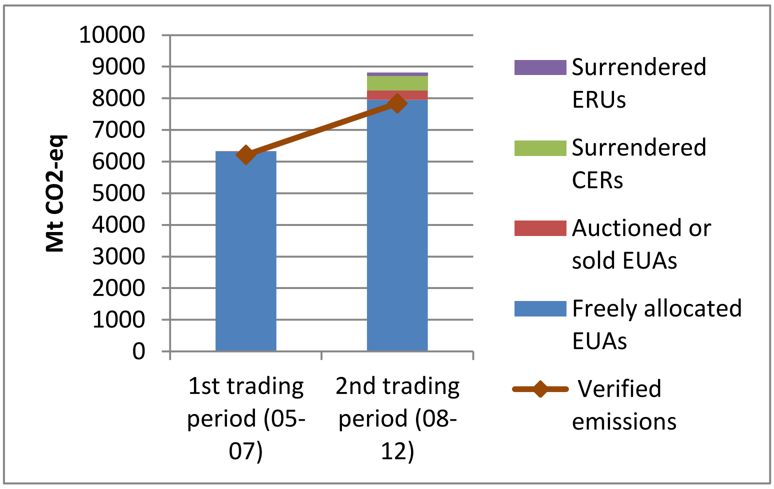


Source: EEA

In the EU ETS sectors, total GHG emissions are limited by the number of allowances allocated by this scheme. However, verified emissions do not have to correspond to the number of allowances allocated. Figure 4 compares verified emissions with the amount of available emission units. In the first phase, verified emissions were 115 Mt CO_2-eq below the total number of allocated allowances in all EU ETS countries. This period was characterized by an oversupply of allowances. The excessive number of allowances caused the price fall to zero.

In the second phase, in addition to the freely allocated and auctioned allowances, operators were allowed to buy international offset credits from JI or CDM projects. These two mechanisms provided additional flexibility to the EU ETS scheme. Although total EU allowances (freely allocated and auctioned allowances) were more than verified emissions, operators made use of JI and CDM credits (ERUs and CERs). In this period, allocated allowances were 5% above verified emissions, while surrendered ERUs and CERs accounted for 7% of verified emissions.

Figure 4. Verified emissions vs. Allocated allowances



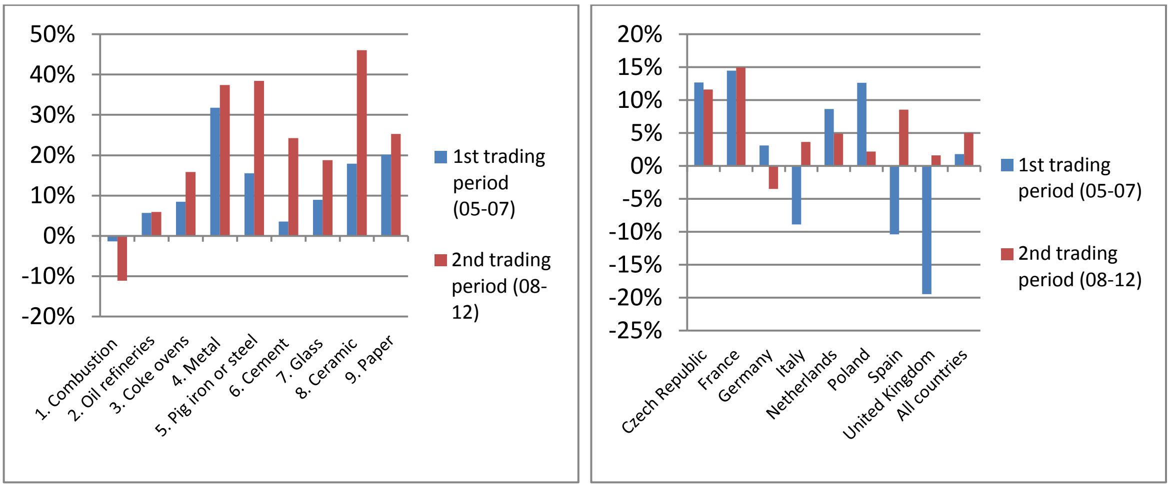
Source: EEA

Apart from the combustion installations, in the rest of the EU ETS sectors, verified emissions were below freely allocated allowances, both in the first and the second trading period. Between 2005 and 2007, combustion installations emitted 62 Mt CO_2-eq above freely allocated allowances. In the second phase, this value increased to 571 Mt CO_2-eq, which represented 11% of allocated allowances (see figure 5). In contrast to combustion installations, some sectors such as ceramic and metal industries only used around 50% of their allowances. In all industries, verified emissions as a proportion of allocated allowances decreased from the first to the second trading period. This is mainly explained by the economic crisis, which affected industrial sectors more than combustion installations.

Figure 5 shows the rate of verified emissions with respect to allocated allowances (freely and auctioned) at national level. Only in Germany verified emissions were higher than total allowances in the second trading period. In some countries such as Italy, Spain and UK, total emissions decreased considerably between the first and second period. Indeed, in the first period verified emissions were above EU allowances, while in the second period they were below.

The difference between allocated allowances and verified emissions generates surpluses which are accumulated, since unused allowances can be used in future years. This provides more flexibility to the scheme. The current low carbon price can be interpreted as an indicator that participants are not expecting scarcity in allowances and, therefore, a rise in the carbon price.

Figure 5. Differences between verified emissions and allocated allowances by sector and country



Source: EEA

As mentioned above, EU ETS sectors have reduced emissions by 11% from 2005 to 2012 in the EU27. However, it is not straightforward to distinguish the impact of the EU ETS from other factors.

The European Commission states that the carbon price signal of the EU ETS has contributed to reduce emissions since the start of the second trading period, but the economic crisis has been the major cause of the emission reduction (EC, 2012). CDC Climate (2013) also considers that the carbon price of the EU ETS has not been the main driver of the reduction. They estimate that over the period 2005-2011 around 30% of the emission reduction was due to a decrease in manufacturing output and 60% of the reduction was due to the development of renewable energy and the improvement of the energy intensity. According to Point Carbon (2013) the low carbon price of the EU ETS reflects that the emission target has become easier to meet. They find two main reasons for this: the economic recession and the effects of other instruments on the promotion of the renewables and energy efficiency.

Most of the academic studies use econometric methods to analyse the role played by the EU ETS in the emission reduction. They estimate avoided emissions comparing verified emissions with an estimated business-as-usual (BAU) scenario. Ellerman and Buchner (2008) use this methodology to estimate avoided emissions by the EU ETS in the period 2005-2006. Verified emissions are controlled with economic activity indicators, energy prices and trends in energy and carbon intensities. They find that the EU ETS led to reduce CO_2 emissions by between 50 and 100 million tonnes per year, or similarly, between 2.4% to 4.6% of what emissions would otherwise have been. Anderson and Di Maria (2011) use a dynamic panel data model to improve the BAU scenario. They include other historical data such as industrial production, energy production, and temperature and precipitation values. They find that during 2005-

2007 the EU ETS contributed to reduce 174 Mt CO_2 in the EU25, that is, a net abatement of 2.8%.

Delarue et al (2008) focus on the power sector to calculate avoided emissions due to the EU ETS in 2005 and 2006. An electricity generation simulation model is used to perform simulations on the switching behaviour in the European electric power sector. They estimate that around 88 and 59 Mt GHG emissions were avoided in 2005 and 2006 respectively. Abrell et al (2011) use firm level data to assess the effectiveness of the EU ETS. More than 2,000 firms are analysed from 2005 to 2008; the first phase and the beginning of the second phase. The results show that the transition from the first phase to the second phase led companies to change their behaviour. When controlling for companies' turnover, number of employees, sector and home country, they find the emission reductions between 2007 and 2008 were 3.6% larger than between 2005 and 2006. The response to the shift from the first to the second phase was significant in some sectors such as basic metals and non-metallic minerals, while electricity and heat generation did not show an increase in their reduction efforts.

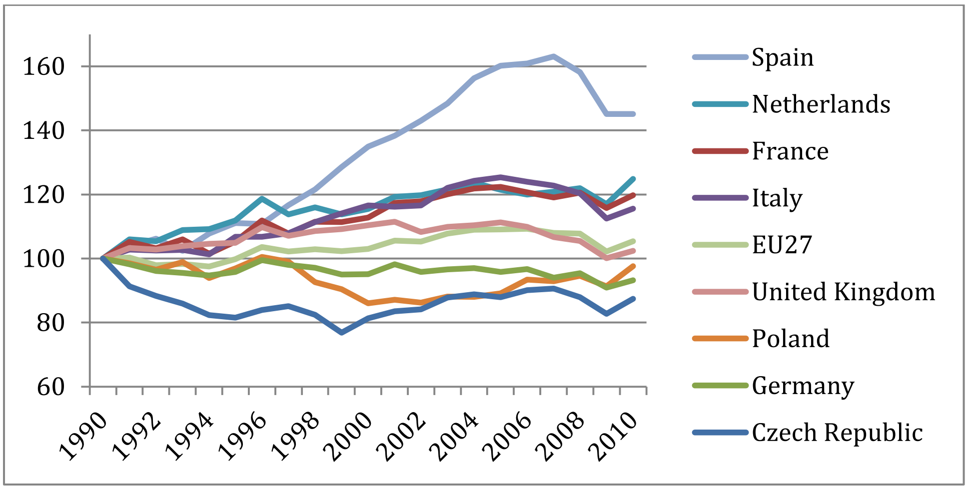
4.2 Energy Consumption and Energy Efficiency

The EU set the objective of improving energy efficiency by 20% by 2020. This objective implies achieving a 20% reduction of annual consumption of primary energy compared to the energy consumption forecasts for 2020. To meet this objective several instruments have been implemented both at European and national level. These instruments have mainly focused on those sectors not covered by the EU ETS, in particular the building and transport sectors.

In the period 1990-2010, the primary energy consumption increased in 84.5 million toe in the EU27, or 5.4% with respect to 1990 level. In the same period, the GDP increased more than 40%. This implies a considerable improvement in energy efficiency. However, as mentioned by the European Commission, the EU27 is not on the track to reach its 20% target. Under current path only half of the 20% objective would be achieved[10].

[10] According to the Commission estimates and taking into account energy efficiency measures implemented up to December 2009.

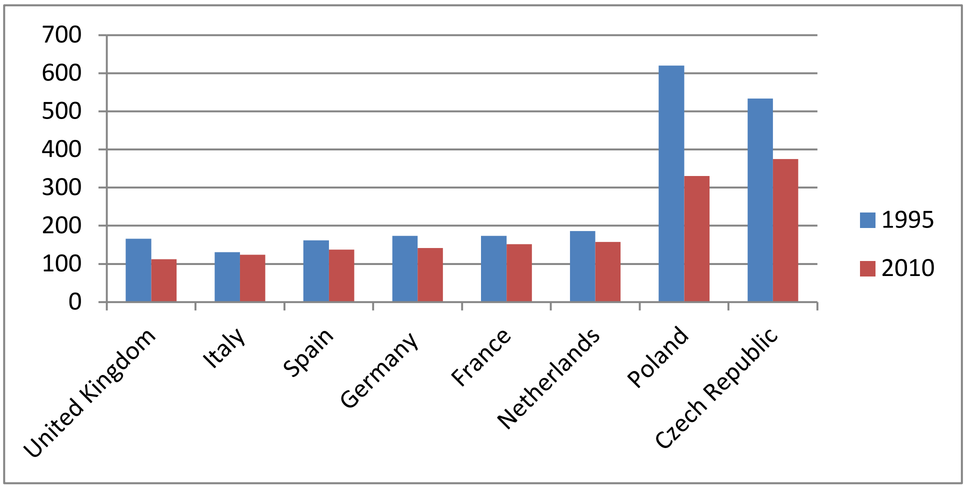
Figure 6. Evolution of primary energy consumption by country (1990-2010)



Source: Eurostat

The EU has launched several directives (e.g. the Directives on End-use Energy Efficiency and Energy Services (ESD) and the Energy Efficiency Directive (EED)) and Plans (e.g. the Energy Efficiency Action Plan 2006 and the Energy Efficiency Plan 2011), which represent the pillar for the majority of the instruments implemented at the national level. Energy intensity has evolved differently in each country. In some countries, particularly in Spain, primary energy consumption has considerably increased since 1990 (figure 6). However, this has not led to a rise in energy intensity, given that the GDP has increased even more. In none of the countries analysed in this report, the energy intensity has risen since 1995 (figure 7). Those countries where energy intensity is higher have experienced larger improvements in energy efficiency (e.g. the Czech Republic and Poland). In Poland, for instance, the required energy to produce one unit of GDP has been halved. However, it is still well above the EU average. On the other hand, Italy, where energy intensity is one of the lowest in the EU27, it has barely improved. A remarkable energy intensity improvement was achieved in the UK, where it has been reduced by around 33% during the period 1995-2010, although the UK were already among the more energy-efficient countries to begin with.

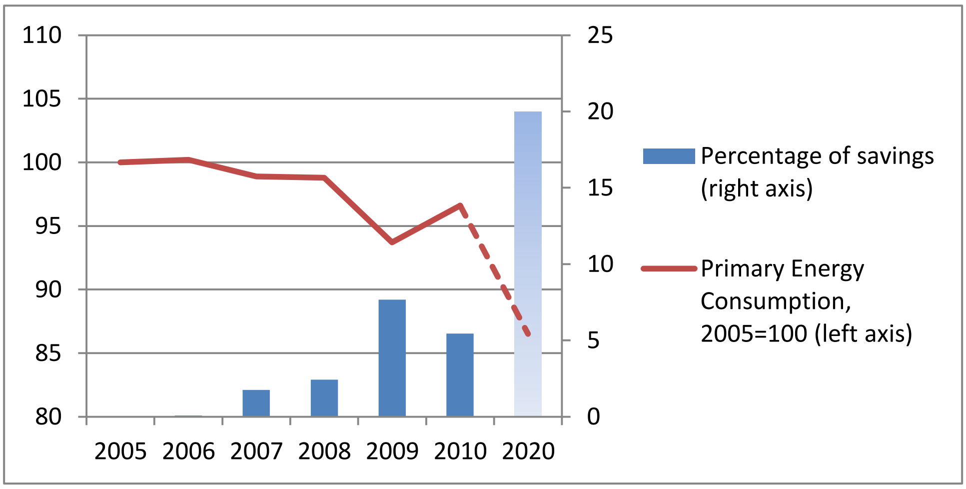
Figure 7. Total energy consumption per unit of GDP (at ppp) (ktoe/€2005)



Source: Odyssee

In the EU27 as a whole the primary energy consumption has decreased by 3.6% since 2005. This value is far from the 2020 objective, which sets a reduction of 13.5% compared to 2005 level. This target is equivalent to reduce energy consumption by 20% with respect to the baseline scenario[11]. In 2010 primary energy consumption was 5.4% lower than the baseline scenario and, therefore, a higher effort it will be needed to reach the 20% target by 2020 (figure 8).

Figure 8. Energy Consumption and Savings (EU 2020 target)



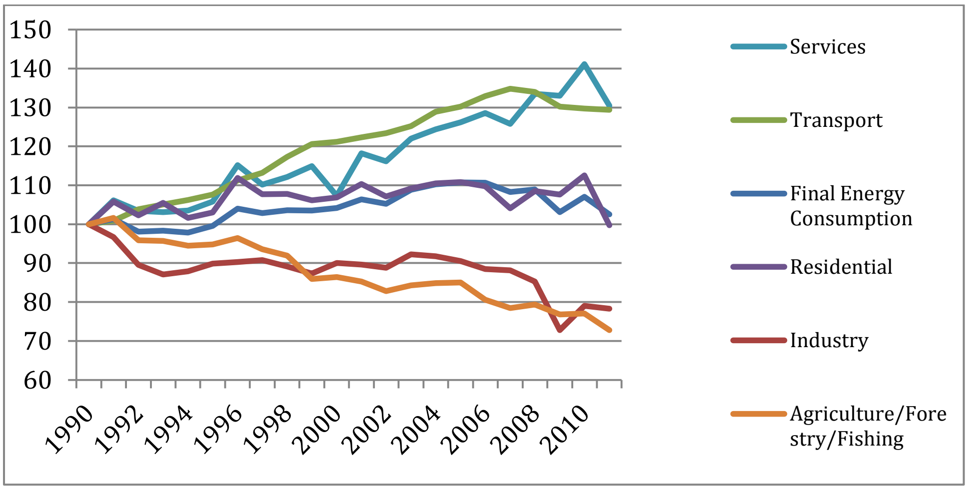
Source: Eurostat

Figure 9 shows how final energy consumption has evolved since 1990. While some sectors have been able to reduce final energy consumption (e.g. industry and agriculture), others such as transport and service sectors have increased their consumption by more than 25%.

[11] The difference between actual energy consumption and projected consumption is considered as energy savings.

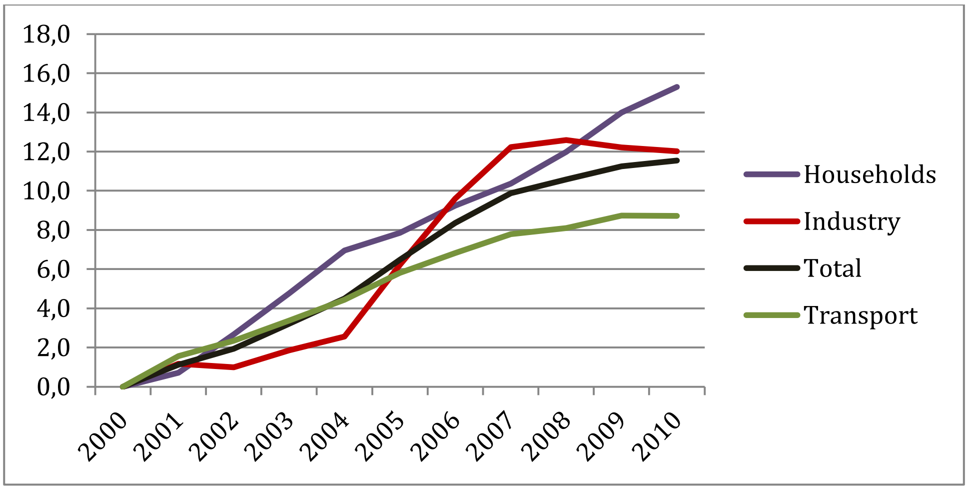
However, in the case of the transport sector, energy consumption has stabilized in recent years. In terms of energy efficiency, according to the Odyssee dataset, the transport, households and industry sectors show energy efficiency gains since 2000. On average, in the EU27 the energy efficiency gains in these sectors account for 11.5% (see figure 10). The sector with the highest energy efficiency gain is households (15.3%) while the transport is the lowest (8.7%). Energy efficiency gains did not lead to proportional energy reductions, because of rebound effects.

Figure 9. Final energy consumption (1990-2011)



Source: Eurostat

Figure 10. Final energy efficiency gains[12] (2000-2010)



Source: Odyssee

[12] A detailed description on energy efficiency indicators can be found in http://www.odyssee-indicators.org/ .

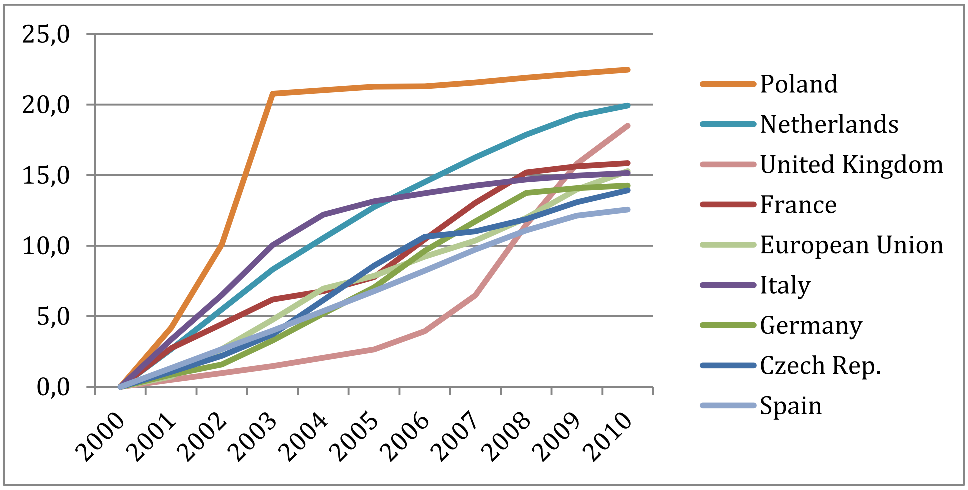
As with the carbon price landscape, it is difficult to evaluate the effectiveness of the instrument mix in the landscape of energy consumption and energy efficiency. The majority of the instruments on energy efficiency are rather new and, thus, there are limited ex-post studies of the current instrument mix. However, as mentioned above, EC (2011) estimates that under the current scenario, which includes those policies implemented by December 2009, the reduction in the energy consumption (with respect to the baseline scenario) would be only about 8.9% in 2020. Therefore, the current instrument mix will not reach the 20% target and further efforts will be necessary.

Current measures on the landscape of energy efficiency and energy consumption are mainly based on the EU's Energy Efficiency Action Plan (EEAP) and the National Energy Efficiency Action Plans (NEEAP). Given that industrial installations are mostly covered by the EU ETS, the majority of measures have been implemented in the transport and buildings (residential and services) sectors.

The European directive on buildings standards has contributed to reduce energy consumption in new dwellings. Thus, the dwellings built in 2009 consume between 30 to 60% less than dwellings built in 1990 (Odyssee, 2011). However, the final effect on energy efficiency improvement depends on the share of new buildings. The share of dwellings built since 1990 in some countries such as Italy, the Czech Republic and the UK is less than 15% and, therefore, its impact has been limited. On the other hand, Spain, where around 50% of the dwelling stock was built after 1990, has not benefited from the new European directive, given that it was not implemented until 2006, when the housing boom was ending.

In the residential sector, the highest energy efficiency gains have taken place in Poland (see figure 11). According to the Odyssee index, in the period 2000-20010 efficiency gains accounted for 22.5%. However, since 2003 energy efficiency improvement has been negligible. In Poland, in addition to the European measures such as the Energy Performance Building Directive (EPBD) and the Labelling Directives, environmental funds have been implemented to improve energy efficiency in buildings. The last subsidy scheme launched by the National Fund is a program of support for energy-efficient houses, which is estimated to achieve annual energy savings of 93.5 GWh.

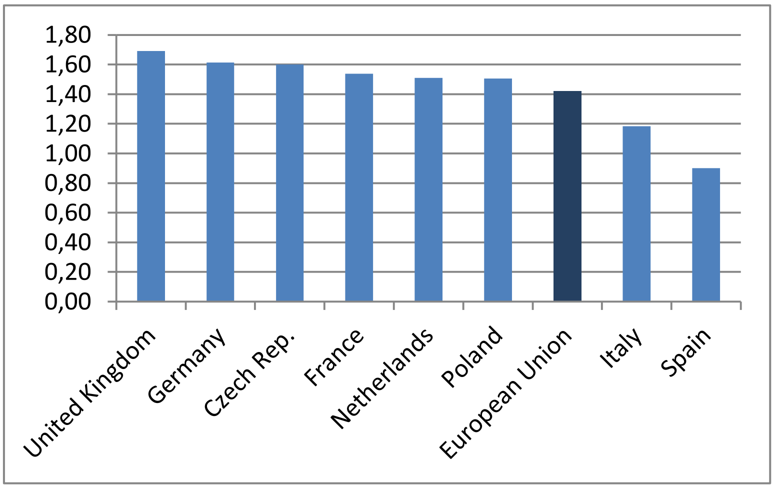
Figure 11. Energy efficiency gains in households since 2000 (%)



Source: Odyssee

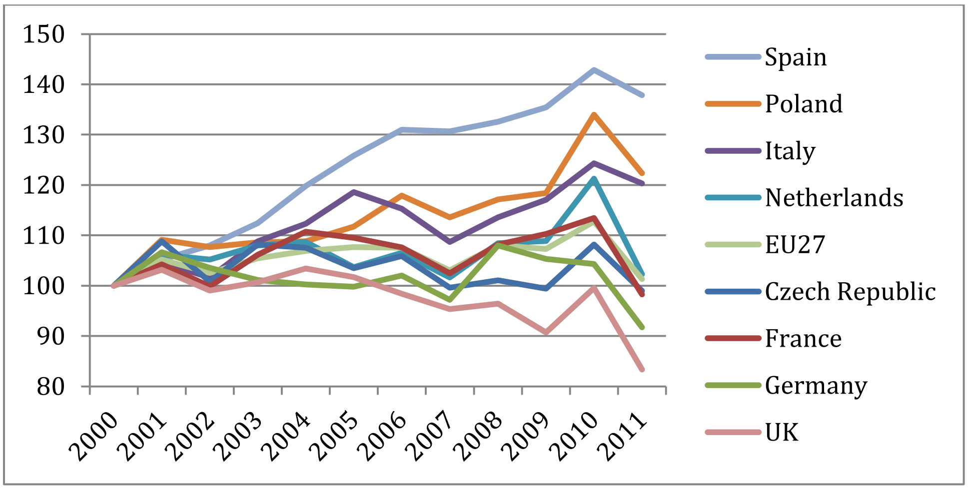
The Netherlands has experienced a steady improvement in energy efficiency over the last ten years. Their instrument mix is based on European regulations in the form of performance standards and national market-based instruments (e.g. taxes, subsidies, fiscal incentives). According to Gerdes and Boonekamp (2012) energy saving policies contributed to reduce energy consumption (with respect to projected energy consumption) by 1.1% per year over the period 2000-2010. Despite the improvement in energy efficiency, services and residential consumption has not decreased in this period, and is still above the European average. Also remarkable is the huge improvement in energy efficiency in the UK since 2005. The UK has reduced final energy consumption in buildings more than any other country analysed in this report. Despite all this, energy consumption per dwelling is still one of the highest in the EU27. The majority of the instruments within this landscape are imposed at the UK level and are economic instruments.

Figure 12. Consumption per dwelling (toe/dw) in 2010



Source: Odyssee

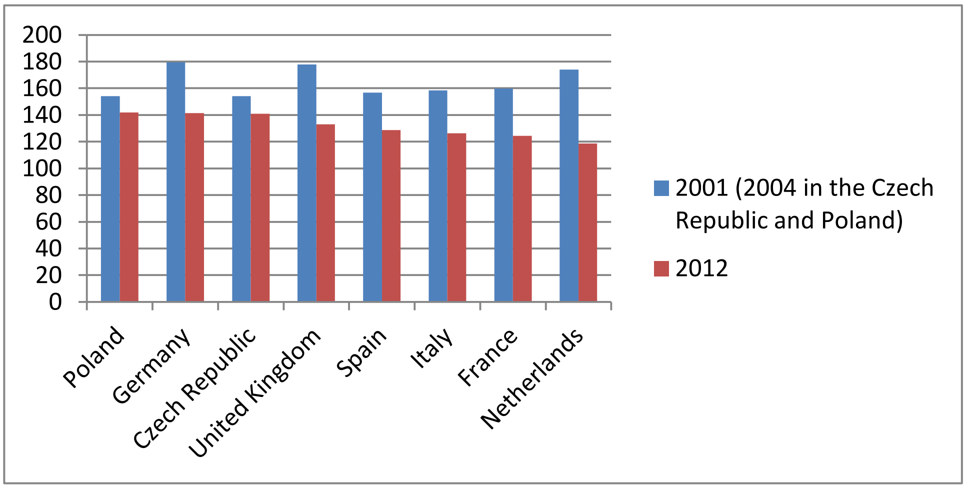
Figure 13. Energy consumption in the residential and service sector (2000-2011)



Source: Eurostat

Despite the increase in energy consumption in the transport sector, it is estimated that in the EU27 energy efficiency gains accounted for 8.7% since 2000 (see figure 15). The EU's measures to improve efficiency have mainly been implemented through regulations targeted at vehicle manufacturers (e.g. efficiency standards for new cars), while national measures have focused on encouraging the purchase of cleaner vehicles (e.g. financial incentives). These measures have reduced the average CO_2 emissions of new passenger cars. In some countries such as the Netherlands, average CO_2 emissions of new passenger cars have been reduced by around 30% in the period 2001-2012 (see figure 14). Since 2000 the energy efficiency of cars is improving by around 1%/year (Odyssee, 2012).

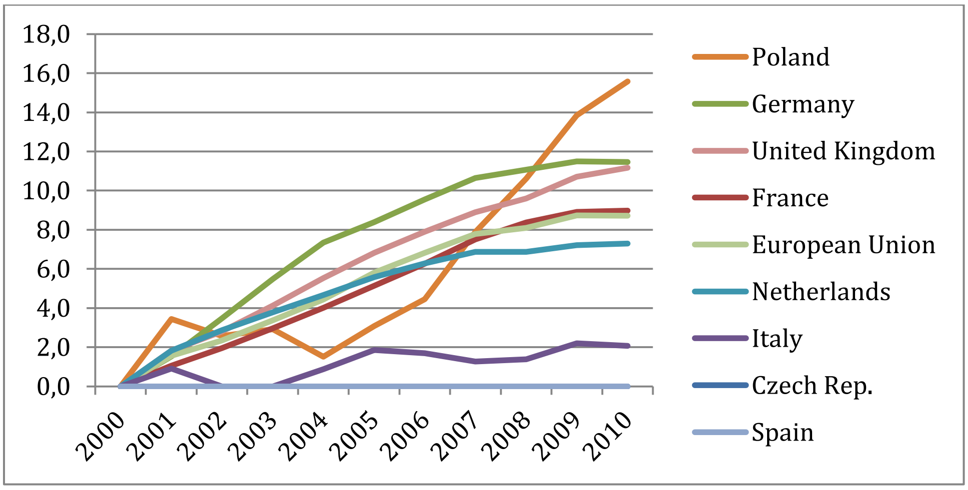
Figure 14. Average CO_2 emissions (gCO_2/km) from new passenger cars by country



Source: Odyssee

Poland, Germany and the UK are the countries with the highest energy efficiency gains in this sector. However, in contrast to Germany and the UK, efficiency improvements have not reduced energy consumption in Poland. Indeed, it is the country with the highest increase in energy consumption since 2000 (80%), caused by the increase in the motorisation rate. The Czech Republic, where efficiency gains have not been observed, energy consumption has also increased by around 40%.

Figure 15. Energy efficiency gains in transport since 2000 (%)[13]

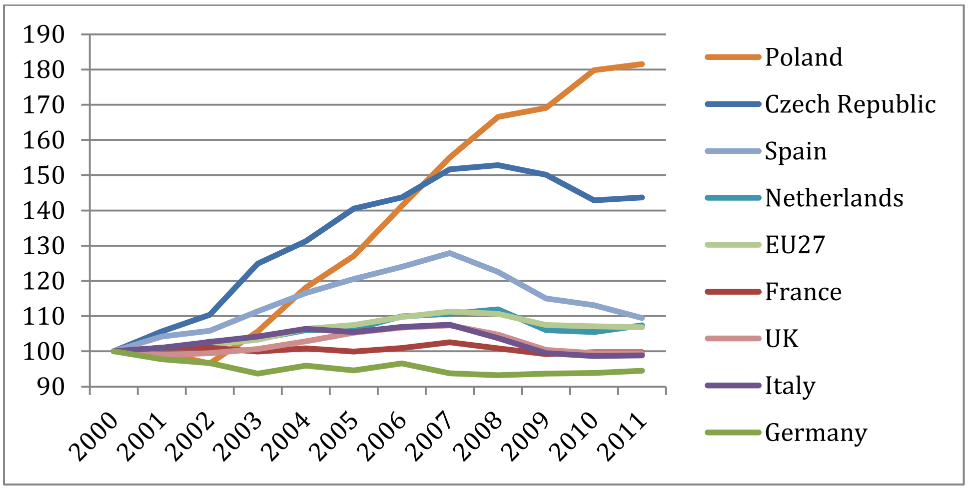


Source: Odyssee

In the EU27, the transport is the sector with the lowest energy efficiency gains in the period 2000-2010. In the same period, final energy consumption has increased by 7% (around 22 Mtoe). According to Odyssee (2012), the freight transport was responsible for a consumption increase of 13 Mtoe, while the energy consumption of passenger transport increased by 9 Mtoe. Although energy savings account for 10.5 Mtoe, they have been offset by the growth in the traffic and modal shift from rail and water to road transport.

[13] Index equal to zero means no energy efficiency gains (Spain and the Czech Republic).

Figure 16. Energy consumption in the transport sector (2000-2011)



Source: Odyssee

The interaction of market-based instruments and both technology standards and information instruments can result in an improvement of the environmental effectiveness in this landscape. However, when energy prices are not high enough, rebound effects can be considerably large (Gago et al, 2012). Energy efficiency can lead to lower energy demand and, thus, to lower energy prices, resulting in price and income effects. This causes an increase in energy demand again. This can be important in countries such as Spain, Poland and the Czech Republic, where energy taxes are below EU average.

4.3 Promotion of Renewable Sources of Energy

The promotion of renewable energy sources is an important pillar of the EU's climate strategy. In relation to renewable energy, the EU has two objectives for 2020: at least 20% of EU gross final energy consumption and at least 10% of transport final energy consumption should come from renewable energy sources. In 2011, the share of renewable energy in gross final energy consumption reached 13% in the EU27, while the share of renewable energy in fuel consumption of transport was 3.8%.

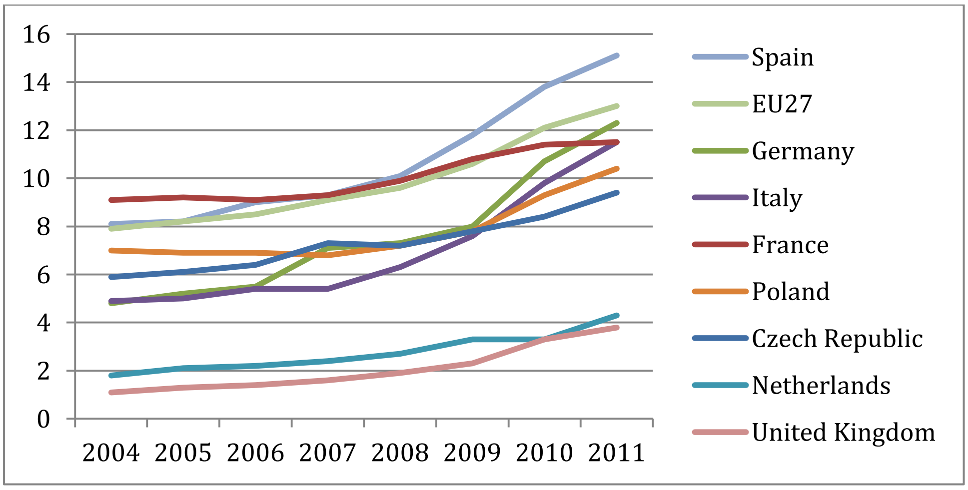
Although EU legislation defines the targets on renewable energy for each Member State, the majority of the instruments have been implemented at national level (National Renewable Energy Action Plans). Thus, the environmental effectiveness of the instrument mix within this landscape varies considerably among countries. Figure 17 shows how the share of renewable energy in final energy consumption has evolved in recent years. The share of renewables has increased in all countries, particularly since 2008. Looking at Spain and Germany we see significant changes: the former has increased the share of renewables from 8.1% in 2004 to 15.1% in 2011 and the latter has increased from 4.8% to 12.3%. These two countries have mainly promoted renewable energy sources through a feed-in tariff scheme. The system has provided high enough price premiums to incentivise the use of renewable sources. This, as shown in section 5, has also affected the cost-effectiveness of the scheme.

According to Linares et al (2008), in Spain the EU ETS did not make renewables more attractive than conventional electricity technologies and, thus, did not encourage its deployment. A carbon price of at least €39/tCO2 would be needed to promote the cheapest renewable energy source (wind) (del Río, 2009). This author also states that the feed-in tariff was the major incentive to spur renewables in Spain.

Among RES-E support schemes, feed-in tariff systems (e.g. Germany, Spain) have been generally more effective than quota obligations (e.g. UK). However, the effectiveness of the instrument depends on the maturity of a technology. Thus, quota obligations tend to be more effective in promoting more mature technologies (e.g. wing onshore, biomass) than less mature technologies (e.g. wind offshore, PV) (Steinhilber et al, 2011). Consequently, some countries such as Italy have applied both instruments.

Political uncertainty related to the future development of the scheme is also a major factor in the promotion of renewables. Considerable changes in the legal framework may threaten the investment security. This is particularly true for the feed-in tariff scheme.

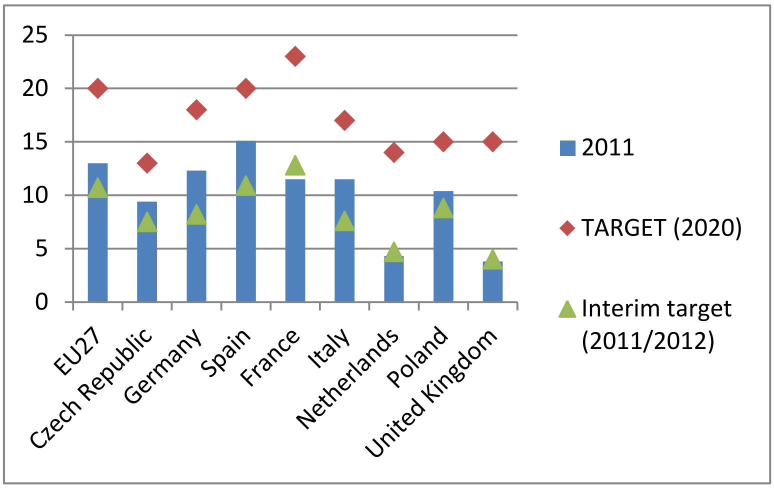
Figure 17. Share of renewable energy in gross final energy consumption (%)



Source: Eurostat

Despite the low development of renewable energy sources in some Member States (e.g. the Netherlands and the UK), the EU as a whole is on the trajectory to meet the 2020 targets. The EU interim target for 2011/2012 was 10.7% and, according to Eurostat, the share of renewable energy in gross final energy consumption was 13% in 2011. Among the Member States analysed in this report, only France and the Netherlands did not meet their respective interim target. In both countries, the policy mix to promote renewable sources of energy was mainly based on a feed-in tariff scheme. This shows that the effectiveness not only depends on the type of instrument, but also on the level of support that is granted.

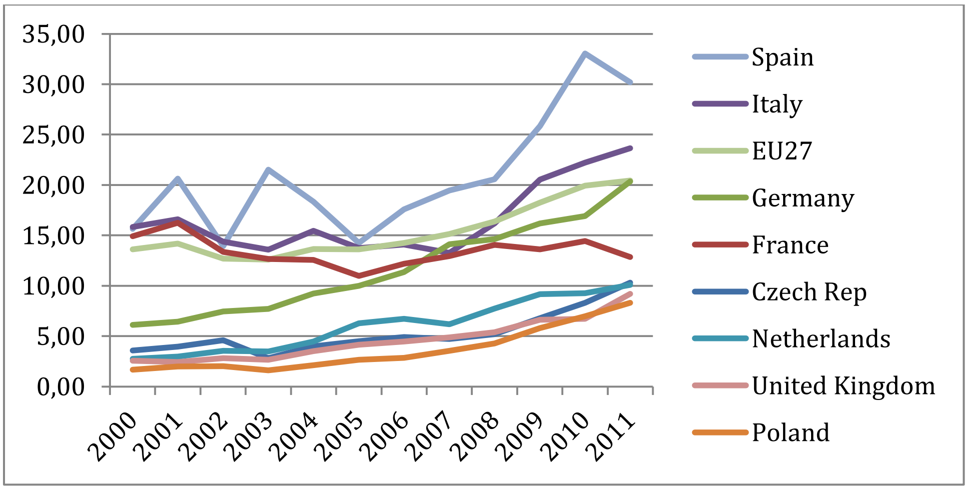
Figure 18. Share of renewables in 2011 and 2020 target



Source: Eurostat

In the period 2000-2011 the electricity generated from renewable sources increased from 13.6% to 20.4% in the EU27. Excluding hydropower, which represents around 50% of renewable electricity, wind power is the largest renewable source (25%). Germany and Spain are the largest wind power producers, together account for around 55% of installed capacity. In recent years, the installed capacity of solar photovoltaic technology has increased considerably. Since 2002 the installed capacity has almost doubled every year and currently accounts for 6% of renewable electricity. Around 50% of installed capacity is in Germany, while Italy and Spain account for 25% and 10%, respectively. The feed-in tariff scheme, with high premiums in Germany, Spain and Italy, has been responsible of the huge increase of renewable electricity in these countries.

Figure 19. Electricity generated from renewable sources (%)



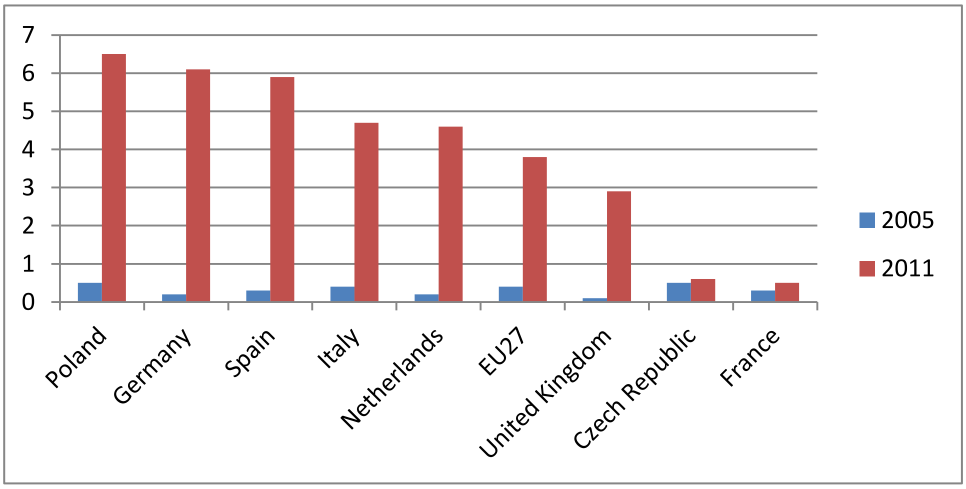
Source: Eurostat

Although the EU27 has met its interim target, ECOFYS et al (2012) argue that the economic crisis has affected the reliability of the current instrument mix and, therefore, further efforts will be needed to reach the 2020 target. Their estimates suggest that, in the absence of additional policies, the share of renewables will be around 5 percentage points below the 2020 target. Indeed, under current financial support for renewable energy sources, none of the countries analysed in this report would meet the 2020 target.

The second EU objective on the promotion of renewable sources of energy is to increase the use of renewable energy in the transport sector to at least 10% of final energy consumption by 2020. According to Eurostat, the share of renewables has increased from 0.4% in 2005 to 3.8% in 2011 in the EU27[14] (see figure 20). The majority of renewable energy use in transport is focused on biofuels, of which around 60% is produced within the EU (EC, 2013). Based on national reporting, it is estimated that the use of biofuels have generated 25.5 Mt CO_2-eq savings, although these estimates do not include indirect effects (EC, 2013). The contribution of renewable electricity in transport is very small and most of its use is in trains. The market penetration of electric cars is still negligible.

In 2011, the Member States with the highest penetration of renewables in transport were Poland, Germany and Spain, where the share of renewable sources of energy account for around 6%. Most Member States support biofuels through a combination of an obligation and tax reduction.

Figure 20. Share of renewable energy in fuel consumption of transport (%)



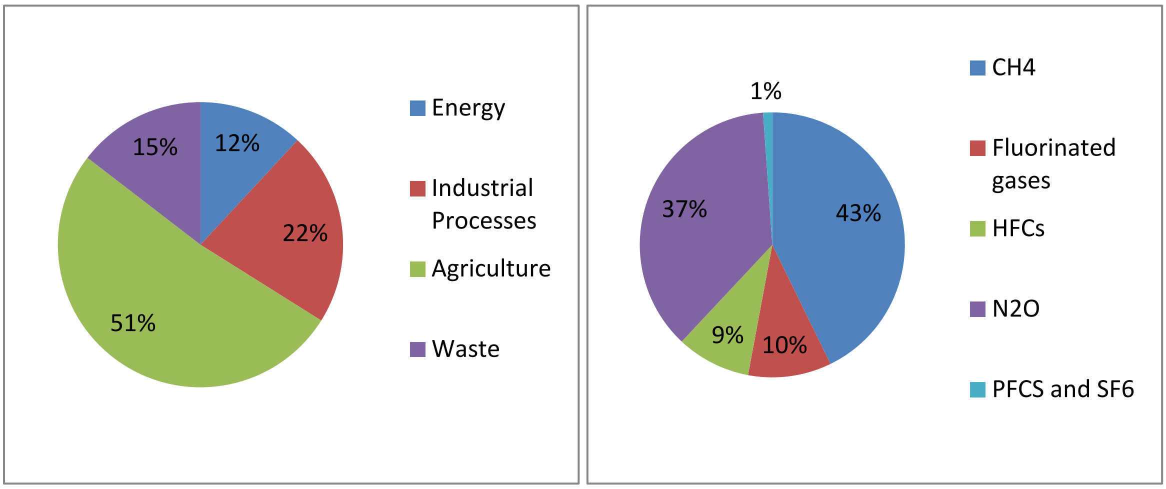
Source: Eurostat

[14] This indicator is calculated on the basis of Renewable Energy Directive 2009/28/EC on the promotion of the use of energy from renewable sources. This indicator is used for the assessment of the progress towards the EU targets.

4.4 Non-Carbon Dioxide GHGs

Non-CO_2 emissions account for 19.7% of total GHG emissions in the EU27. The share of non-CO_2 emissions has declined since 1990, when represented 22% of the total. Agriculture is the main contributor to non-CO_2 emissions; it accounts for around 51% of the total. Waste, industry and energy generation are the other emitters of non-CO_2 emissions. The emissions of CH_4 and N_2O represent 43% and 37% of the total, respectively. N_2O emissions take mainly place in agriculture, while CH_4 emissions are also considerable in waste and energy generation.

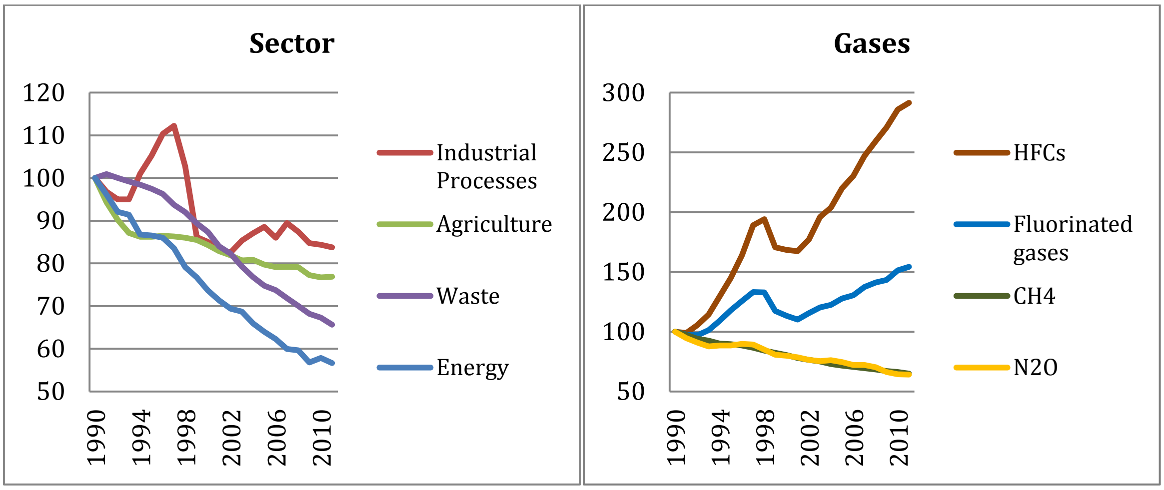
Figure 21. Non-CO_2 GHG emissions by sector and type in the EU27 (2012)



Source: EEA

Since 1990 non-CO_2 greenhouse gas emissions have declined by around 27% in the EU27. The current policy mix has been more successful in decreasing emissions in energy generation (43%) and waste (34%) than in agriculture (23%) and industry (16%). Over the period 1990-2011 CH_4 and N_20 emissions reduced by around 35%. On the other hand, the emission of Fluorinated gases and HFCs, which are only present in industrial processes, increased considerably.

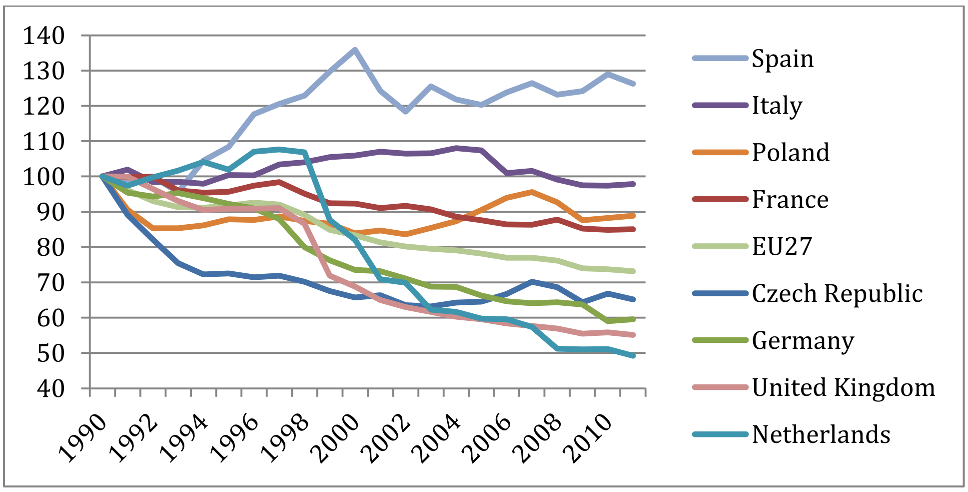
Figure 22. Evolution of non-CO_2 GHG emissions by sector and type in the EU27 (1990=100)



Source: EEA

The Netherlands has been the most successful country in reducing non-CO_2 emissions (50%), particularly in industry and waste, where emissions decreased by around 70% since 1990. This was mainly due to a reduction of landfill waste and the Reduction Program Other Greenhouse Gases which ran from 1999 to 2012. Over the period 1990-2011, non-CO_2 emissions declined by 44% and 40% in the UK and Germany, respectively. As in the Netherlands, the policy mix implemented in the UK and Germany has been more successful in reducing non-CO_2 emissions in waste and industry than in agriculture. Both the landfill tax implemented in the UK and the ban of landfilling untreated waste has been effective in reducing methane emissions. On the other hand, Spain has increased non-CO_2 emissions by around 26%. In 2011, agricultural emissions were almost the same as in 1990, and in recent years they show a downward trend. However, the current policy mix has failed to reduce emissions from waste. These account for 19% of non-CO_2 emissions in Spain, when in 1990 they represented around 12%.

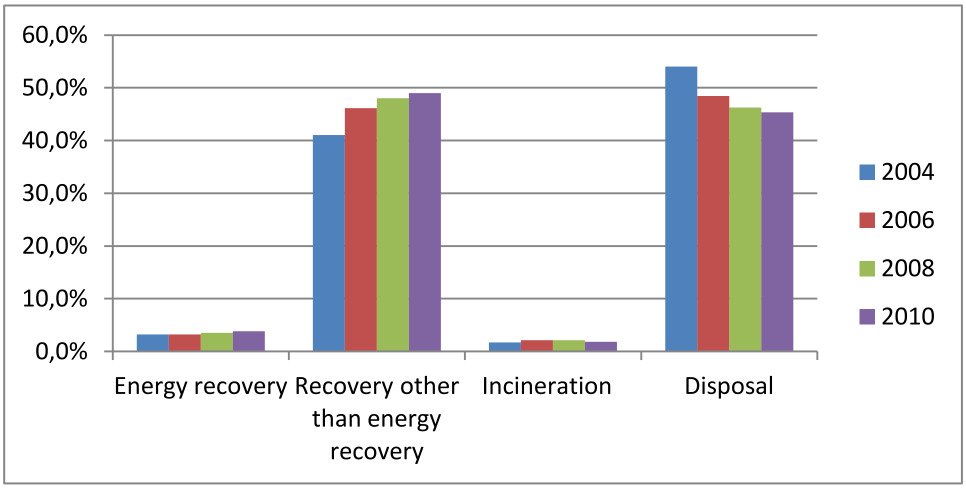
Figure 23. Evolution of Non-CO_2 emissions by country (1990-2011)



Source: EEA

In the EU as a whole, the lower emissions from waste are caused by a decline in the generation of waste and a better waste treatment. Waste generation declined by 5% from 2004 to 2010. In terms of population, the generation of waste per capita has been reduced by around 7%. In addition to this, recovery has increased in recent years. The percentage of waste that is used for energy recovery has risen from 3.2% in 2004 to 3.8% in 2010. And total recovery accounts for more than 50% (see figure 24). Thus, in the period 2004-2010 the share of waste that is deposited (into land or water) has been reduced from 54% to 45%.

Figure 24. Waste management in the EU27 (2004-2010) (%)



Source: Eurostat

According to Fellmann et al (2013), the reduction of non-CO_2 emissions in agriculture was caused by several factors. A key determinant was the adjustment of agricultural production, which led to a decrease in cattle numbers. This explains the reduction in CH_4 emissions; 23% from 1990 to 2011. The increase in animal productivity (milk and meat) and the improvements in the efficiency of feed use also contributed to the reduction of CH_4 emissions in agriculture. Over this period a similar reduction has been observed in N_2O emissions. This is explained by the lower use of organic and mineral nitrogen fertilizers.

4.5 Instrument mix integration and the efficiency of the overall mix

This section discusses and evaluates how well the current instrument mix is integrated. It analyses the interactions between instruments and how they overlap in the biggest GHG emitting sectors. The goal of this section is to evaluate the environmental effectiveness of the current instrument mix.

The current instrument mix is mainly characterized by the interaction between the EU ETS and those instruments that promote energy saving and renewable energy. The electricity sector, for instance, is subject to the EU ETS and the promotion of renewable sources of energy. Other EU ETS sectors, such as energy-intensive industries, interact with the IPPC Directive.

The EU ETS scheme establishes a cap which fixes total CO_2 emissions. The contribution of other policy instruments was anticipated when the EU ETS cap was set. But, once the cap is set, further measures in the EU ETS sectors, either promoting renewables or energy efficiency, will not result in additional emission cuts. As pointed out by Sijm (2005), other energy policies affecting the EU ETS sectors cannot affect CO_2 emissions. Moreover, policies affecting electricity use by non-ETS sectors, such as taxes on household electricity consumption, only reduce CO_2 emissions in that particular sector, but are not effective at the EU level. Sijm (2005) also states that the coexistence of the EU ETS and other instruments is needed to correct for market failures, improve the design of the system and meet other policy objectives.

Given that the EU ETS is a 'cap and trade' system, it ensures a certain emission reduction but not a carbon price level. When overlapping instruments are implemented, they introduce an element of uncertainty because their success cannot be predicted. The overachievement on their targets does not result in lower emissions, but in a lower EU ETS price. According to Point Carbon (2013), in addition to the economic recession, the EU's policies for promoting renewable energy and energy efficiency have been the main cause for a low carbon price. CDC Climate (2013) also considers that these policies have been the main drivers for emission reductions.

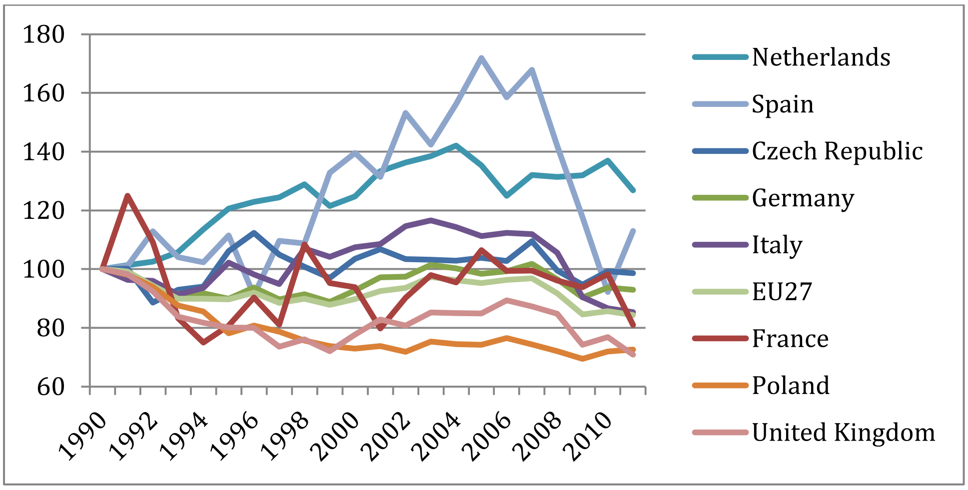
The interaction between the EU ETS and RES-E schemes has been debated in the literature[15]. The major criticism raised with respect to RES-E support schemes is that they do not generate additional emission cuts. Thus some authors argue that RES-E support schemes increase costs and, therefore, they should be abolished (Frondel et al 2010; Sinn, 2011). Although from the effectiveness point of view, the overlapping of instruments is not effective in the electricity sector, other authors claim that the coexistence of the EU ETS and RES-E schemes can be desirable (del Rio, 2009; Lehmann and Gawel, 2013). Sijm (2005) finds two main reasons for the overlapping of instruments: correcting for market failures and meeting other policy objectives. The next sections analyse these other dimensions of the interaction between the EU ETS and RES-E schemes.

Electricity generation, the sector with the highest weight in the EU ETS, is subject to other instruments, particularly in the promotion of renewables (e.g. feed-in tariff scheme). Although, as mentioned above, once the EU ETS cap is set, these instruments cannot generate additional emission cuts, they can be important to meet national targets on emissions or on the share of renewable energy sources. In some countries such as Germany, Italy and Spain, the promotion of renewables in the electricity generation sector has been effective (see figure 19). The coexistence of the EU ETS and RES-E (electricity from renewable energy sources) support schemes has led to a reduction in CO_2 emissions in electricity and heat production. In Spain, where emissions are still above 1990 levels, GHG emissions have decreased around 35% since 2005. For the EU27 as a whole, emissions have reduced by 15%

[15] Lehmann and Gawel (2013) present a complete survey of the literature on this topic.

in the period 1990-2011, however most of the decline has occurred in recent years. Between 1990 and 2004 emissions have reduced at an average rate of 0.23% per year and between 2005 and 2011 they decreased by 1.82% per year.

Figure 25. Evolution of GHG emissions in power and heat generation by country (1990-2011)

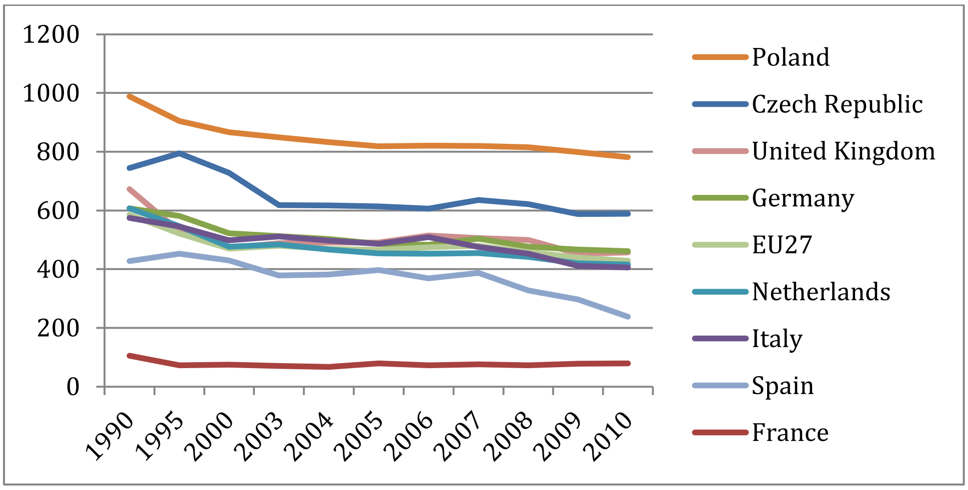


Source: EEA

Electricity generation has also reduced considerably emissions intensity. This is particularly true for Spain and Italy, where in the period 2003-2010 CO_2 emissions per kWh from electricity generation decreased by 37% and 20%, respectively. In the EU27 as a whole, emissions intensity declined by 10% since 2003. The instruments implemented in the promotion of renewables have been essential in raising the share of renewable energy sources in the electricity mix and, thus, in reducing emissions intensity. Delarue et al (2008) show how the carbon price of the EU ETS has also reduced emissions intensity through switching from coal to gas in the electricity sector.

Although total GHG emissions have declined in the electricity sector, disentangling the effects of the current instrument mix from other factors is not straightforward. The financial crisis, for instance, has had a considerable impact on emissions reduction. The economic downturn has reduced the demand for electricity and, thus, GHG emissions in this sector. According to Declercq et al (2010), the effect of economic crisis on emissions accounted for 150 Mt CO_2-eq.

Figure 26. CO_2 emissions per kWh from electricity generation

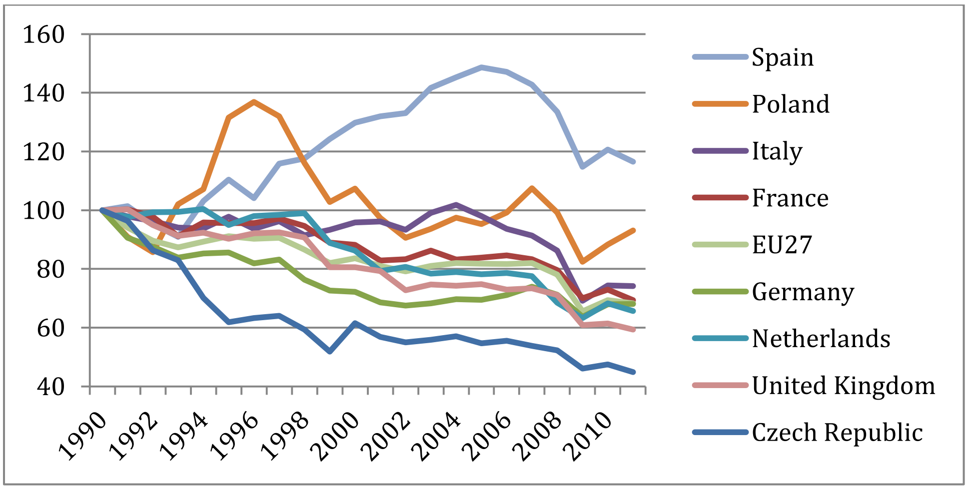


Source: IEA (2012b)

The current instrument mix also overlaps in the industrial sector where, in addition to the EU ETS, other instruments have been implemented, particularly the IPPC Directive. Most of the EU ETS sectors are also regulated under the IPPC Directive, although it is not primarily a climate policy instrument. It indirectly affects CO_2 emissions by setting energy efficiency requirements, but does not impose emission limits.

The consequences of the instrument overlap in the industry sector are similar to the electricity sector. Once the EU ETS sets a cap on emissions, other instruments implemented in EU ETS sectors cannot generate additional emission cuts. Thus, the majority of Member States have considered reducing or eliminating energy taxes for firms that are subject to the EU ETS. This is argued by Böhringer et al (2008), who use a partial equilibrium framework to show that emission taxes are environmentally ineffective and all firms that are subject to emissions trading should be exempted from these taxes.

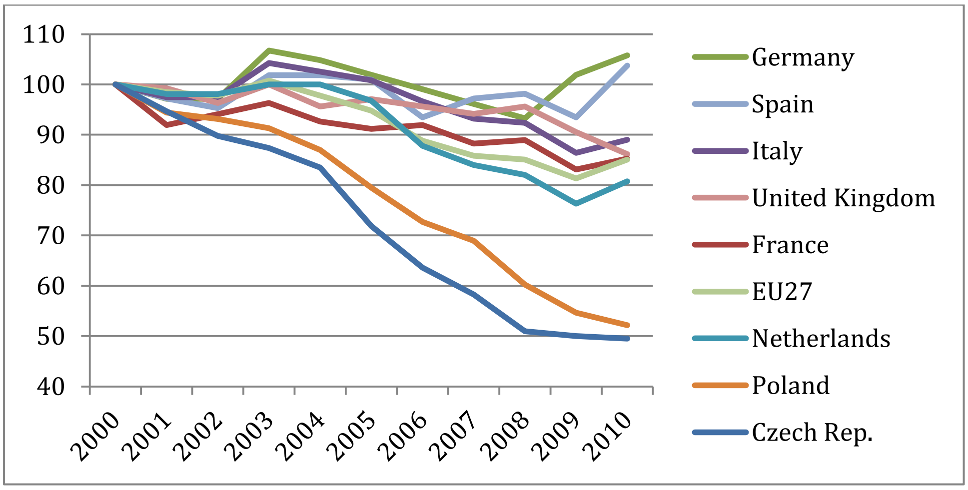
Figure 27. Evolution of GHG emissions in energy-intensive industry sectors (1990-2011)



Source: EEA

Since 1990, total GHG emissions have been reduced by around 30% in the industrial sector in the EU27. In recent years, the emission reduction has accelerated: thus, while between 1990 and 2004 the average reduction rate was 1.4%, in the period 2005-2011 emissions declined by 2.4% per year. Emissions have been reduced in all Member States analysed in this document except Spain. The Czech Republic is the country where industrial emissions have declined most; around 50% since 1990. This has been achieved by improving energy intensity. According to Odyssee (see figure 28), energy consumption of industry per unit of value added in the Czech Republic was reduced by 50% in the period 2000-2010. In the EU27 as a whole, the energy intensity of the industry sector has decreased around 15% since 2000; only in Germany and Spain it has increased. This may be due to the crisis: 6 out of 8 countries saw a deterioration of energy efficiency in 2010, against the long-term trend.

Figure 28. Consumption of industry per unit of value added (at ppp) (koe/€2005)



Source: Odyssee

The empirical evidence on the impact of the current instrument mix on industrial emissions is limited. However unexpected large emissions reductions have been observed in some sectors (Laing et al, 2013). Cement, which accounts for 8% of EU ETS emissions, has reduced emissions by 25% since the EU ETS was implemented. This has mostly been achieved by using alternative fuels such as waste and biomass, and by producing cement of lower clinker intensity. Other sectors such paper, metal and chemicals have also reduced GHG emissions around 20% in this period.

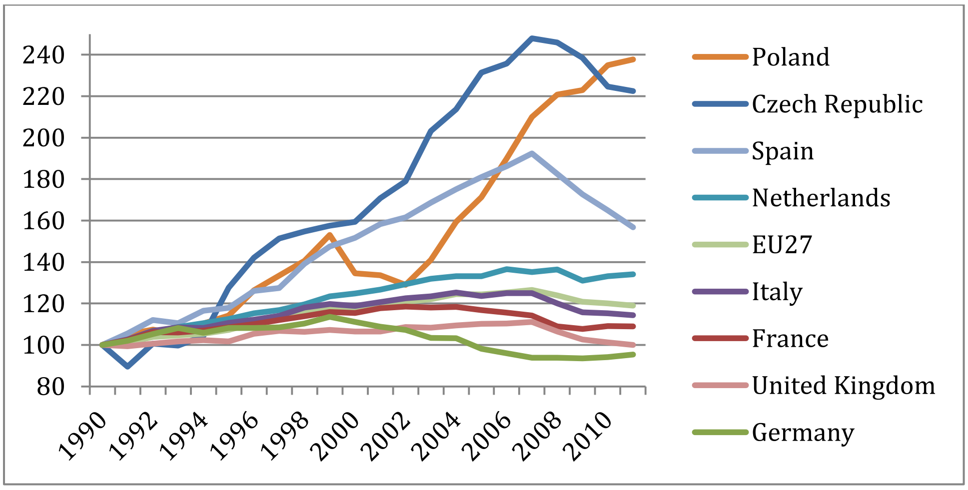
Figure 5 shows that verified emissions have been below allocated allowances in all industrial sectors subject to the EU ETS. The considerable difference between verified emissions and the number of allocated allowances has been interpreted as evidence of over-allocation, hindering the effectiveness of the scheme (Ellerman and Joskow, 2008). Besides, as in the electricity sector, emissions in the industrial sector have been affected by the economic crisis. CDC Climat (2013) points out that the fall in manufacturing output has been a key factor of the emission reduction in the EU ETS sectors. In 2009, industrial emissions fell by over 15% in the EU27; and in some countries such as Italy, it was around 20%. However, in most sectors, emissions recovered in 2010 and have stabilized at those levels. The decline in industrial output, and thus emissions, has resulted in the build-up of a massive allowance surplus, which will suppress the price of EU ETS allowances for years to come.

Emissions reduction in the industrial sector has been driven not only by a lower activity but also by a decrease in energy intensity (figure 28). The improvement in energy intensity occurred particularly in the period 2004-2007, and in recent years this trend has slowed, probably due to the economic crisis.

Apart from the EU ETS sectors, transport is the biggest emitting sector in the EU27. It accounts for around 20% of total GHG emissions and, unlike other sectors, emissions from transport did not decrease since 1990. While total GHG emissions decreased by 18% between 1990 and 2011, in the transport sector they increased by 19%. However, this trend has changed in recent years. Since 2007, when transport emissions peaked in the EU27, they have declined by 6.3%.

Only Germany and the UK managed to reduce their emissions from transport since 1990 (see figure 29). The largest increases were observed in Poland and the Czech Republic, where emissions have more than doubled. In Spain, although transport emissions have declined by around 20% since 2007, in the period 1990-2011 they increased by over 50%. The Netherlands has also shown a pronounced rise in transport emissions; in 2011 they were 34% higher than in 1990.

Figure 29. Evolution of GHG emissions in transport (1990-2011, 1990 = 100)



Source: EEA

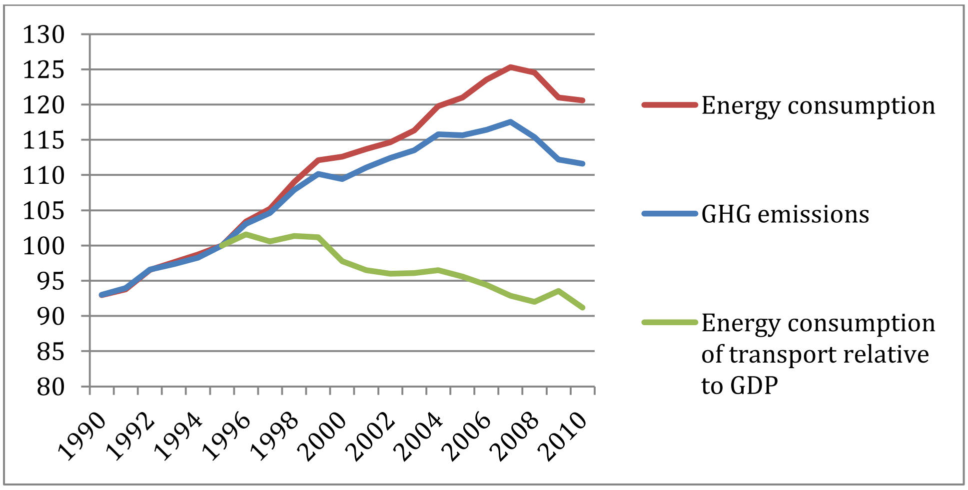
Road transport is responsible for over 90% of domestic transport GHG emissions[16]. Consequently, the majority of instruments implemented to reduce emissions have been in this sector. The policy mix in road transport consists includes a range of instruments,

[16] It accounts for around 70% of overall transport emissions.

including carbon pricing tools (e.g. excise duties on fuels), energy consumption and energy efficiency measures (e.g. efficiency standards for new cars) and the promotion of renewable energy sources (e.g. biofuels). The empirical evidence which disentangles the impact of the economic crisis and the current policy mix is limited. However, we can already get an insight from available data.

The available data show that the evolution of GHG emissions, energy consumption and GDP has been similar until 1995. From that year onwards there has been a decoupling of the three paths (see figure 30). On the one hand, the growth in GHG emissions has been slower than the growth in the energy consumption. This can be explained by the use of cleaner energy sources and the development of biofuels. On the other hand, energy intensity has decreased, that is, the growth in transport-related energy consumption has been slower than the growth in GDP. According to Odyssee, in the period 2000-2010 energy efficiency gains in transport accounted for 8.1%. The volume of both freight and transport relative to GDP has also decreased in recent years, and the energy consumption of road transport of goods per tonne-km was 5% lower in 2010 compared to 2000 (see figure 32). Besides, in this period, the average CO_2 emissions from new passenger cars declined by around 20%. All these factors may explain the improvement of the energy intensity in transport. Thus, although emissions have increased since 1990, the current instrument mix has had some positive effects. The European regulations targeted at vehicle manufacturers and the national measures which promote the purchase of cleaner vehicles (e.g. vehicle registration tax and financial incentives) have led to increase the average energy efficiency of the vehicle fleet.

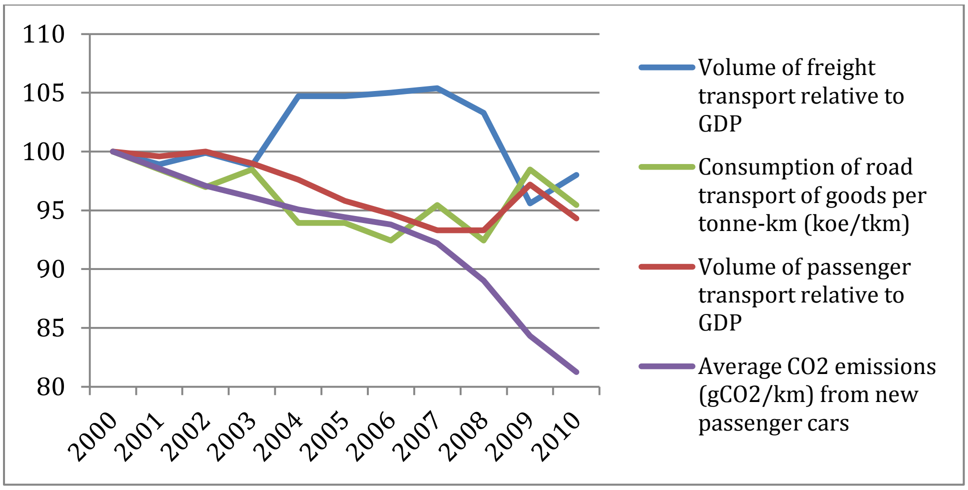
Figure 30. Evolution of GHG emissions, energy consumption and energy intensity in transport (1995=100)



Source: EEA and Eurostat

Although the current instrument mix has been successful in improving the efficiency of vehicles, EC (2011) states that the potential for additional energy savings is still significant, and only half of it is expected to be realized with the current policy mix. There is a high potential in the modal shift, which the current policy mix has failed to improve. Since 2000, the share of lower-carbon transport modes is decreasing in both the passenger and the freight transport (Odyssee, 2012). In the EU27, the share of public transport in passenger traffic decreased from 17% in 2000 to 15.9% in 2011. Only the UK, Italy and France show a small increase. The strongest reduction in public transport took place in Poland. Similarly, the share of rail and water in total freight traffic decreased from 26.2% in 2000 to 24.6% in 2011. Poland is again the country with the greatest reduction, while the Netherlands and the UK have slightly increased the share of efficient modes in freight transport.

Figure 31. Evolution of energy and emissions intensity in transport (2000-2010)

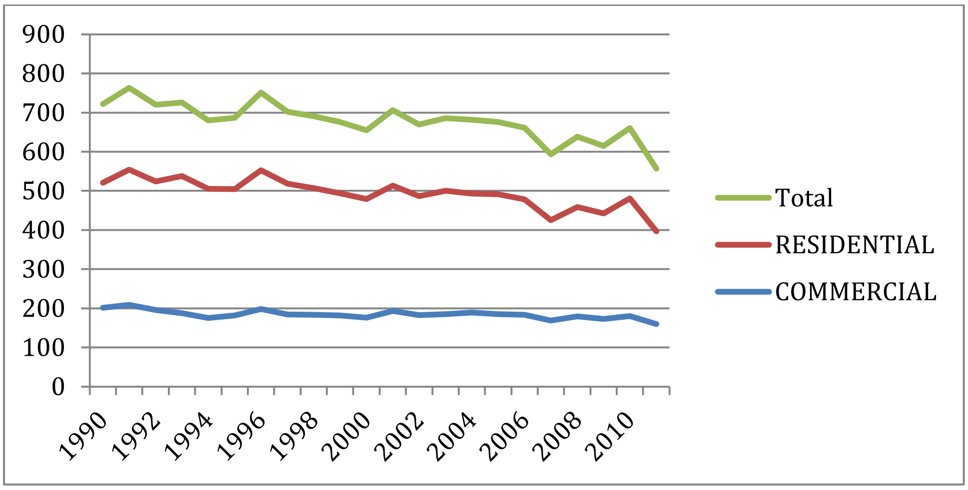


Source: Odyssee

In contrast to the transport sector, the current policy mix has been successful in decreasing direct GHG emissions in the building sector[17]. This sector accounts for around 13% of total direct emissions, however it represents around 36% of total emissions if indirect emissions are included, mainly from electricity use. Residential buildings emit 71% of total direct emissions in this sector, while commercial buildings account for 29%.

[17] In the building sector we include two main categories of buildings: residential buildings and non-residential buildings.

Figure 32. GHG emission in the building sector (Tg (million tonnes) CO_2 equivalent)

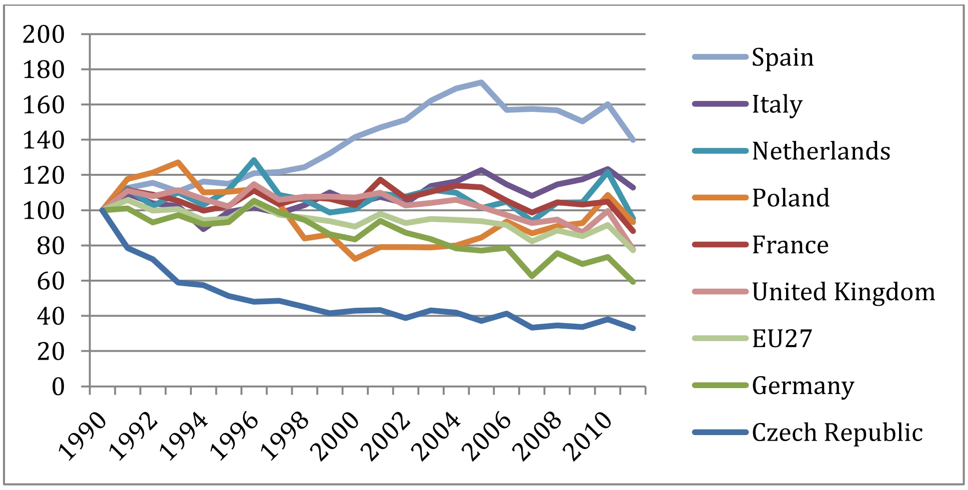


Source: EEA

In 2011 direct emissions of buildings were 23% lower than in 1990. However, notice that this sector is subject to large fluctuations caused by weather conditions. Indeed, a huge drop is observed from 2010 to 2011, when emissions decreased by around 16%. Comparing longer periods, average direct emissions in the period 2001-2011 were 8% lower than in the period 1990-2000. Figure 33 shows that since 1990 the direct emissions trend has been downwards. On the other hand, from 1990 to 2010 electricity consumption in buildings rose by around 60%, increasing the indirect emissions of this sector (Odyssee, 2011).

Spain is the country with the strongest rise in direct emissions (40%). This was mainly caused by the economic growth of the mid 90s, which increased energy consumption (e.g. air condition systems), the population and the housing stock. On the other hand, the Czech Republic has reduced direct emission by around 67% since 1990. Germany and the UK have also been successful in decreasing GHG emissions in buildings.

Figure 33. Evolution of GHG emissions in buildings (1990-2011)

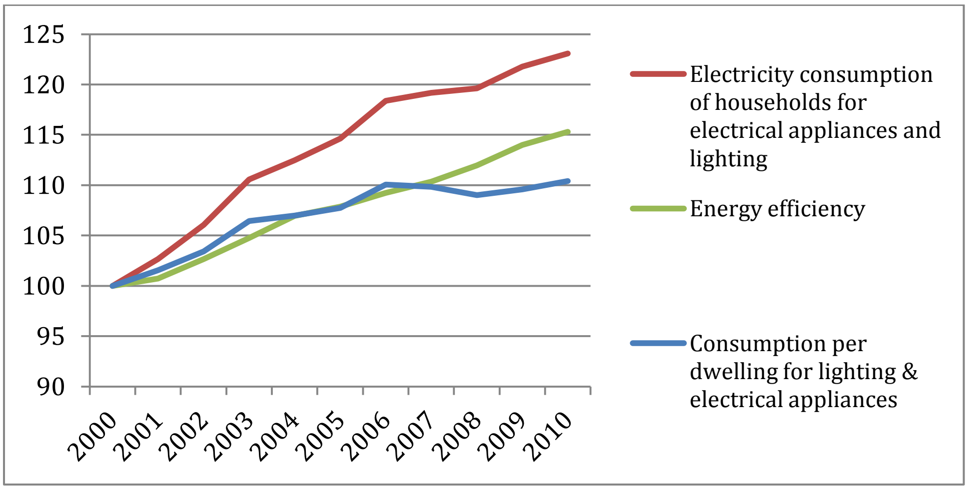


Source: EEA

The policy mix implemented to reduce GHG emissions in buildings is aimed at reducing both direct and indirect emissions. Similarly to those instruments that promote RES-E, the instruments that induce a reduction of electricity consumption (indirect emissions) overlap with the EU ETS (e.g., Energy Labelling Directive, Ecodesign Directive). When these instruments are not considered in the setting of the EU ETS cap, they do not contribute to reducing GHG emissions. Electricity savings lead to a lower electricity generation, decreasing the demand of the emission permits and thus their price.

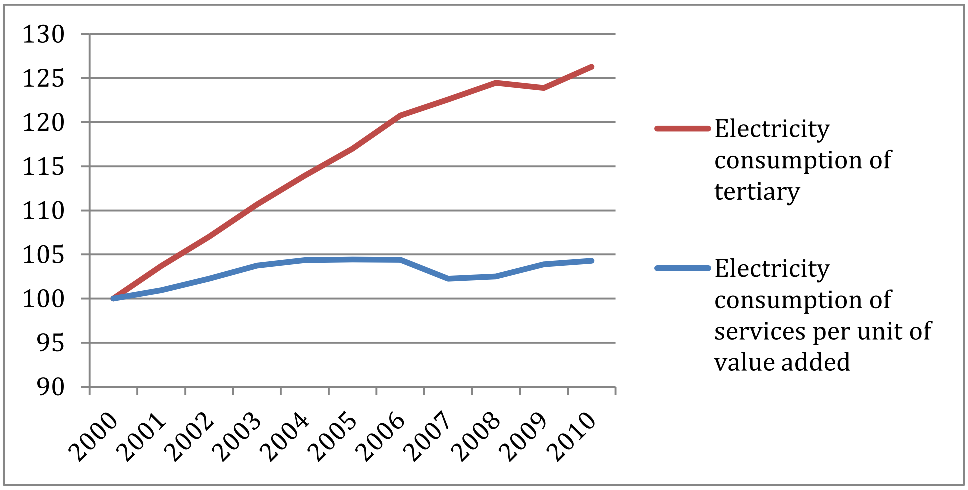
Despite the energy efficiency gains, the electricity consumption of residential buildings for electrical appliances and lighting is increasing (see figure 34). Since 2000, the total electricity consumption and the electricity consumption per dwelling rose by 23% and 10%, respectively. Commercial buildings show a similar trend (figure 35). Over the period 2000-2010 the electricity consumption of the service sector increased by 26%. Electricity intensity has also increased; in terms of value added, electricity consumption rose by 4%.

Figure 34. Energy intensity in residential buildings (2000=100)



Source: Odyssee

Figure 35. Energy intensity in commercial buildings (2000=100)

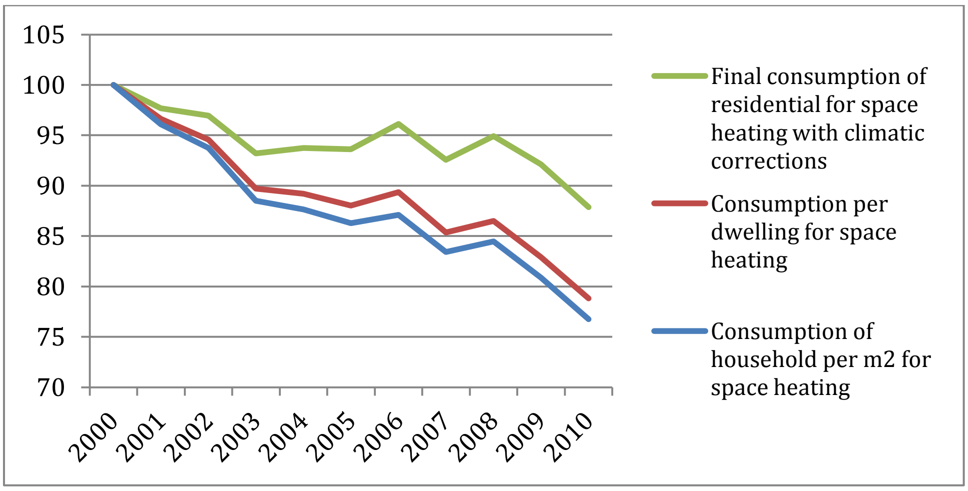


Source: Odyssee

The current instrument mix has been more successful in decreasing direct emissions. In order to reduce direct emissions, several instruments have been implemented at both European (e.g., Energy Performance Directive for Buildings) and national level (e.g., National Building Codes, Building Certificates, Financial and fiscal measures). Over the period 2000-2011, direct GHG emissions declined by 15.7%. The strongest decline took place in residential buildings where emissions decreased by 17%, while commercial buildings emitted 9% less.

Over the period 2000-2010 energy consumption for space heating which represents the largest share of household energy use, declined by 12%. The energy efficiency gains have been more significant. In the EU27 the energy use per square metre for space heating was 20% lower. This has been partially offset by the increase in dwelling size. In this period, the lower energy consumption for water heating and the diffusion of solar water heaters has also contributed to decrease direct emissions in residential buildings.

Figure 36. Energy consumption for heating in residential buildings (2000=100)



Source: Odyssee

5 Cost effectiveness

5.1 Static efficiency

As mentioned in the previous section, the instruments implemented in recent years have helped to reduce GHG emissions. However, not all the instruments have had the same economic impact. The static efficiency of the current policy instrument mix is assessed in terms of how successful the current policy mix is in equalising the marginal abatement cost across sectors and across emitters. As it is very difficult to measure the actual marginal abatement cost for a large number of emitters, this measure is typically approximated through the carbon price: the policy mix is statically efficient if it succeeds in generating a uniform carbon price across sectors and emitters. Carbon prices can be explicit, such as the carbon price of the EU ETS, or implicit, reflecting the abatement effort (and hence cost) implied by a policy measure. This section examines the carbon price (explicit or implicit) emerged from the implementation of the key instruments in the EU: EU ETS, energy taxes and feed-in tariff scheme.

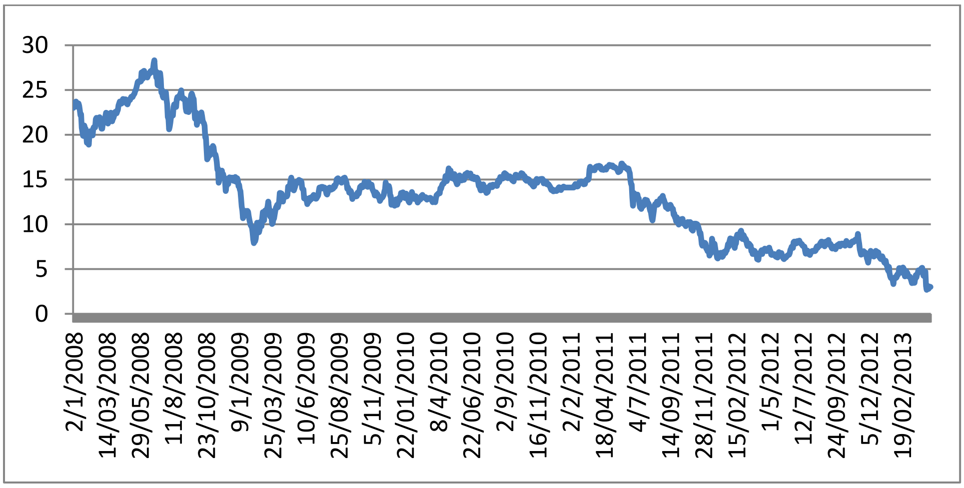
5.1.1 The EU ETS

In the EU ETS, there is one single carbon price for all emitters covered by the scheme, based on the allowance supply (cap) and the demand of different emitters. The theory says that, in the absence of transaction costs or market imperfections, companies will reduce emissions until the marginal abatement cost equals the carbon price. Thus, emissions trading systems give companies the flexibility to achieve the emission goal in a cost-effective way. This equalisation applies not only to the direct emitters covered by the scheme. At least in theory, emitters will pass on the carbon price signal by factoring the cost of allowances into their price calculation, thus increasing the prices of goods according to their emission intensity. This also creates an incentive to reduce indirect emissions.

In reality, some market barriers and failures reduce the static efficiency of the EU ETS. For instance, several energy efficient measures are subject to a number of market failures (e.g. principal-agent problem, capital market imperfections), which reduce savings potential (Linares and Labandeira, 2010). In other cases, the carbon price of the EU ETS might not be passed through to end users and, therefore, do not incentivise cost-effective energy saving opportunities (Sijm, 2005). Moreover, households, in general, respond poorly to price incentives. Thus, the EU ETS might not encourage the adoption of all cost-effective measures with an abatement cost lower than the carbon price set by the EU ETS.

Given its technical design, the EU ETS is subject to market forces. The EU ETS is recognised as a liquid market and, therefore, the carbon price reflects market conditions. The carbon price evolution is driven by the demand and the supply of allowances. Consequently, as expected, the economic slowdown reduced the demand for allowances and, thus, the carbon price slumped. Low carbon prices do not imply that the EU ETS is not achieving to reduce GHG emissions in a cost-effective manner. From a static efficiency perspective, it should be irrelevant how high the EU ETS carbon price is. Static efficiency implies that emissions are reduced at the lowest cost. In the EU ETS, a single carbon price provides a common signal to participants of the most cost-effective options to address their emissions. A low carbon price signals a low marginal abatement cost. However, as pointed out by the European Commission, the EU ETS also aims to promote investment in clean low-carbon technologies (EC, 2012). But this is related to the dynamic efficiency which is analysed in section 5.2.

Figure 37. Evolution of the carbon price of the EU ETS



Source: SENDECO2

5.1.2 Energy taxes

In 2004 the EU adopted the Directive 2003/96/EC which sets the minimum tax rate for energy products. The Directive included not only oil products but also coal, natural gas and electricity. The main objective was to reduce distortions of competition between member states and energy products. Besides, it aimed to increase incentives to use energy more efficiently. However, in the majority of member states energy taxes are not calculated according to GHG emissions or other environmental externalities. This is because energy taxes reflect more concern about competitiveness and distributive impact rather than environmental impact.

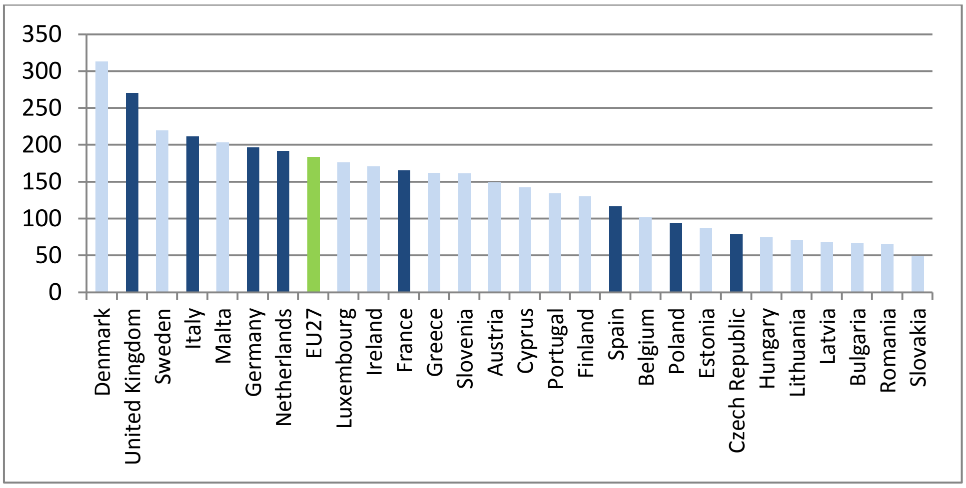
Thus, energy taxes vary substantially among countries. According to the Eurostat dataset, the implicit energy tax rate[18] varies from €269.8 per tonne (of oil equivalent) in the UK to €78.3 per tonne (of oil equivalent) in the Czech Republic (see figure 38). However, energy tax rates not only vary between countries but also by energy source and user group. This, consequently, implies a wide range of tax rates, when expressed per tonne of carbon.

[18] This indicator is defined as the ratio between energy tax revenues and final energy consumption.

In this section we calculate the implicit carbon tax for different energy sources and user groups. Following OECD (2013), the implicit carbon tax (€/tonne of CO_2-eq) is computed as the amount of excise tax levied per unit of energy product (€/unit) divided by the CO_2-eq emissions per unit (tonne of CO_2-eq/unit).

Table 5 shows excise tax rates obtained from IEA (2012a). As mentioned above, tax rates vary considerably among countries and energy sources. Electricity, for instance, is highly taxed in countries such as Italy and Germany, while the tax rate in the Czech Republic and the UK is very low. Likewise, the electricity emission factor is very different among countries (see Table 6). In France, the production of 1 MWh of electricity causes the emission of 0.079 tCO_2, while in Poland it is around 10 times higher.

Figure 38. Implicit energy tax (€/tonne of oil equivalent)

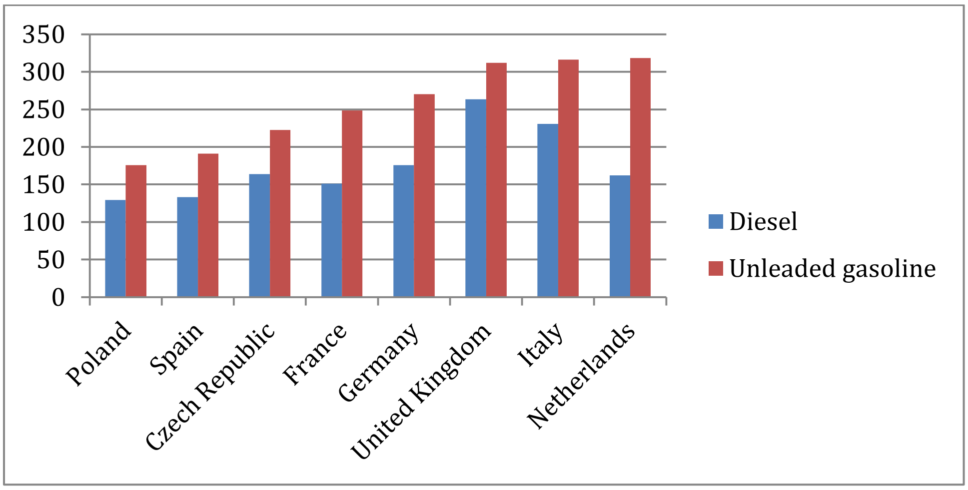


Source: Eurostat

The implicit carbon prices for energy products are presented in Table 1. These values should be put into perspective. The majority of energy taxes were not implemented with the aim to limit GHG emissions. For example, gasoline and diesel excise taxes are often considered to be road-user charges or general taxation and, in most countries, GHG emissions reduction was only a minor motivation for their introduction. In many countries, excise duties on transport fuels were introduced several decades ago, long before climate policy ever became an issue. It is therefore practically impossible to decide which share of these taxes should be considered as climate-related, and share part as serving other objectives. However, irrespective of their motivation, such excise duties on fuels also have an impact on emissions and are economically equivalent to a carbon tax on transport fuels. Hence they have been included in this analysis.

The results show that the implicit carbon prices for energy products vary widely. The differences are not only among countries but also among energy products. When expressed per tonne of carbon, fuels for transport (diesel and gasoline) are taxed at a much higher level than any other energy product. In the Netherlands, Italy and the UK, the implicit carbon price for unleaded gasoline is above €300, and, on the other hand, in Poland and Spain is around €200. Given that taxes on transport fuels include other objectives, the comparison with other energy products may not be meaningful. However, some useful information can be drawn from the comparison between transport fuels (figure 39). In all Member States, the implicit carbon price for diesel is lower than for gasoline, although the carbon content of diesel is higher than of gasoline. In the Netherlands, for instance, the implicit carbon price of diesel is half of that for gasoline.

Figure 39. Implicit carbon price of gasoline vs diesel (€/tCO2) (2012)



Source: own elaboration

Another important result is that the implicit carbon price for natural gas is very low in most countries. In the Czech Republic, Poland, Spain and the UK natural gas is not taxed in households, and the implicit carbon price for the industry is not more than €6.

The implicit carbon price for electricity shows the largest differences among countries. This is partly because of the differences in the emission factors. The implicit carbon price for electricity in the Czech Republic is around €2. On the other hand, Italy, where the excise tax is high, and France, where the emission factor is very low, the implicit carbon price for electricity is around 200€. It is also significant that in the UK the implicit carbon price of electricity for households is zero.

Although these values should be put into perspective, Table 1 shows how far the EU is from a uniform carbon price across countries and across fuel types. The differences between user groups also reflect concerns about competitiveness. In the Netherlands, for instance, the implicit carbon price of natural gas for households is six times higher than for the industry. Similarly, in Germany, electricity for households is taxed at higher level than for the industry.

Table 1. Implicit carbon price for energy products (€/tCO_2) (2012)

	Electricity	Natural gas	Diesel	Unleaded	Light	LPG

						gasoline	fuel oil	
	Industry	Households	Industry	Households				
Czech Republic	1.91	2.03	6.03	0.00	163.61	222.40	9.86	53.10
France	212.41	299.49	7.23	5.50	151.10	248.71	20.86	37.09
Germany	72.67	160.52	19.95	27.23	175.71	270.36	22.94	56.87
Italy	196.11	152.04	21.79	:::	230.74	316.01	151.28	90.87
Netherlands	30.84	18.77	13.37	84.42	162.02	318.20	:::	58.11
Poland	6.12	6.12	0.00	0.00	129.19	175.54	20.73	68.25
Spain	21.85	36.76	0.00	0.00	133.26	191.20	31.20	19.78
United Kingdom	7.55	0.00	4.40	0.00	263.54	312.09	50.62	:::

Source: own elaboration

5.1.3 Renewable support schemes in electricity production

The promotion of renewable energy sources in the electricity sector is essential for achieving the EU aim to get 20% of its energy from renewable sources. Most of the member states have implemented a feed-in tariff scheme to reach their objective. However, the financial support has been very different across countries and technologies.

Table 2 shows the CO_2 abatement costs implied by the financial support for the promotion of renewables in the generation of electricity. This is computed as the weighted average financial support by technology divided by the amount of CO_2 emissions avoided[19]. CO_2 emissions of supported technologies are assumed to be zero. Thus, avoided emissions are the average CO_2 emissions from the current electricity mix in the respective Member State, excluding renewable energy sources (see Table 8).

The cost of abating one tonne of CO_2 emissions varies according to the technology and the Member State. Abatement costs not only depend on the financial support by technology but also on the current electricity mix. In those member states where electricity is produced with low carbon intensity, the abatement costs are higher. This is because it is assumed that renewables crowd out electricity from all existing technologies, and not only the most carbon intensive ones. Thus, in France, where nuclear power accounts for the lion's share of the electricity, it is more costly to reduce CO_2 emissions from electricity generation than in any other country.

[19] Table 7 shows the weight average support by technology (€/MWh).

Table 2 shows how far the EU is from a unified abatement cost across countries and technologies. The financial support for the photovoltaic is the highest among all technologies. This implies that the abatement of CO_2 emissions is more costly when this technology is promoted. On the other hand, the abatement cost implied by the promotion of hydro and wind energy is lowest.

Table 2. Abatement costs implied by the promotion of renewables in 2010 (€/tCO_2). National electricity mix

	Hydro	Wind	Biomass	Biogas	PV	Geo-thermal	Waste
Czech Republic	83.2	21.1	59.3	166.2	790.4	::	::
France	133.2	385.2	536.8	420.7	5381.0	::	::
Germany	67.4	77.6	228.6	::	733.8	294.5	::
Italy	149.9	142.1	224.8	::	759.5	153.8	::
Netherlands	224.9	185.4	171.0	::	890.2	::	111.3
Poland	::	::	::	::	::	::	::
Spain	124.8	129.2	219.8	::	1134.3	::	84.5
United Kingdom	131.0	145.4	129.5	127.6	416.7	::	::

Source: own elaboration

Table 2 assumes that renewables crowd out all existing technologies within a country. Thus, avoided emissions are the average CO_2 emissions from the current electricity mix in the respective Member State, excluding renewable energy sources. Given the increasing interconnection between countries, this assumption might be inaccurate. A higher electricity production in one country may imply a lower production in another country. Hence, an alternative approach to calculate the abatement costs implied by the promotion of renewables is assuming that renewables crowd all existing technologies in the EU. Thus, avoided emissions are the average CO_2 emissions from the current electricity mix in the EU. Under this assumption, national emission factors are not relevant and, therefore, the difference among abatement costs are determined by the financial support granted in each country. Table 3 highlights the differences across countries and, thus, the economic inefficiency in the promotion of the RES-E. From the economic efficiency perspective, it makes no sense that each Member State has its own RES support scheme; electricity should be produced where it is cheapest, regardless of national boundaries.

Table 3. Abatement costs implied by the promotion of renewables in 2010 (€/tCO2). EU electricity mix

	Hydro	Wind	Biomass	Biogas	PV	Geo-thermal	Waste
Czech Republic	97.5	24.7	69.5	194.8	926.2	::	::
France	22.9	66.3	92.3	72.4	925.7	::	::
Germany	66.5	76.6	225.6	::	723.9	290.5	::
Italy	149.9	142.0	224.7	::	759.2	153.8	::
Netherlands	183.7	151.5	139.7	::	727.2	::	90.9
Poland	::	::	::	::	::	::	::
Spain	82.1	85.0	144.6	::	746.3	::	55.6
United Kingdom	117.1	129.9	115.8	114.0	372.5	::	::

Source: own elaboration

It can also be assumed that renewables do not crowd out all fossil fuels in equal measure, but only the most expensive ones. With the current low carbon price of the EU ETS, the electricity supply tends to favour coal. Thus, in most countries, renewables are crowding out natural gas. Therefore, we also calculate the implicit abatement cost when renewables replace natural gas (Table 4). According to IEA (2012b), in the EU27 the average CO_2 emissions from electricity generation using natural gas were 365 g/kWh. This value is below the average CO_2 emissions from the current electricity mix in the EU. Hence, the abatement cost implied by the promotion of renewables is higher when renewables are assumed to replace electricity from natural gas rather than the average emissions of all electricity from fossil sources.

Table 4. Abatement costs implied by the promotion of renewables in 2010 (€/tCO2). Natural gas

	Hydro	Wind	Biomass	Biogas	PV	Geo-thermal	Waste
Czech Republic	143.2	36.3	102.0	285.9	1359.8	::	::
France	33.6	97.3	135.6	106.2	1359.0	::	::
Germany	97.7	112.5	331.2	::	1062.8	426.5	::
Italy	220.0	208.5	329.9	::	1114.5	225.8	::
Netherlands	269.8	222.4	205.0	::	1067.6	::	133.5
Poland	::	::	::	::	::	::	::

Spain	120.6	124.8	212.4	::	1095.7	::	81.7
United Kingdom	172.0	190.8	170.0	167.4	546.9	::	::

Source: own elaboration

5.1.4 Interactions and the static efficiency of the overall mix

Static efficiency implies that GHG emissions reduction is achieved at least cost. This is obtained when marginal abatement costs are equalised across sectors and emitters, so that reductions take place where they are cheapest to obtain. One way of achieving this is an instrument mix that sets a uniform carbon price (explicit or implicit) for different sectors and fuel types.

Our analysis shows that the current policy mix generates a wide variety of explicit and implicit carbon prices. In addition to the carbon price generated in the EU ETS, we calculate the implicit carbon price from energy taxation and the implied abatement costs of the promotion of renewables in power generation. These instruments overlap in several sectors, providing different incentives for the reduction of emissions.

The EU ETS is a cap-and-trade system which provides the incentive to cut emissions in the cheapest ways. In the absence of transaction costs or market imperfections, the EU ETS can be considered (statically) efficient by itself. Thus, implementing additional instruments in the EU ETS sectors may distort carbon prices and reduce its static efficiency.

The carbon price of the EU ETS provides a signal to all participants of the marginal abatement cost. That is, the EU ETS price determines the cost of emitting one tonne of CO_2. In theory, those measures with a marginal abatement cost above the EU ETS price should not be implemented. An installation subject to the EU ETS would prefer to buy an allowance rather than implementing a measure with a higher abatement cost.

However, the results show that in some EU ETS sectors (e.g., power generation) additional instruments have been implemented with an implied marginal abatement cost higher than the EU ETS price. From a static efficiency perspective, this is not optimal. In the promotion of the renewables in power generation, the abatement cost of all technologies is well above the average EU ETS price. , the abatement costs implied by the promotion of renewables should be similar to the EU ETS. Moreover, all technologies should imply a similar abatement cost. As shown in Table 2, this is not true.

Frondel et al (2010) argue that the FiT scheme implemented in Germany has failed to introduce renewables in a cost-effective way. The high subsidies, particularly for PV, are not aligned with other abatement costs. Besides, they claim that the interaction with the EU ETS did not contribute to a further emissions reduction.

Sijm (2005) and del Rio (2009) admit that the coexistence with other instruments may reduce the static efficiency of the EU ETS. As our results show, the economic support for each technology leads to important differences in the implicit marginal abatement costs. This prevents the cheapest technologies being implemented first. However, there are other reasons that may justify the coexistence of the EU ETS and the promotion of renewables (e.g. dynamic efficiency).

Similarly to the renewable energy promotion schemes, the implicit carbon price for energy products is above the current EU ETS price (table 2). The gap between carbon prices reduces the cost-effectiveness of the instrument mix. Energy taxes are not set according to CO_2 emissions and, consequently, they do not provide the proper incentives to reduce emissions cost-effectively.

According to Böhringer et al (2008) carbon taxes increase abatement costs for those sectors covered by the EU ETS. They conclude that the interaction between instruments alters the incentives to reduce emissions, and thus the cost-effectiveness of the scheme. Hence, those sectors covered by the EU ETS should be exempt from energy taxes.

The promotion of renewables (e.g. feed-in tariff) and energy efficiency (e.g. energy taxes) may have affected the functioning of the EU ETS. In addition to the economic crisis and the overly generous allocation rules, the low EU ETS prices could be a consequence of the interaction with other instruments (Point Carbon, 2013). When the EU ETS cap was set, the effects of other policy instruments were considered, but they inevitably introduced an element of uncertainty, because the success of other policies cannot be predicted. If the other instruments over-achieve their target, it does not result in lower emissions, but in a lower EU ETS price.

On the other hand, some market barriers and failures reduce the static efficiency of the EU ETS. Thus, the EU ETS might not encourage the adoption of cost-effective measures with an abatement cost lower than the carbon price set by the EU ETS. The interaction with other instruments, particularly those instruments which promote energy efficiency, can improve the static efficiency of the EU ETS.

5.2 Dynamic Efficiency and the role of uncertainty in the instrument mix

The dynamic efficiency implies the capacity of a policy instrument to induce innovation and diffusion of low-carbon technologies, in order to lower abatement costs in the future. Thus, it may be inefficient from a static perspective to fund technologies that are currently costly, but may lead lower abatement cost in the future or avoid situations of technological lock-in. The dynamic efficiency involves minimising the total cost of achieving climate targets over a given period. In order to evaluate the dynamic efficiency, we will analyse how the current instrument mix has contributed to drive innovation in low-carbon technology and, thus, reduce abatement costs in the future. As a forward looking criterion, dynamic efficiency involves an element of uncertainty. Several aspects such as the development of new technologies, carbon prices, and legal frameworks are uncertain and, therefore, hinder the investment into innovation.

As mentioned above, the EU ETS is the cornerstone of the current European instrument mix. The EU ETS was established to reduce GHG emissions in “a cost-effective and economically efficient manner” (Directive EC/87/2003). Under the ‘cap and trade’ scheme, the overall GHG that can be emitted is limited ex-ante, ensuring the effectiveness of the system. Besides, by putting a unique carbon price for all emitters, the EU ETS incentives the cheapest option to reduce emissions (static efficiency). However, several authors argue that the EU ETS scheme does not incentivise the investment in new low-carbon technologies, hindering its dynamic efficiency (del Río, 2009; Egenhofer, 2011). This may induce a technological lock-in, avoiding the innovation and diffusion of low-carbon technologies which can lower abatement costs in the future.

A key factor to promote investments in low-carbon technologies is a sufficiently high carbon price. This is a necessary condition to make an investment profitable. However, a high carbon price may not be enough to incentivise investment. High price volatility may also hamper investment decisions. In the first and second trading periods, the carbon price of the EU ETS has not been stable, certain or high enough to provide a signal to emitters to invest in low-carbon technologies (Capozza and Curtin, 2012).

While the EU ETS scheme ensures a certain quantity reduction, it cannot provide any certainty about the carbon price. Given the market structure of the EU ETS, the carbon price is determined by the supply and demand of allowances. By setting an annual linear reduction of 1.74%, the EU ETS reduces the uncertainties over the allowances supply. However, the demand depends on a large set of uncertain variables (e.g. economic activity, energy prices, and weather conditions). This makes carbon prices volatile and unpredictable.

The number of studies that try to quantify the impact of the EU ETS on innovation is increasing. Several methodologies (e.g. case studies, surveys, econometric studies) have been used to assess the impact of the EU ETS in different sectors and countries. However, the existing studies are limited to a few sectors and countries, and some methodologies are not rigorous enough to identify causal relationships (Martin et al, 2012). Besides, available data on innovation is limited, and innovation is measured in different ways. Therefore, it is difficult to draw a conclusion from existing literature, but, in general, the results do not show strong evidence on an impact of the EU ETS on innovation.

In order to assess the impact of the EU ETS on innovation, Martin et al (2011) conduct a survey at almost 800 manufacturing firms in six European countries. Although EU ETS participants are more likely to adopt measures to reduce GHG emissions, they conclude that there is no significant difference in engaging innovation between EU ETS and non-EU ETS firms. They also find that the firms which are just below the threshold established for free allowances are more likely to engage in innovation. This suggests that the auctioning of allowances may have a positive impact on innovation. Using a similar methodology, Rogge et al (2010) and Hoffman (2007) analyse the German power sector. They find that the EU ETS has had limited impact on innovation and investment decision. Only small-scale investments with short amortization time have been encouraged by the EU ETS.

Calel and Dechezleprêtre (2012) use patent data to assess the impact of the EU ETS on innovation. They compare the patenting behaviour of non-EU ETS and EU ETS firms, employing a difference-in-difference method. They find that there was an increase in low-carbon patenting since 2005, but they cannot conclude that this was caused by the implementation of the EU ETS. Indeed, they do not find significant differences between non-EU ETS and EU ETS firms. Hagberg and Roth (2010) and Borghesi et al (2012) analyse a large data set of EU ETS firms in Sweden and Italy, respectively. They find a correlation between the EU ETS and environmental innovation, but this does not imply causation.

Therefore, the existing literature suggests that the EU ETS has not been able to spur innovation in new low-carbon technologies by itself. As pointed out by Sijm (2005), this can justify the coexistence of the EU ETS and other instruments. In order to overcome market barriers and failures, the implementation of other instruments may be necessary. Lehman and Gawel (2013) summarize the main reasons for combining the EU ETS with RES-E support schemes. They state that the EU ETS generates a high level of uncertainty and, thus, cannot set appropriate long-term signals. Hence, the EU ETS is unlikely to induce innovation. The combination of RES-E schemes and the EU ETS can provide investors greater certainty and incentive investments in new technology.

In the current instrument mix, the EU ETS overlaps with other instruments in the promotion of renewables (e.g. feed-in tariff) and in the energy reduction and efficiency (e.g. energy taxes, technology standards). Although empirical evidence is very limited, the literature suggests that the interaction of the EU ETS with other instruments may have a positive impact on the dynamic efficiency of the overall instrument mix (del Rio, 2009; Lehman and Gawel, 2013).

Johnstone et al (2010) is one of the few studies that analyse empirically the effect of different policy instruments on renewable energy innovation. They use patent data of 25 OECD countries over the period 1978-2003. They find that public policy has had a positive effect on the development of new technologies. However, the effects of each instrument depend on the renewable energy technology. Thus, quantity-based instruments (obligations and tradable certificates) are most effective in inducing innovations in wind technology[20], while price-based instruments (investment incentives, tax measures and tariffs) are most effective in solar, biomass and waste-to-energy technologies. The feed-in tariff scheme, which has been widely implemented in the Member States, is effective in encouraging innovations in all technologies, and particularly in capital intensive technologies (solar and waste-to-energy). Del Rio (2009) also suggests that the implementation of the feed-in tariff scheme might have contributed to significant improvements and cost reductions in renewable energy

[20] According to the authors, this is because firms focus their innovative effort on the most competitive technology.

technologies in Spain. However, he acknowledges that it is difficult to differentiate the contribution of the feed-in tariff scheme in Spain with the contribution of similar support schemes in other countries or/and of other policy instruments. Other instruments such as energy taxes and public R&D support also benefit innovation in renewable energy technologies (Lanzi and Sue Wing, 2011; Braun et al, 2010).

In the industrial sector, the interaction of the EU ETS and energy taxes may have positive impacts on innovation. Ley et al (2013) analyse patent data of 18 OECD countries since 1975 in order to determine the effects of energy prices on green innovation in the industry. They find that a 10% increase of the average energy prices leads to a 2.7% increase of the number of green inventions. They conclude that energy taxes may serve as an instrument to promote innovation.

Verdolini and Galeotti (2011) carry out an empirical analysis of innovation in energy-efficient technologies. They use a panel data of 17 countries and find a significant effect of energy prices on technological innovation. Moreover, those countries that implement policies targeting energy efficiency are characterized by a higher level of innovation.

In non-EU ETS sectors, public policy is also important to induce innovation in low-carbon technologies. Aghion et al (2012) use worldwide patents since the mid-1960s to examine innovations in the transport sector. The results show that higher fuel prices encourage firms to redirect technical change towards clean innovation (electric, hydrogen and hybrid cars) and away from dirty innovation. Thus, fuel taxes are a good measure to induce innovation in the transport sector. Based on US patent data, Crabb and Johnson (2010) find that higher fuel prices are important in generating innovation, while fuel standards have no significant effects.

In contrast to other sectors, higher energy prices might not incentivise technological innovation in buildings (Noailly, 2012). This study analyses three types of instruments (energy standards in building codes, energy prices and public R&D expenditure) in seven European countries[21]. Using patent data, they measure technological innovation in eight technologies related to energy efficiency in buildings[22]. They find that strengthening standards in building codes leads to a higher innovation. On the other hand, energy prices have no significant impact, while public R&D expenditure has a small positive effect. According to the authors, the little impact of energy prices could be explained by the very low real prices over the analysed period and the presence of market failures (e.g. principal-agent problem).

This raises the question whether market-based instruments provide greater incentives for innovation. According to Popp (2010), market based instruments are not as much effective to incentivise long-term investments. Thus, they are dynamically efficient for those technologies

[21] Germany, Denmark, Finland, Austria, Belgium, Ireland and UK.

[22] Insulation, high-efficiency boilers, heat-and-cold distribution, ventilation, solar boilers and other renewables, energy-saving lightings, building materials and climate controls.

which are more mature and near market competitiveness. This can be the case of wind technology in the promotion of renewable energy sources for electricity generation. On the other hand, emerging technologies, which face high uncertainty, would benefit from non-market based instruments such as investment grants or a feed-tariff scheme. These instruments ensure long-term investments and encourage innovation in those technologies which are not yet cost-effective. Non-market based instruments can also incentivise innovation in the buildings sector, which is characterized by the principal-agent market failure (Noailly, 2012). Popp (2010) proposes an instrument mix which combines market based instruments to ensure short-run compliance at low cost and public investment incentives to support research on emerging technologies.

The literature suggests that public R&D expenditure is effective in promoting clean innovation. Popp (2010) states that the uncertain nature of long-run research makes firms underinvest, which could be compensated by public R&D spending. Public R&D expenditure induces innovation in both renewable energy (Braun et al, 2010) and energy-efficient technologies (Verdolini and Galeotti, 2011). Both studies use patent data from OECD countries to analyse empirically the effect of public R&D funding to spur innovation in renewable and energy-efficient technologies, respectively.

In a theoretical framework, Fischer (2008) shows that the public support for R&D is only effective if it is accompanied by other environmental policies which encourage the adoption of the resulting technologies. Using a partial equilibrium model, they analyse the interaction between environmental policies, R&D externalities, and the social return to innovation. When emissions are not penalized, public support for R&D is not justified, since the innovation will not be used. Using the ENTICE model, Popp (2006) find that the optimal policy mix to promote innovation in clean technologies includes both a carbon tax and R&D subsidies. In order to incentivise the adoption new clean technologies, the public support for R&D must be accompanied by a policy to address emission reduction. Acemoglu et al (2009) use a general equilibrium model with endogenous growth to analyse the effects of different environmental policies. They also find and optimal policy involves both carbon taxes and public R&D subsidies. The latter are useful to avoid excessive use of carbon taxes and, thus, increase the cost effectiveness.

The dynamic efficiency implies the capacity of a policy instrument to induce innovation and diffusion of low-carbon technologies, in order to lower abatement costs in the future. Thus, it may be inefficient from a static perspective to fund technologies that are currently costly, but may lead lower abatement cost in the future or avoid situations of technological lock-in. The dynamic efficiency involves minimising the total cost of achieving climate targets over a given period. In order to evaluate the dynamic efficiency, we will analyse how the current instrument mix has contributed to drive innovation in low-carbon technology and, thus, reduce abatement costs in the future. As a forward looking criterion, dynamic efficiency involves an element of uncertainty. Several aspects such as the development of new technologies, carbon prices, and legal frameworks are uncertain and, therefore, hinder the investment into innovation.

The dynamic efficiency implies the capacity of a policy instrument to reduce abatement costs in the future. In order to evaluate the dynamic, we have analysed how the current instrument mix has contributed to drive innovation in low-carbon technology and, thus, reduce abatement costs in the future. Although empirical evidence for EU's current instrument mix is limited, some conclusions can be drawn on its dynamic efficiency. Most of the studies suggest that the EU ETS is not effective in inducing innovation in low-carbon technological innovation. The low and uncertain carbon price did not provide a signal to invest in clean technology. The implementation of non-market based instruments (e.g. feed-in tariff) in the promotion of RES-E has had a positive impact on innovation, particularly in the less mature technologies. Given some market failures such as the principal-agent problem, market-based instruments have little impact on the building sector and, thus, the Energy Performance of Buildings Directive has been the main driver of innovation. Empirical evidence also shows that those Member States with higher energy taxes encourage more innovation in energy-efficient technologies. This is particularly true for the industrial and transport sector. Finally, public R&D financing plays an important role to compensate for underinvestment in the private sector.

6 Feasibility

The third criterion for assessing the optimality of the current instrument mix is feasibility. This category addresses those aspects related to practical implementation. It describes the risks that a planned policy might not be implemented as designed or that the policy does not deliver the expected results. This criterion does not provide a quantitative measurement and, therefore, it cannot be expected to sort policy instruments into those that are feasible and those that are infeasible. It provides, however, information on the degree of feasibility or the risk of failure.

The feasibility criterion covers several aspects. The political feasibility encompasses the acceptance or resistance of an instrument by citizens (voters) and local companies. This, in turn, largely depends on distributional impacts and other important effects on the economy such as competitiveness of domestic firms and job creation. Another dimension of this criterion is the legal feasibility which assesses the compatibility of policy instruments with existing EU and national legislation. Finally, the feasibility criterion also covers the administrative burden which can be a constraint for the implementation of a policy.

The feasibility of the EU ETS, the key climate instrument in the EU, is generally high. There is little political or public resistance to this instrument. Major stakeholders, including covered companies, support the scheme. Although in some Member States the introduction of the EU lead to lengthy legal disputes, the legality of the instrument is now widely accepted. The complexity of the EU ETS has led to a high administrative burden associated to the monitoring, reporting and verification processes. The pressure from interest groups has also led to complex allocation rules. However, some improvements have been observed in recent years. Despite the widespread acceptance of the EU ETS, some important problems arose in the first and second trading periods.

The EU ETS has mainly been criticized in two respects: ‘windfall profits’ and ‘over-allocation’ (Ellerman and Joskow, 2008). These two aspects affect the feasibility of the scheme. The windfall profits are associated to the additional profits earned by some companies to which allowances were allocated for free. It is argued that several electricity generators included the market value of the freely allocated allowances in the marginal cost of generation, raising wholesale prices (Ellerman et al, 2010). Windfall profits may have been instrumental in getting support from big utilities for the EU ETS. However, they also have distributional impacts, given that they increase companies’ profits, while households face higher energy prices. The auctioning of allowances for electricity generators, which was adopted in the third trading period, has reduced these windfall profits (in conjunction with the decline in allowance prices). Besides, extra revenues could be used for the purpose of improving efficiency and equity (Ellerman and Joskow, 2008).

The over-allocation problem arose in both the first and second period. In the second period it was due to the economic crisis while in the first period it was due to overly generous allocation rules. The latter was caused both by Member States governments who wanted to make sure no burden was imposed on their domestic industries and by the pressure from operators and their interest groups who wanted to receive as many allowances as possible. The over-allocation problem highlights a trade-off between the effectiveness of the instrument and its political feasibility. Ambitious targets and restrictive allocation rules enhance the effectiveness and, possibly, the efficiency, but may lead to the resistance of the participants. Generous allocation rules and a lax cap, however, increase the political feasibility but undermine the effectiveness and, possibly, the efficiency. Besides, in some Member States such as Poland, the high complexity of allocation rules created an impression among participants that the scheme was subject to manipulation. This can also hamper the political feasibility of the EU ETS. The auctioning of allowances can provide transparency to the system and may arguably increase efficiency, but has significant implications for the covered firms and, possibly, their competitiveness.

Although auctioning is considered a more efficient and transparent allocation method, manufacturing industry and the installations of eight Member States[23] which have joined the EU since 2004 will receive most of their allowances for free until at least 2020[24]. Energy-intensive industries that are exposed to international competition receive preferential

[23] Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Lithuania, Poland and Romania.

[24] Manufacturing will receive the vast majority of allowances for free, with a decreasing trend until 2020. More details can be found at: http://ec.europa.eu/clima/policies/ets/cap/allocation/index_en.htm.

treatment. Tight climate policies may reduce the competitiveness of domestic companies and lead to the transfer of production to other countries (‘carbon leakage’). The empirical evidence of the EU ETS on international competitiveness shows that the EU ETS has not caused changes in trade flows (Reinaud, 2009). Carbon leakage is an isolated phenomenon, which may affect few sectors, but is generally not nearly as big a threat as it is made out to be. On the other hand, the EU ETS has contributed to reduce emissions beyond the EU, through the CDM and JI mechanisms.

The economic crisis has also reminded us that the EU ETS is a long-term instrument that sets ex-ante emission limits, not one that guarantees a certain carbon price. The lower demand of allowances due to the economic slowdown has led the carbon price to slump. The length of the eight-year trading period – which was introduced to give more stability and longer-term expectations – means that the EU ETS lacks flexibility to alter the intra-phase emission cap and keep the carbon price high if economic framework conditions or abatement costs change drastically. This is not necessary a failure of the scheme. On the one hand, the countercyclical effect of the EU ETS relieves the burden on companies in a time of crisis. However, on the other hand, a low price is not in line with the expected role of the EU ETS in the transition to a low-carbon economy (EC, 2012). Moreover a low and uncertain carbon price fails to encourage investment in clean technology and may induce a technological lock-in. The European Commission has proposed six measures to address the structural supply-demand imbalance (EC, 2012). The proposal includes increasing the reduction target, including other sectors in the EU ETS and limiting the access to international credits.

In 2004 the EU adopted the Directive 2003/96/EC which sets the minimum tax rate for energy products. Member States had to adapt their legislation to the new European Directive. Thus, from 2004 onwards, national legislation on energy taxation must be compatible with EU legislation.

In most Member States, energy-intensive industries are totally or partially exempted from taxes on energy use. This is often justified as a measure to prevent the loss of international competitiveness. It has, however, important distributional effects, because the tax burden falls on a small share of the total energy consumption (e.g. households)[25]. It is often argued that energy taxes would generate a disproportionate burden on low income households, yet the empirical evidence is less clear[26]. In any case, an increase in energy/carbon taxes for consumers is likely to meet resistance. In some countries, the rise in energy taxes has been used to reduce other distortionary taxes (e.g. labour taxes), increasing the efficiency of the

---

[25] Given that energy-intensive industries are covered by the EU ETS, some authors argue that the tax exemption is both desirable and static efficient (Böhringer et al, 2008).

[26] A number of studies have shown that energy/carbon taxes are regressive, (e.g. Rausch et al, 2011, Callan et al, 2009) but others do not find this result (Ekins et al, 2011; Labandeira and Labeaga, 1999). Sterner (2012) finds that the regressivity of the fuel tax is so small that the tax can be considered broadly proportional or neutral.

overall economy and stimulating employment. The higher tax revenues can also be used to support poor households and, thus, limit distributional effects.

The subsidies for coal mining in some Member States (e.g. Spain and Germany) are mainly due to political reasons. Although they have a negative impact on the overall instrument mix, they were established to protect local industries and jobs. These subsidies are to be phased out by 2018.

In the landscape of energy efficiency and energy consumption, the majority of instruments are imposed at national level, although they are strongly influenced by EU Directives (e.g. energy standards and energy labelling for buildings and cars). Thus, national legislation has to be compatible with EU legislation. Regarding administrative feasibility, the instruments within this landscape typically generate high transaction costs due to the different public administrations involved in their compliance and enforcement. Thus, some Member states, which lack administrative capacity, do not implement energy efficiency instruments and wait for its advancement at EU level (EC, 2011).

In general, the general public supports those instruments that improve energy efficiency and reduce energy consumption. This is because, in addition to emissions abatement, these instruments may achieve cost reductions in the energy bill. Besides, energy efficiency policies often work with subsidies which are of course popular with those who receive them. Lower energy costs may ease economic recovery and raise the competitiveness of the industry. Moreover, lower energy consumption reduces the reliance on energy imports and, thus, increases energy security.

Several Member States have implemented public funding instruments to improve energy efficiency and reduce energy consumption (e.g. financial support for refurbishment of buildings and financial support for replacing inefficient cars). The political feasibility of these instruments is high, given that are well accepted by both consumers and producers. They have a positive impact on the economic activity and job creation in these sectors. Yet the net effect on the overall economy is less clear – the budget used for such support measures in not available for other uses, and taxpayers may realise that tax revenues must increase to finance these instruments. When low income households are the target group, public funding has positive distributional effects and might even reduce energy poverty. These instruments are, however, subject to a constant uncertainty about the amount of available funding. The economic crisis and the rise of public debts have forced governments in several countries to reduce public funding. The lack of a long-run policy framework makes these instruments very dependent on economic cycles.

The instrument mix for the promotion of renewable energy sources is driven by the Renewable Energy Directive, which establishes national energy targets by 2020. The main concern within this landscape is the political feasibility. On the positive side, the support for renewable sources of energy by the public is generally high. The promotion of renewables has contributed to the development of a highly dynamic sector, job creation and the improvement in local air quality. However, on the negative side, there is an increasing debate about the costs. In contrast to the instruments that promote energy efficiency, renewables increase energy costs at least in the short to medium term, they require an adaptation of the electricity supply system, and challenge established business models in the sector. In Spain and Germany, where the financial support for the RES-E has been high, private electricity consumers are facing a rise in their final price. This can gradually reduce the support by the general public. In general, its legal and administrative feasibility is high. Nevertheless, a higher effort from Member States to remove administrative barriers is needed (EC, 2013). The implementation of a single administrative body for dealing with renewable energy projects would simplify administrative procedures and, thus, reduce the costs of renewable energy.

In most Member States, the landscape of non-CO_2 GHG emissions receives little attention by the general public and policymakers, especially in the agriculture sector. Landfill taxes have been implemented in most countries, probably because of their high feasibility. Their legal and administrative feasibility is high, and the general public is not reluctant to their implementation. On the other hand, the administrative burden of the instruments implemented in the agriculture sector (e.g. fertilization standards) is high. There are high transaction costs related to their compliance and enforcement. This is especially true for instruments which target individual farms.

7 Conclusion

The current EU climate policy mix aims to meet the "20-20-20" targets for 2020. Although the EU is on track to reduce emissions to 20% below 1990 levels by 2020, the current instrument mix has shortcomings. The policy mix has a strong focus on energy and industry. There is much less attention for transport and buildings, and virtually none for agriculture and waste. Indeed, transport is the only major sector where emissions continue to grow and where we haven't seen major new policy initiatives in recent years. The current instrument mix has also failed to promote energy efficiency. In 2010 primary energy consumption was 5.4% lower than the baseline scenario and, therefore, a higher effort it will be needed to reach the 20% target by 2020.

The EU ETS is the central pillar of European climate policy. It is a 'cap and trade' system which ensures a certain emission reduction, but not a carbon price level. Since 2008, the economic recession has reduced the demand for allowances and, hence, the carbon price has slumped. Low carbon prices do not imply that the EU ETS is not achieving to reduce GHG emissions in a cost-effective manner, at least in the short-run. However, the price signal is not in line with the role that the EU ETS as the climate policy flagship of the EU could or should have in the transition to a low-carbon economy. The low carbon price observed since 2012 reflects that the current emission reduction target for 2020 has become easier to meet than originally anticipated. Hence, the implementation of one of the structural reforms proposed by the

European Commission can benefit the functioning of the EU ETS. A low carbon price also hinders the dynamic efficiency of the scheme and may induce a technological lock-in. The empirical evidence suggests that the low and uncertain carbon price of the EU ETS did not incentivise innovation in low-carbon technology. However, in order to determine the appropriate role of the EU ETS in the climate policy mix, and to evaluate its performance, it should be clarified whether the function of the EU ETS is to promote investment and innovation. The majority evidence suggests that pricing tools like an ETS can only have a supporting role for driving innovation, but should be complemented with other, technologic-specific tools.

The interaction of the EU ETS and other policy instruments may be beneficial to improve the design of the scheme, correct for market failures and meet other policy instruments. RES-E support schemes, for instance, have been the major incentive to deploy renewable sources of energy in electricity generation. Moreover, some instruments, such as the feed-in tariff scheme, have had a positive impact on innovation, particularly in the less mature technologies. In the promotion of energy efficiency measures, different market failures may limit the effect of the carbon price set by the EU ETS to encourage the adoption of cost-effective measures (e.g. principal-agent problem, capital market imperfections). Non-market based instruments (e.g. energy efficiency standards) are beneficial to implement those measures with an abatement cost lower than the carbon price set by the EU ETS.

On the other hand, the interaction of the EU ETS with other instruments is affecting the functioning of the scheme. Although, when the EU ETS cap was set, the effects of other policy instruments were considered, they inevitably introduced an element of uncertainty, because the success of other policies cannot be predicted with certainty. The overachievement on their targets did not result in lower emissions, but in a lower EU ETS price. RES-E schemes, for instance, have been instrumental in increasing the share of renewable energy in gross final energy consumption to 13% in 2011, which is above the EU interim target for 2011/2012 (10.7%). However, from the static efficiency perspective, emission reductions achieved through RES-E schemes come at very high abatement costs, well above the EU ETS price, affecting the static efficiency of the instrument mix. Besides, the different abatement costs across countries and technologies highlight the economic inefficiency in the promotion of RES-E.

In the non-EU ETS sectors (e.g. buildings, transport) most of the measures are focused on the promotion of energy efficiency (e.g. energy taxes, energy efficiency standards). The instrument mix has succeeded in improving energy efficiency. This, however, has not led to a proportional reduction in energy consumption. When energy prices are not high enough, energy efficiency improvements are compensated partly or entirely by rebound effects. In the buildings sector, this can be particularly important in countries such as the Czech Republic, Poland, Spain and the UK, where the implicit carbon price of electricity and natural gas for households is zero or nearly zero.

In the transport sector, unlike other sectors, emissions did not decrease since 1990. Although there have been energy efficiency improvements and transport fuel taxes are relatively high, in the EU as a whole energy consumption is increasing. The current instrument mix has failed to spur a modal shift. From the economic efficiency perspective, taxes on transport fuels are not optimal. In particular, the implicit carbon price for diesel is lower than for gasoline in all Member States although the carbon content of diesel is higher than that of gasoline. In the Netherlands, for instances, the implicit carbon price of diesel is half of that of gasoline.

In relation to non-CO_2 emissions, the current instrument mix has been more successful in reducing emissions in waste and industry than in agriculture. Some instruments such as landfill taxes and the ban of landfilling untreated waste have been effective in reducing CH_4 emissions. In agriculture, the decline of non-CO_2 emissions has been caused by the reallocation of agricultural production, the increase in animal productivity and the lower use of organic and mineral nitrogen fertilizers. Despite the decline in emissions, generally non-CO_2 GHG emissions receive little attention by the current instrument mix.

From the dynamic efficiency perspective, as mentioned above, the EU ETS has not been able to spur innovation in new low-carbon technologies by itself. The implementation of non-market based instruments (e.g. feed-in tariff) has had a positive impact on innovation in RES-E, particularly in the less mature technologies. In the industrial and transport sector, the empirical evidence shows that those Member States with higher energy taxes encourage more innovation in energy-efficient technologies. In buildings, it seems that energy prices have not been high enough to promote innovation or that other market failures have been at work, such as the landlord-tenant-dilemma. Therefore, energy efficiency standards have been the main drivers of innovation. The literature also suggests that public R&D financing plays an important role to compensate for underinvestment in the private sector.

The feasibility of the current instrument mix is generally high. Although the EU ETS has been criticized for generating windfall profits and because of the apparent over-allocation, there is little political or public resistance to this instrument. An increase in energy taxes for consumers is likely to meet more resistance. While energy-intensive industries are generally exempted, a small share of the total energy consumption – mostly private households and small businesses – has to bear the majority of the cost burden, which may generate a disproportionate burden on low income households. The subsidies to improve energy efficiency and reduce energy consumption are more accepted by both consumers and producers. They may achieve cost reductions in the energy bill for consumers and have a positive impact on the economic activity of some sectors. These instruments are, however, subject to a constant uncertainty about the amount of available public funding. The rise of public debts and the increasing burden for taxpayers may reduce their feasibility. The support for renewable sources of energy by the general public is also high. The promotion of renewables has contributed to the development of a highly dynamic sector, job creation and the improvement in local air quality. However, there is an increasing debate about the costs. In Spain and Germany, where the financial support for the RES-E has been high, private electricity consumers are facing a rise in their final price. This can gradually reduce the support by the general public for renewable energy. Finally, in most Member States, non-CO2 GHG emissions receive little attention, especially in the agriculture sector. There are high transaction costs related to their compliance and enforcement, which increase the administrative burden.

References

Anderson, B. and Di Maria, C. (2011). Abatement and allocation in the pilot phase of the EU ETS. Environmental and Resource Economics, pages 1–21, 2011.

Acemoglu, D., Aghion, P., Bursztyn, L. and Hemous, D. (2009). The environment and directed technical change. NBER Working Paper, No. 15451.

Aghion, P., Dechezleprêtre, A., Hemous, D., Martin, R. and Van Reenen, J. (2012). Carbon taxes, path dependency and directed technical change: evidence from the auto industry. NBER Working Paper, No. 18596.

Böhringer, C., Loschel, H. and Moslener, U. (2008). Efficiency losses from overlapping regulation of EU carbon emissions. Journal of Regulatory Economics, vol. 33(3), 299-317.

Borghesi, S., Cainelli, G. and Mazzanti, M. (2012). Brown Sunsets and Green Dawns in the Industrial Sector: Environmental Innovations, Firm Behavior and the European Emission Trading. Fondazione Eni Enrico Mattei Working Papers, 654.

Braun, F. G., Schmidt-Ehmcke, J. and Zloczysti, P. (2010). Innovative Activity in Wind and Solar Technology: Empirical Evidence on Knowledge Spillovers Using Patent Data. DIW Berlin, German Institute for Economic Research, No. 993.

Calel, R., and Dechezleprêtre, A. (2012). Environmental policy and directed technological change: evidence from the European carbon market. EUI Working Papers.

Callan, T., Lyons, S., Scott, S., Tol, R. S. and Verde, S. (2009). The distributional implications of a carbon tax in Ireland. Energy Policy, 37(2), 407-412.

Capozza, I. and Curtin, J. (2012). Towards Consistent and Effective Carbon Pricing in Germany? OECD Environment Working Papers, No. 52, OECD Publishing. Available at: http://dx.doi.org/10.1787/5k8x7gx58r0t-en

CDC Climat (2013). Climate Brief No 32. October 2013. Available at: http://www.cdcclimat.com/IMG//pdf/13-10-22_climate_brief_no_32__co2_emissions_and_eu_ets.pdf

CEER (2013). Status Review of Renewable and Energy Efficiency Support Schemes in Europe. Available at: http://www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_PAPERS/Electricity/Tab2/C12-SDE-33-03_RES%20SR_25%20June%202013%20revised%20publication.pdf

Clo, S. (2009). The effectiveness of the EU emissions trading scheme. Climate Policy, 9(3):227–241, 2009.

Crabb, J. M. and Johnson, D. K. (2010). Fueling innovation: The impact of oil prices and cafe standards on energy-efficient automotive technology. The Energy Journal, 31(1), 199-216.

Delarue, E., Voorspools, K. and D'haeseleer, W. (2008). Fuel Switching in the Electricity Sector under the EU ETS: Review and Prospective. Journal of Energy Engineering 134(2): 40-46.

del Rio, P. (2009). Interactions between climate and energy policies: the case of Spain. Climate Policy, 9, 119-138.

Declercq, B., Delarue, E. and D'haeseleer W. (2010). Impact of the Economic Recession on the European Power Sector's CO_2 Emissions, TME Working Paper, WPEN2010-08.

ECOFYS et al (2012). Renewable energy progress and biofuels sustainability.

Egenhofer, C., Alessi, M., Georgiev, A. and Fujiwara, N. (2011). The EU Emissions Trading System and Climate Policy towards 2050: Real incentives to reduce emissions and drive innovation? CEPS Special Reports.

Ekins, P., Pollitt, H., Barton, J. and Blobel, D. (2011). The implications for households of environmental tax reform (ETR) in Europe. Ecological Economics, 70(12), 2472-2485.

Ellerman, D. and Buchner, B. (2008). Over-allocation or abatement? A preliminary analysis of the EU ETS based on the 2005–06 emissions data. Environmental and Resource Economics, 41(2):267–287, 2008.

Ellerman, D. and Joskow, P. L. (2008). The European Union's Emissions Trading System in perspective. Pew Center on Global Climate Change, Washington, DC.

Ellerman, D., Convery, F. and de Perthuis, C. (2010). Pricing Carbon: The European Union Emissions Trading Scheme, Cambridge: Cambridge University Press.

European Commission (EC) (2011). Impact Assessment. Energy Efficiency Plan 2011.

European Commission (EC) (2012). The state of the European carbon market in 2012. Report from the Commission to the European Parliament and the Council. Available at: http://ec.europa.eu/clima/policies/ets/reform/docs/com_2012_652_en.pdf

European Commission (EC) (2013). Report from the Commission to the European Parliament, the Council, the European economic and social Committee and the Committee of the regions. Renewable energy progress report.

Fellmann, T., Dominguez, I. P., Witzke, H. P., Jansson, T., Oudendag, D., Gocht, A. and Verhoog, D. (2013). Agricultural GHG emissions in the EU: an exploratory economic assessment of mitigation policy options (No. JRC69817). Institute for Prospective and Technological Studies, Joint Research Centre.

Fischer, C. (2008). Emissions pricing, spillovers, and public investment in environmentally friendly technologies. Energy Economics, 30(2), 487-502.

Frondel, M., Ritter, N., Schmidt, C. M., Vance, C. (2010). Economic impacts from the promotion of renewable energy technologies: The German experience. Energy Policy, 38, 4048-4056.

Gago, A., Hanemann, M., Labandeira, X. and Ramos, A. (2012). Climate Change, Buildings and Energy Prices. Economics for Energy Working Paper, 04-2012.

Gerdes, J. and Boonekamp, P. (2012). Energiebesparing in Nederland 2000-2010. Petten: Energy Centre Netherlands (ECN).

Hagberg, T. and Roth, S. (2010). Trading with Carbon: Technological Trends in Swedish Industries from a Climate Perspective.

Hoffman, V. (2007). EU ETS and Investment Decisions: The Case of the German Electricity Industry. European Management Journal 25(6), 464-474.

IEA (International Energy Agency) (2012a). Energy Prices and Taxes.

IEA (2012b). CO_2 Emissions from Fuel Combustion. IEA Statistics.

IPCC (2006). IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Tables 1.4 and 2.3.

Johnstone, N., Hascic, I. and Popp, D. (2010). Renewable energy policies and technological innovation: Evidence based on patent counts. Environmental and Resource Economics, 45(1), 133-155.

Kettner, C., Köppl, A., Schleicher, S. and Thenius, G. (2008). Stringency and distribution in the EU emissions trading scheme: first evidence. Climate Policy, 8(1):41–61, 2008.

Labandeira, X. and Labeaga, J. (1999). Combining input-output analysis and micro-simulation to assess the effects of carbon taxation on Spanish households. Fiscal Studies, 20(3), 305-320.

Laing, T., Sato, M., Grubb, M., Comberti, C. (2013). Assessing the effectiveness of the EU Emissions Trading System. Centre for Climate Change Economics and Policy. Working Paper No. 126.

Lanzi, E. and Sue Wing, I. (2011). Directed technical change in the energy sector: an empirical test of induced directed innovation. In WCERE 2010 Conference, mimeo.

Lehmann, P. and Gawel, E. (2013). Why should support schemes for renewable electricity complement the EU emissions trading scheme? Energy Policy, 52, 597-607.

Ley, M., Stucki, T. and Woerter, M. (2013). The Impact of Energy Prices on Green Innovation. KOF Working Paper, No. 340.

Linares, P., Santos, F. J. and Ventosa, M. (2008). Coordination of carbon reduction and renewable energy support policies. Climate Policy, 8(4), 377-394.

Linares, P. and Labandeira, X. (2010). Energy efficiency: Economics and policy. Journal of Economic Surveys, 24(3), 573-592.

Martin, R., Muûls, M. and Wagner, U. (2011). Climate change, investment and carbon markets and prices-evidence from manager interviews. Climate Strategies, Carbon Pricing for Low-Carbon Investment Project.

Martin, R., Muûls, M. and Wagner, U. (2012). An Evidence Review of the EU Emissions Trading System, Focussing on Effectiveness of the System in Driving Industrial Abatement. Technical report, Department of Energy and Climate Change.

Noailly, J. (2012). Improving the energy efficiency of buildings: The impact of environmental policy on technological innovation. Energy Economics, 34(3), 795-806.

Odyssee (2011). Energy Efficiency Trends in Buildings in the EU. Available at http://www.odyssee-indicators.org/publications/PDF/Buildings-brochure-2012.pdf

Odyssee (2012). Energy Efficiency Trends in the Transport sector in the EU. Available at http://www.odyssee-indicators.org/publications/PDF/transport-energy-efficiency-trends.pdf

OECD (2013). Taxing Energy Use: A Graphical Analysis, OECD Publishing. Available at: http://dx.doi.org/10.1787/9789264183933-en

Point Carbon (2013). Carbon 2013. Dimantchev, E. et al. 33 pages. Available at: http://www.pointcarbon.com/polopoly_fs/1.2236558!Carbon%202013%20-%20At%20a%20tipping%20point.pdf

Popp, D. (2006). R&D subsidies and climate policy: is there a “free lunch”? Climatic Change, 77(3-4), 311-341.

Popp, D. (2010). Innovation and Climate Policy. Annual Review of Resource Economics, 2(1), 275-298.

Rausch, S., Metcalf, G. E. and Reilly, J. M. (2011). Distributional impacts of carbon pricing: A general equilibrium approach with micro-data for households. Energy Economics, 33, 20-33.

Reinaud, J. (2009). Trade, competitiveness and carbon leakage: challenges and opportunities. Energy, Environment and Development Programme Paper, 9(01).

Rogge, K., Schneider, M. and Hoffman, V.H., 2010. The innovation impact of the EU emission trading scheme – Findings of company case studies in the German Power Sector. Ecological Economics, 70 (3), 513-523.

Sijm, J. (2005). The interaction between the EU emissions trading scheme and national energy policies. Climate Policy 5 (1): 79-96.

Sijm, J.P.M., Neuhoff, K. and Chen, Y. (2006). CO_2 cost pass through and windfall profits in the power sector, Climate Policy, 6:1 (49-72).

Sinn, H.-W. (2011). The Green Paradox. MIT Press, Cambridge, MA.

Steinhilber, S., Rathmann, M., Klessmann, C. and Noothout, P. (ECOFYS) (2011). Indicators assessing the performance of renewable energy support policies in 27 Member States. A report compiled within the European project RE-Shaping, supported by the European Commission, EACI within the “Intelligent Energy Europe” programme.

Sterner, T. (2012). Distributional effects of taxing transport fuel. Energy Policy, 41, 75-83.

Verdolini, E. and Galeotti, M. (2011). At home and abroad: An empirical analysis of innovation and diffusion in energy technologies. Journal of Environmental Economics and Management, 61(2), 119-134.

ANNEX

Table 5. Energy Excise Taxes (2012)

	Electricity (€/MWh)		Natural gas (€/MWh)		Diesel (€/litre)	Unleaded gasoline (€/litre)	Light fuel oil (€/litre)	LPG (€/litre)
	Industry	Households	Industry	Households				
Czech Republic	1.13	1.19	1.22	0.00	0.44	0.51	26.25	0.09
France	16.78	23.66	1.46	1.11	0.41	0.58	56.60	0.06
Germany	33.50	74.00	4.03	5.50	0.47	0.66	61.35	0.09
Italy	79.62	61.73	4.40	:::	0.62	0.73	403.20	0.15
Netherlands	12.80	7.79	2.70	17.05	0.44	0.74	:::	0.09
Poland	4.78	4.78	0.00	0.00	0.35	0.40	55.44	0.11
Spain	5.20	8.75	0.00	0.00	0.37	0.46	86.16	0.03
United Kingdom	3.45	0.00	0.89	0.00	0.72	0.72	137.35	:::

Source: IEA (2012a)

Table 6. Emission Factors

	Electricity (tCO_2/MWh)[27]	Natural Gas (tCO_2/GJ)[28]	Diesel (tCO_2/litre)	Unleaded gasoline (tCO_2/litre)	Light fuel oil (tCO_2/litre)	LPG (tCO_2/litre)
Czech Republic	0.599	0.0561	0.00266	0.00230	0.00266	0.00162
France	0.077	0.0561	0.00271	0.00234	0.00271	0.00162
Germany	0.468	0.0561	0.00267	0.00242	0.00267	0.00162
Italy	0.423	0.0561	0.00267	0.00230	0.00267	0.00162
Netherlands	0.425	0.0561	0.00270	0.00231	0.00270	0.00162

[27] Average values from 2008 to 2010.

[28] Gross Calorific Values: 0.00028 MWh/MJ.

Poland	0.798	0.0561	0.00267	0.00227	0.00267	0.00162
Spain	0.287	0.0561	0.00276	0.00242	0.00276	0.00162
United Kingdom	0.47	0.0561	0.00271	0.00229	0.00271	0.00162

Source: IEA (2012b), IPCC (2006)

Table 7. Weighted average support in 2010 (€/MWh)

	Hydro	Wind	Biomass	Biogas	PV	Geo-thermal	Waste
Czech Republic	52.25	13.24	37.22	104.37	496.31	::	::
France	12.28	35.51	49.48	38.78	496.03	::	::
Germany	35.65	41.05	120.88	::	387.92	155.69	::
Italy	80.3	76.1	120.4	::	406.8	82.4	::
Netherlands	98.46	81.16	74.84	::	389.68	::	48.73
Poland	::	::	::	::	::	::	::
Spain	44.01	45.55	77.51	::	399.93	::	29.81
United Kingdom	62.77	69.63	62.04	61.11	199.63	::	::

Source: CEER (2013)

Table 8. CO_2 emissions in the electricity mix (2010)

	CO_2 gr/kWh	Percentage of conventional fuels and nuclear	CO_2 gr/kWh (excluding renewables)
Czech Republic	589	93.8%	627.9
France	79	85.7%	92.2
Germany	461	87.2%	528.7
Italy	406	75.8%	535.6
Netherlands	415	94.8%	437.8
Poland	781	96.4%	810.2

Spain	238	67.5%	352.6
United Kingdom	457	95.4%	479.0
EU27	429	80.1%	535.8

Source: IEA (2012b) and Eurostat