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

Assessment of EU Instrumentation Options under Different Supranational Governance Scenarios

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LIST OF ABBREVIATIONS

ACER	Agency for the Co-operation of Energy Regulators
BAT	Best Available Technology
CCS	Carbon Capture and Storage
EITE	Energy-intensive trade-exposed
ENTSO-E	European Network of Transmission System Operators Electricity
EU ETS	European Union Emission Trading System
GHG	Greenhouse Gas
MSR	Market Stability Reserve
R&D	Research and Development
TSO	Transmission System Operator
UNFCCC	United Nations Framework Convention on Climate Change
WTO	World Trade Organisation

Executive summary

In addition to the challenge of reducing emissions to 80% below 1990 levels by 2050, the EU has to be prepared to respond suitably to different external factors. Two of the most critical factors for success in meeting this target are: (i) what climate policies other countries will follow and (ii) how governance rules will evolve within the EU? Given that supranational governance scenarios are going to be crucial for the effectiveness and feasibility of EU climate policy, the aim of this document is to assess EU instrument options under different scenarios and come up with general insights for EU policy makers.

Drummond (2015) and Huppes (2015) have proposed different development options for EU climate policy in the short-term and long-term, respectively. Their analysis assumes international governance and the level of EU centralisation will remain roughly as they are now. This document goes one step further and carries out a sort of resilience analysis. We analyse climate instrumentation in two additional international governance scenarios:

i. No-global-deal scenario, which assumes very ambitious international commitments but without legally binding agreements and a low degree of convergence and harmonization of climate instruments, and
ii. A middle-of-the-road scenario, which assumes a high degree of policy convergence but a lack of ambition in emission reduction.

We also analyse climate instrumentation in two additional EU governance scenarios:

i. An EU centralised scenario, which assumes most of the climate decisions are established at the EU level and, therefore, where there is a centralisation of EU governance structure, and
ii. An EU decentralised scenario, which assumes a re-nationalisation of climate policy and thereby climate instruments that are designed and implemented at national level.

Our analysis for each scenario is developed from the four instrument packages proposed by Huppes (2015): (a) the technology-specific pathway whose focus is on regulatory standards and subsidies; and in which market-based instruments such as the EU ETS are phased out in a stepwise fashion; (b) the ETS pure-cap pathway where the EU ETS is the main driver of decarbonisation and where the emission cap is expanded to cover the main sectors; (c) the ETS price stabilization pathway in which a reform of the EU ETS takes place, setting a price floor and ceiling for carbon; and (d) the emission tax pathway where a transformation of the EU ETS into an emission tax occurs and technology-specific instruments are removed.

The key results of the report are summarized below.

Non-global-deal scenario

- In a non-global-deal scenario, carbon leakage remains a big challenge for EU climate policy. The lack of international coordination and harmonization of climate instruments may create divergences between countries.
- The performance of a technology-specific pathway relative to market-based pathways depends on the stringency level chosen for the former: too low a level of stringency and the carbon target is not met; too high a level of stringency and EU competiveness is compromised. Moreover, a technology-specific pathway is not superior to market-based pathways in order to avoid carbon leakage. Inappropriate stringency levels of standards may reduce the EU competitiveness. The volatility and uncertainty associated with a pure cap ETS system is also an obstacle to reduce carbon leakage in this scenario.
- Regardless of the policy pathway, additional anti-leakage measures should be implemented in the energy-intensive and trade-exposed industries. The free allocation of allowances is the most effective and feasible way to avoid carbon leakage in those sectors covered by the EU ETS. Exemptions could be applied to those sectors subject to standards. When an emission tax is implemented, border carbon adjustment is the best option. However, compatibility with World Trade Organization (WTO) is unclear, and political feasibility is probably low.
- In presence of market failures (e.g. principal agent problem), market-based pathways could benefit from technology-specific instruments, which would promote investment and innovation in low carbon technologies. This is particularly important in the ETS pure-cap pathway, where the price signal may be very uncertain and volatile, and possibly weak.
- The global ambition to reduce emissions would increase the demand of low carbon technologies, creating business opportunities for many industries. Technology-specific instruments could help to encourage technology development and innovation, and thus, gain market share in the world economy.
- A reform to stabilize prices in the EU ETS is necessary to decrease price uncertainty. Moreover, such a reform would allow additional instruments to be used without affecting the price signal. However, a price collar is outside the structural reform proposed by the European Commission and its political feasibility may be low. Likewise, an emission tax would also face feasibility problems.

Middle-of-the-road scenario

- The low international ambition under this scenario may reduce the political feasibility of EU climate policy. In such an international context, EU climate policy will probably focus on maximizing non-climate benefits of emissions reduction (e.g. health, energy security).
- The static efficiency of market-based pathways is generally high because marginal abatement costs are equalised across sectors and emitters. However, emission price

would not internalise non-climate benefits. Emissions reductions are determined regardless of the co-benefits. Hence, a technology-specific pathway may be superior to market-based pathways in this international context. Market-based pathways could be improved adding technologic-specific instruments to those sectors which can deliver high non-climate benefits.

- Although international coordination offers the opportunity to harmonize climate instruments across borders, some pathways may have difficulties to take advantage of this international context. For instance, there is a trade-off between stabilizing allowances price within the EU and linking the EU ETS with other trading systems.
- The low international ambition would increase the risk of carbon leakage, particularly through the price channel.
- Regardless of the specific policy pathway taken, non-climate benefits of emission reductions should be highlighted to increase the public acceptability of instrument mixes.

EU centralised scenario

- This scenario would increase the political feasibility of all pathways. The centralisation of the EU climate policy would allow a structural reform of the EU ETS and expand the coverage of the EU ETS, including the transport and the buildings sector.
- The effectiveness of the instrument packages will depend on the stringency levels. However, in the absence of a price signal, a technology-specific pathway may be subject to rebound effects. Likewise, market failures (e.g. principal agent problem) may reduce the effectiveness of market-based pathways.
- A price stabilization reform may be beneficial to reduce price uncertainty and encourage investment and innovation in those sectors covered by the EU ETS. Besides, the EU ETS could be compatible with national initiatives, without affecting the price signal. Although this scenario assumes a centralisation of climate policy, national and/or sub-national measures would be useful to take into account national differences. Moreover, they would encourage front-runners and increase the feasibility of the instrument package.
- In a technology-specific pathway, higher centralisation could increase bureaucracy and reduce the capacity for modification as new information emerges.

EU decentralised scenario

- This scenario would limit the number of pathways that the EU climate policy could take. The most feasible would be the technologic-specific pathway.
- The role of the EU would focus on coordinating national policies and recommending effective pathways in emission reduction. The EU should aim to harmonise emission standards in key sectors, particularly energy-intensive and trade-exposed industries, to avoid a race to the bottom and standard based competition between Member States.
- In order to deal with the intermittency in most renewables, the role of the EU should be focused on reducing barriers to link national electricity markets.

- In a decentralised scenario, it looks unrealistic that the EU ETS could play a leading role. The EU ETS could remain to guarantee a minimum emission reduction target. Member States could introduce a carbon price floor to maintain the price signal meaningful.
- A price stabilization reform and emission tax pathway would require a high centralisation of EU climate policy and, therefore, these pathways are infeasible in this scenario.

Supranational governance scenarios will be a key factor when designing EU climate policy. However, some robust conclusions can be drawn regardless of the governance scenarios:

- Establish a meaningful carbon price (either EU ETS or emission tax) is essential to ensure effectiveness and cost-efficiency. A technology-specific pathway without a price signal would show critical weaknesses. The transport and buildings sector would face a high risk of rebound effects. Too much interventionism could hinder private actions. The flexibility of the instrument package to deal with changing circumstances would be very low.
- Carbon price is necessary but not sufficient. A market-based pathway based exclusively on carbon pricing may not produce the expected results. Market failures would lead to important efficiency losses. A single carbon price would not internalise non-climate benefits, and thereby, climate policy may not take advantage of additional co-benefits.
- The reform of the EU ETS would be beneficial to improve the performance of the scheme. A more predictable carbon price would help to encourage investment and innovation in low carbon technologies. This would also facilitate implementing additional instruments without affecting the price signal.

The state of knowledge on which scenarios are likely to be realized is not static. Information will come at various stages over the coming years. COP21 will be an important milestone, as will the UK referendum. As this new information emerges, policy makers can modify the package of measures accordingly. In particular the analysis indicates the following changes may be appropriate:

<u>Non-global-deal-scenario</u>:

- Additional anti-leakage measures should be implemented.
- Development and innovation in low carbon technologies should be promoted to take advantage of business opportunities.

<u>Middle-of-the-road scenario</u>:

- The co-benefits (e.g. health and energy security) of emission reduction should be emphasized.
- Anti-leakage measures may be required.

EU centralised scenario:

- The EU ETS should be reformed. A price collar could be implemented and, eventually, transformed in an emission tax.
- The expansion of the EU ETS should be considered to cover the transport and buildings sectors.

EU decentralised scenario:

- EU climate policy should focus on technology regulation.
- The role of the EU should be based on harmonizing national initiatives.

1 Introduction

The European Union (EU) faces a major challenge in cutting emissions to 80% below 1990 levels by 2050. In order to meet this target, and at the same time stimulate economic growth and ensure competitiveness of the EU, the Union is looking at cost-efficient ways to make the European economy more climate-friendly and less energy-consuming. Drummond (2015) and Huppes (2015)[1] have proposed different policy instrumentation pathways to meet these targets. Drummond (2015) focuses on the short-term development options for the EU climate policy. His analysis identifies short-term improvements to make the current policy mix more effective and efficient. Huppes (2015) investigates how effective climate policy instrumentation could be developed in the long-term. Both Drummond (2015) and Huppes (2015) based their analysis on the most reasonable expected development of the international and EU governance scenarios. It is assumed that the level of international cooperation will be a 'middle of the road' track and the level of EU centralisation will remain roughly as it is now. This document goes one step further and carries out a sort of resilience analysis, where we investigate how the instrument mixes could be adapted depending on which scenarios regarding international governance and EU governance are realised. The CECILIA2050 project does not assess whether the costs of meeting EU's targets are justified by the benefits of avoided emissions. It is assumed that EU's long run targets are met regardless of the climate actions of other countries. The EU climate targets are taken as a starting point.

The instrument mixes are assessed according to the criteria developed by Görlach (2013). The assessment covers three dimensions: environmental effectiveness, cost-effectiveness and feasibility. The environmental effectiveness evaluates whether the instrument mix is able to bring about the necessary emission reduction. The cost-effectiveness criterion measures the cost associated with the emission reduction. This criterion has as the ideal the least cost reduction in emissions at least cost now (static efficiency) and over time (dynamic efficiency). The feasibility criterion indicates the risk that the policy fails to be adopted as planned and/or to deliver as expected.

The international context will be a key element of EU climate policy. Not only the effectiveness but also the efficiency and the feasibility of EU climate policy will depend on the climate polices in the rest of the world. Although the COP21 in Paris should reveal climate actions and/or commitments outside the EU, the uncertainty about the evolution of the international context is likely to remain. Hence, the EU should be prepared to respond suitably to different international scenarios. In this document, we suggest two alternative scenarios to the one proposed by Drummond (2015) and Huppes (2015). First, we assume that international climate negotiations lead to very ambitious commitments but without legally binding agreements and a low degree of convergence and harmonization of climate

[1] Drummond (2015) and Huppes (2015) are part of a coordinated effort in the CECILIA2050 projects.

instruments. On the other hand, our second scenario assumes low ambition by the rest of world but legally binding agreements and a high degree of convergence and harmonization of climate instruments. As will be seen later these scenarios span a wide range of possible economic outcomes within which the EU actions can be evaluated.

EU governance will also play an important role on EU climate policy, particularly for the feasibility of several instruments. Past experiences show that not all policy instruments are politically feasible. The rejection to the proposal of the European Commission to establish a carbon tax in the 1990s illustrates that EU governance will be crucial for the feasibility of several instruments. In this document, we suggest two alternative scenarios to the one proposed by Drummond (2015) and Huppes (2015). In the first scenario, we assume that most of the climate decisions are established at the EU level and, therefore, there is a centralisation of EU governance structure. In the second scenario, we assume a re-nationalisation of the climate policy and thereby climate instruments are designed and implemented at national level.

The rest of the document is organized as follows. The next section describes governance scenarios. Section 2.1 and section 2.2 focuses on the international and the EU governance, respectively; current features of the international and EU governance are described and two scenarios are proposed for each governance dimension. Section 3 assesses the instrument packages proposed by Huppes (2015) in each governance scenario. Initially, Section 3.1 summarizes the key characteristics of the climate policy pathways. Section 3.2 and section 3.3 assess the climate policy pathway in the international and EU governance scenarios, respectively. Section 4 concludes.

2 Governance Scenarios

2.1 International Governance

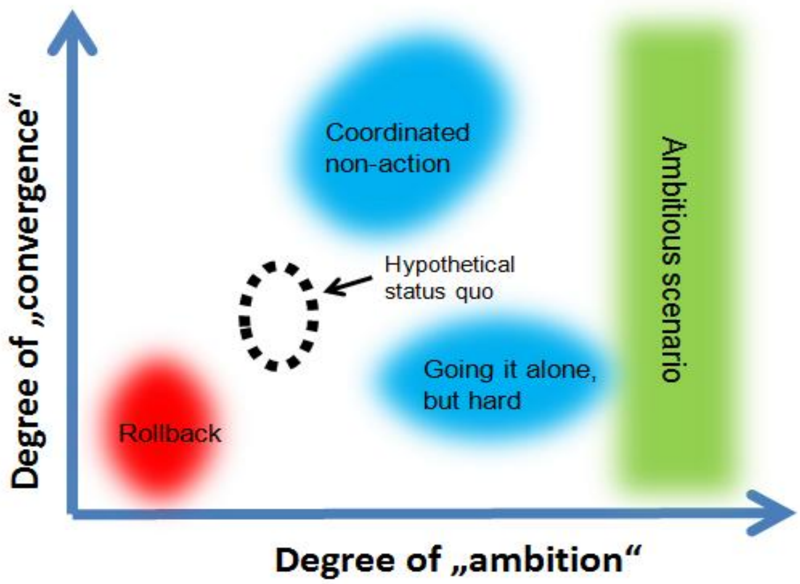
Climate change is a global problem and faces the difficulties common to all global public goods. The main benefits of unilateral actions are shared with other countries, while the cost is assumed by the region/country which implements mitigation measures. This makes the international dimension of the EU climate policy particularly important. In 2012 the EU accounted for around 10% of global emissions. This implies that the influence of the EU is very limited. Without international contribution, the impact of EU actions on emissions mitigation would be insufficient. Moreover, EU’s climate policies could lead to higher emissions outside the EU (i.e. carbon leakage).

The CECILIA2050 project does not assess whether the costs of meeting EU’s targets are justified by the benefits of avoided emissions. It is assumed that EU’s long run targets are met regardless of the climate actions of other countries. The EU climate targets are taken as a starting point. However, these targets can be achieved with different strategies and the international context should be a key factor to determine these strategies. International cooperation may a have a role in stimulating green investment and technological innovation. It can also be crucial for the acceptability of EU climate policies by the general public and the cost of meeting the EU targets.

This document explores the implications of the international context on the EU climate policy. Following Zelljadt (2014) we propose different international scenarios based on two criteria: ambition and convergence. The degree of ambition measures how many countries implement climate policies and how stringent they are. The degree of convergence assesses the similarity between instrument structures and their harmonization. It also measures the likelihood of reaching binding international agreements.

International climate negotiations have shown that there may be a trade-off between these two criteria (IPCC, 2014). Participating countries may be willing to accept more ambitious commitments when there are not strong and mandatory, while international cooperation and coordination may result in less ambitious targets. The Kyoto Protocol showed that when targets are ambitious the number of participants may be very low. On the other hand, in the Copenhagen 2009 conference a higher consensus was achieved, given that countries registered voluntary actions under non-committal pledges. Ideally international agreement should move to a scenario with a high degree of ambition and convergence, but this does not look very likely.

Figure 1 Scenario landscapes



Source: Zelljadt (2014)

In Drummond (2015) and Huppes (2015), an international policy context is assumed in which the degree of ambition and convergence is slightly higher than current status quo. Thus, they do not assume major changes in the international arena and the balance between ambition and convergence remains roughly like now. In this document two additional scenarios are explored. Following the nomenclature given by Zelljadt (2014), we analyse the implications for the EU climate policy of the Non-global-deal scenario and the Middle-of-the-road scenario. The Non-global-deal scenario assumes a high degree of ambition and a low degree of convergence. This implies that the likelihood of reaching a legally binding international agreement on global emission reduction target is very low. National measures are not coordinated, but they are ambitious enough for limiting global warming to 2˚C. The Middle-of-the-road scenario assumes a high degree of policy convergence but a lack of ambition. Countries agree on joint programs and global mitigation instruments. However, given the low ambition of climate policy instruments, global warming would tend to 4˚C.

According to IPCC (2014) the structure of international governance can be specified around four elements: (i) legal binding nature, (ii) goals and targets, (iii) flexible mechanisms and (iv) equitable methods for effort sharing. We will base our analysis on these four elements to construct the international governance scenarios.

2.1.1 Current features of International Governance

The United Nations Framework Convention on Climate Change (UNFCCC) is the main forum for climate change negotiations. The UNFCC is an international treaty which aims to "stabilize GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". It was adopted in 1992 and entered into force in 1994. Today, 196 countries have ratified the convention. Since 1995, the parties to the convention have met annually to assess the evolution of climate change.

In 1997 the Kyoto Protocol was adopted with the aim to commit UNFCCC parties by setting internationally binding emission reduction targets. It entered into forced in 2005, and has two commitment periods, the first started in 2008 and ended in 2012, and the second runs from 2012 to 2020. Under Kyoto's first commitment period, industrialised countries agreed to cut GHG emissions by about 5% over the period 2008-2012 from the 1990 levels. The 15 countries that were EU Member States at the time Kyoto Protocol was adopted committed to reduce GHG emissions by 8%. In the second Kyoto period 38 developed countries have agreed to participate, including the EU Member States. The Parties committed to cut emissions by at least 18% from 1990 levels. However, the impact of the Kyoto Protocol has been limited because several developed countries such as the United States, Russia, Canada, Japan and New Zealand are not participating. Moreover, the agreement only covers emissions on developed countries. This implies that the Kyoto Protocol applies to only around 14% of the world's emissions.

After the Kyoto Protocol, UNFCCC parties have agreed to further commitments. In 2009, 114 country Parties agreed on the Copenhagen Accord, which states that "deep cuts in global emissions are required according to science, and as documented by the IPCC Fourth Assessment Report with a view to reduce global emissions so as to hold the increase in global temperature below 2ºC, and take action to meet this objective consistent with science and on the basis of equity" (UNFCCC, 2009). The accord agreed that developed countries would commit to emissions targets for 2020. Developed countries should also raise funds to help developing countries cut emissions. These would implement mitigations actions to slow growth in their GHG emissions. The Copenhagen Accord includes countries representing over 80% of global emissions. However, in contrast to the Kyoto Protocol, the accord is not legally binding.

In the last Conference of the Parties of UNFCCC held in Lima, the basis for a new global climate agreement to be signed at the next meeting in Paris was established. The Parties reached an agreement on conditions for defining the Intended Nationally Determined Contributions (INDC). Each country will define its mitigation commitments for implementation from 2020. Thus, the Parties will have a solid, common basis on which to negotiate in Paris. They also agreed on raise a new Green Climate Fund (GCF) with an initial $10 billion target.

Although the UNFCCC has become the main framework for climate change negotiations, there is a growing number of fora and institutions at multiple scales[2]. Other institutions have emerged in part from the inclusion of climate change issues in other policy arenas (e.g., sustainable development and international trade). IPCC (2014) states the need to account for the variety of international, transnational, regional, national and sub-national agreements and institutions. They may represent an opportunity with potential co-benefits, but could also increase negation costs.

For example, the REDD+ Partnership focuses on reducing emissions from deforestation and degradation. More than 50 have signed non-binding agreements to raise money and thus finance project related to the conservation and management of the forests. The International Renewable Energy Agency (IRENA) brings together 163 states with the aim of developing and financing renewable energy technologies. Although members are only industrialized countries, the International Energy Agency (IEA) and the OECD have become two important fora to provide analytical support on technical issues for climate change.

2.1.2 Non-global-deal Scenario

The philosophy of this scenario is developed by Zelljadt (2014). The Non-global-deal scenario assumes ambitious unilateral initiatives to reduce GHG emissions. In the absence of a UNFCCC legally binding agreement, each country (region) implements individual measures. There is a lack of coordination between national instruments; however they are ambitious enough to limit global warming to 2˚C. The EU initiatives such as the EU ETS are not linked to similar trading systems in other regions. Following IPCC (2014) we specify the structure of international cooperation around four elements:

[2] See IPCC 2014 for a complete review of international fora and institutions.

Legal commitment

IPCC (2014) sets out four indicators of legal binding commitment: (i) legal type, (ii) mandatory commitments, (iii) specificity, and (iv) the type of enforcement procedures. Based on these indicators, they show several examples of commitments in international agreements for climate change. For example, there are legally binding commitments with enforcement mechanism (e.g. Kyoto Protocol[3]) and mandatory provision in a non-legally binding agreement (e.g. Copenhagen Accord and Cancún Agreements).

We assume that in a Non-global-deal scenario the likelihood of reaching a legally binding commitment is very low. Thus, we do not consider that international agreements such as the Kyoto Protocol could be achieved. In this scenario international agreements are 'soft'. There are not mandatory commitments and they are not expressed in sufficient detail. Each country would send their pledges on targets and actions, but there are no enforcement procedures, mechanisms and sanctions. The UNFCCC do not coordinate emissions monitoring, reporting and verification. Reputation and reciprocity are the main drivers of individual actions.

Goals and targets

In this scenario, the world's largest emitters agree on limiting the temperature increase to 2˚C. This implies that GHG concentration level does not exceed 450 ppm and, therefore, requires the climate pledges made by individual parties to be very ambitious. The lack of an international binding agreement facilitates the adoption of ambitious plans. Countries set their GHG emission reduction targets relative to different measures: a historical baseline, economic output, population growth and business as usual projections. The EU maintains the domestic 2030 GHG emission reduction target of at least 40% compared to 1990, 60% by 2040 and 80% by 2050.

Flexible mechanisms

The lack of coordinated actions would not allow the implementation of flexible mechanisms. National instruments would not be harmonized. This will impede countries to have flexibility in meeting their emission targets. The EU ETS, for instance, would not be linked to other emission trading systems. The flexible mechanisms provided under the Kyoto Protocol such as the Clean Development Mechanism (CDM) and Joint Implementation (JI) could not be applied.

Equitable methods for effort sharing

In this context, one might expect that national efforts on emissions reduction would be based on own economic and environmental interests. In the absence of a global agreement, effort sharing may be limited to soft agreements between countries.

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[3] The withdrawal of Canada from the Kyoto Protocol shows that although there are enforcement mechanisms they have never been enforced.

2.1.3 Middle-of the-road scenario

The philosophy of this scenario is based on the Middle-of-the-road scenario developed by Zelljadt (2014). In this scenario, the degree of convergence is higher than that in the Non-global-deal scenario, but it comes at the expense of higher ambition. The lower ambition allows parties to reach an UNFCCC international agreement; however the lack of ambition prevents achieving the objective of limiting global warming to 2˚C. The EU commits to a GHG emission reduction target of 80% by 2050, even though the effort of the rest of the world remains much less ambitious. Given that the EU accounts for around 10% of global emissions, it would have little impact on global warming, which would head for an increase of 4˚C. The convergence of national and regional climate policy would facilitate the coordination of policy instruments. Parties may converge by adopting the same emissions caps, renewable energy quotas, energy efficiency standards or carbon taxes. Thus, the EU climate instruments such as the EU ETS could be linked to similar trading systems in other regions.

In this context the four elements of international governance would be characterized by:

Legal commitment

Based on the IPCC (2014) indicators of international commitments, specified above, this scenario would be characterized by mandatory provisions in a legally binding agreement. The UNFCCC parties would reach an international agreement on emission reductions. The legal commitment would be very similar to that of the Kyoto Protocol. The low ambition on emission targets would facilitate reaching an agreement. Thus, in contrast to the Kyoto Protocol, the world largest emitters would participate in the agreement, including developing countries such as China and India.

Goals and targets

The high degree of convergence comes at the expense of lower ambition on emission reduction targets. Similarly to the Kyoto Protocol there would be fixed targets on developed countries. Developing countries could fix their emission targets relative to economic growth or business-as-usual projections. The EU would keep its long-term emission targets, regardless of the climate actions of other countries. The likelihood of limiting global warming to 2˚C would be very low, and we would tend to an increase of 4˚C.

Flexible mechanisms

The high degree of convergence would allow flexible mechanisms to meet national targets. Although the global target to limit the temperature increase would be fixed, states would have flexibility in meeting their obligations and thereby lower the cost of reducing emissions. National and regional climate policy instrument would be coordinated. The three flexible mechanisms provided under the Kyoto Protocol (or some variants) could be implemented: the Clean Development Mechanism (CDM), Joint Implementation (JI) and international emissions trading (IET). The CDM allows a country to implement an emission-reduction project in developing countries. JI allows a country to earn emission reduction units from an emission-reduction project in another country. IET allows countries trade emissions allowances. Thus, the EU climate instruments such as the EU ETS could be linked to similar trading systems in other regions.

Equitable methods for effort sharing

As pointed out by Bosetti and Frankel (2011), international agreements should be realistic. To make an international agreement politically feasible, countries should perceive the agreement to be fair to its own economic and environmental interests. IPCC (2014) shows a complete summary of effort sharing methods analysed in the literature. The aim of this document is not to assess whether an international agreement is fair or not. We will assume that in this scenario the world's largest emitters agree to reduce emissions and set emissions targets, and these are accepted by all countries.

Table 1 International governance scenarios

	Legal commitment	Goals and targets	Flexible Mechanisms	Equitable methods for effort sharing
Non-global deal scenario	There are not legally binding commitments.	There is an International agreement to limit the temperature increase by 2˚C.	There are not links between national/regional climate instruments.	National efforts are based on each country's economic and environmental interests.
Middle-of-the-road scenario	There are mandatory provisions in a legally binding agreement.	International commitments would limit the temperature increase by 4˚C.	The high degree of international convergence allows the implementation of flexible mechanisms.	International agreements are realistic and accepted by all countries.

2.2 EU Governance

When analysing climate instrument packages, it is essential to consider future EU governance structures. Not only the performance but also the feasibility of the instrument packages proposed by Drummond (2015) and Huppes (2015) will depend on future EU governance structures. Drummond (2015) and Huppes (2015) assume that it will remain roughly as it is now. This situation, however, may change. Governance in the EU is dynamic and may vary in the coming years.

The current climate instrument package is a mix of EU-wide and national initiatives. EU-wide instruments (e.g. EU ETS and Fleet Standards) coexist with national instruments (e.g. feed-in tariff schemes and low-emission-car subsidies). The development of current governance structure may take different pathways. In this section two additional EU governance scenarios are built according to the relationship between the EU and the Member States. There are two possible tendencies: (i) further centralisation or (ii) renationalisation of climate policies, with deviating interpretations of the subsidiarity principle.

Bausch et al. (2015) offer a complete view of centralisation and decentralisation trends in the history of EU climate policy. They argue that, while the 2020 climate and energy package implies further centralisation on EU governance, the 2030 framework represents a more decentralised solution. Based on the current features, we construct two possible pathways for the development of EU governance.

2.2.1 Current features of EU governance

As in other areas where the EU and Member States share competence, climate policy has been a struggle between those Member States wanting more centralisation and others wanting more nationalisation of EU climate policy. Bausch et al. (2015) argue that the centralisation of climate policy instruments has not been an easy task. The first attempts to centralised climate policy instruments failed. For example, in the 1990s the European Commission proposed a carbon tax at the EU level. Taxation measures require unanimity in the Council of Ministers and many Member States opposed to carbon taxation at the EU level. The centralisation of EU climate policy began in the early 2000s. During this period, the Directive 2001/77/EC on the promotion of renewables and the Directive 2003/87/EC establishing the EU ETS were adopted. Although the promotion of renewables did not establish binding targets at national level and the EU ETS was initially a decentralised system, these directives represented a step toward more centralisation of EU climate policy.

The so-called 20-20-20 targets, set by EU leaders in 2007, meant a higher centralisation in climate and energy governance at EU level (Wettestad et al., 2012). The 2020 climate and energy package is based on a set of binding legislation. The Renewable Energy Directive implied an increase in centralisation, making renewable targets binding for each Member State. Similarly the EU ETS became more centralised, substituting national caps with an EU-wide cap, and centralising the allocation of allowances. The Effort Sharing Decision established national emissions targets for those sectors not covered by the EU ETS such as housing, agriculture and transport. However, in contrast to the EU ETS, which is regulated at EU level, it is the responsibility of Member States to design and implement national policies to meet the target set by the Effort Sharing Decision. Although Member States have flexibility to implement their own policy instruments, some measures taken at EU level affect those sectors not covered by the EU ETS (e.g. CO_2 emission standards for new cars and Energy Performance of Buildings Directive). Finally, the 2020 climate and energy package set a 20% improvement in the EU's energy efficiency, but not national targets.

The 2030 framework for climate and energy policies shows a trend towards decentralisation. This framework requires that in 2030 EU emissions should be reduced by at least 40% compared to the 1990 level. Those sectors covered by the EU ETS would have to reduce their emissions by 43% compared to 2005. Although there is no specification for Member States, the non-EU ETS sectors would need to reduce emissions by 30% below the 2005 level[4]. In contrast to the 2020 climate package, the renewable energy target is binding for the EU as a whole, but without national targets. This has meant a lower degree of legal commitment at national level. The energy efficiency target is also set at the EU level. The 2030 framework also presents a proposal to improve the design of the EU ETS. The first stages of the EU ETS were characterized by an oversupply of allowances, partly as a result of the economic crisis. The price of emission allowances slumped, affecting the cost-effectiveness of the system (European Commission, 2014a). The past performance of the EU ETS is a consequence of the design of the instrument and not of its centralisation. However, a structural reform of the EU ETS may lead to reconsider its degree of centralisation. Some Member States have implemented measures to improve the performance of the EU ETS. The UK, for example, introduced a "carbon price floor", so that when the price of allowances falls below the set threshold, the power generation companies covered by the EU ETS would need to pay the difference (UK Parliament, 2013). This case illustrates that the development of the EU ETS can take different ways, and the decentralisation of the system cannot be dismissed.

The 2030 framework proposes a new governance framework, which will respect the Member States' freedom to determine their energy mix while facilitating coordination and cooperation between Member States. The European Council (European Council, 2014) agreed that the new governance structure will:

- Build on the existing building blocks such as national climate programmes.
- Step up the role and rights of consumers, transparency and predictability for investors.
- Facilitate coordination of national energy policies.

The proposal for a new governance framework remains open and poses several questions. An important issue is how the Member States' freedom to determine their energy mix will be shaped in the new proposal for an Energy Union. In February 2015, the European Commission presented a framework strategy for an Energy Union (European Commission, 2015a). The proposed framework aims to:

- Improve energy security, solidarity and trust.
- Integrate European energy market
- Improve energy efficiency
- Decarbonise the economy

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[4] The European Commission notes that this needs to be translated into individual targets for Member States.

- Encourage research, innovation and competitiveness.

Currently each Member State has its own energy regulatory framework. An Energy Union would integrate national energy markets and create an EU-wide energy system where energy flows freely across borders. This would require a structural transformation of Europe's energy system and, consequently, the development of an Energy Union would depend on the evolution of EU governance.

2.2.2 EU centralised scenario

This scenario assumes a centralisation of EU governance structure. This would imply that relevant climate decisions are established at the EU level. The EU would be a supranational body with the authority and control over climate policy. This would result in a harmonisation of climate policy across Member States.

In this section we will focus on some key areas and assess how they would be affected by higher centralisation of the EU governance.

Carbon pricing

As mentioned above, the European Commission is currently assessing different alternatives to carry out a structural reform of the EU ETS. The first trading periods of the EU ETS were characterized by a large imbalance between supply and demand of allowances, which weakened the carbon price signal. This reduced the incentives for low-carbon investment and affected the cost-effectiveness of the system.

We assume that further centralisation in the EU governance would facilitate the implementation of a structural reform of the EU ETS. This scenario assumes that the EU ETS could be reformed applying one of the six options proposed by the European Commission (European Commission, 2014b). In the short-term a market stability reserve could be implemented as proposed by the European Commission (European Commission, 2014c). According to the impact assessment (European Commission, 2014b) such a reserve could help address the current imbalance between the supply and demand for allowances. It would be implemented at the beginning of phase 4 in 2021. Allowances would be placed in and released from the reserve depending on the total number of allowances in circulation. This would provide supply flexibility to respond to demand shocks, caused by economic activity, fuel prices, weather, etc. Moreover, it would make possible to adjust the supply of allowances depending on the impacts of other climate policies such as renewables and energy efficiency instruments. Operating rules would be pre-defined and would leave no discretion to the Commission or Member States in its implementation. The market stability reserve will not affect the cap; thereby the emission reduction objective would be met.

In the long-term, other mechanisms for carbon pricing could be implemented. The market stability reserve could be substituted by a price collar, as proposed by Knopf and Edenhofer (2014), which would keep allowance prices between a floor and a ceiling. The EU ETS could eventually be transformed into an emission tax. All these reforms would be possible thanks to a strong EU.

Energy Union

European Commission (2015a) presents the main implications of an Energy Union. According to the European Commission an Energy Union would need an integrated governance to deepen the cooperation between Member States and with the Commission. An internal energy market would need bodies to ensure cooperation among transmission system operators and regulator. The European Commission considers that the European Network of Transmission System Operators for Electricity and Gas (ENTSO-E/G) should be upgraded to integrate the transmission system operation. Likewise, the authority and independence of the Agency for Cooperation of Energy Regulators (ACER) should be reinforced to carry out regulatory function at the EU level. Currently the ACER has very limited decision-making rights and acts through recommendations and opinions. An Energy Union would also require the implementation of infrastructure projects, such as the minimum interconnection for electricity at 10% of installed production capacity. To achieve this, it will be necessary to provide resources to different funding schemes (e.g. European Fund for Strategic Investments) which could finance viable investments.

All these requirements can only be met with further centralisation of the EU governance. Hence, we consider that this scenario would allow a common energy market. This scenario would also lead to a loss in national powers. Although the 2030 framework proposes a new governance framework, which will respect the Member States' freedom to determine their energy mix (European Council, 2014), we assume that an Energy Union would make this impossible.

Infrastructure

Current EU infrastructures are not sufficient to make the transition to a low carbon economy. The implementation of new infrastructure projects will be particularly important for energy and transport. In this context, the level of governance will be crucial to determine how decisions about infrastructure investment are taken and how they are financed. When considering further centralisation of the EU governance, we will assume that a European body is created or adapted for infrastructure planning and financing[5]. This body would have sufficient financial resources for the implementation of major infrastructure projects. This body would be independent enough to assess objectively national infrastructure needs, considering all the benefits and the risks. This does not imply that infrastructure will be financed only through public funds. Public-private partnership approaches could be created, to attract private investments in infrastructure projects.

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[5] Currently there are several schemes to finance green infrastructure such as the European Regional Development Fund, the European Fund for Strategic Investments and the European Investment Bank.

Target setting

The 2020 climate and energy package set the 20-20-20 targets, regarding GHG emissions, energy consumption produced from renewable resources and energy efficiency at the EU level. The package also included binding national targets for reducing their GHG emissions from the sectors not covered by the EU ETS and national renewable energy targets. The recently agreed 2030 framework for climate and energy policies excludes national targets. This has created a debate about advantages and disadvantages of specific targets and national targets (Bausch et al, 2015). This debate is related to the competences of the EU and the Member States. Some Member states consider that setting specific targets and national targets, they cannot follow their preferences and pathways to reduce emissions. We assume that a centralisation of climate policies would allow the EU to set specific targets and the level of ambition. They EU could also set binding national targets and would have the competence to monitor the compliance of the targets.

2.2.3 EU decentralised scenario

This scenario assumes a shift of the EU governance structure towards nationalisation. This would imply that most of the climate decisions are established at national level. The role of the EU would focus on the coordination and harmonisation of national climate policies. Regarding technology the EU cannot set standards (e.g. fleet, appliances) and it role is limited to information and recommendation.

In this section we focus on some key areas and assess how they would be affected by higher decentralisation of the EU governance.

Carbon pricing

Although the functioning of the EU ETS has been suboptimal, a decentralised scenario would not make possible a structural reform of the system. In this scenario, the European Commission proposal for a structural reform of the EU ETS would not take place.

In a decentralised scenario, we assume that there will not be major changes in the functioning of the EU ETS. We should expect that the current imbalance between supply and demand of allowances would remain in the coming years. The European Commission estimates that the surplus of allowances accounted for 2.1 billion by the end of 2013, and it will grow to more than 2.6 billion by 2020.

In the absence of a structural reform at the EU level, we could expect that some Member States would introduce national mechanisms to correct the poor functioning of the EU ETS. Some Member States could follow the UK, and introduce a carbon price floor (UK Parliament, 2013). Eventually the EU ETS could phase out.

Energy Union

All the requirements for an Energy Union would be impossible to meet without further centralisation of the EU Governance. Consequently, we assume that in this scenario, there are no major changes from current energy market. Currently each Member State has its own regulatory framework and the energy mix is determined at national level. Cross-border connections are limited and, therefore, we assume that they could be expanded in the future only under bilateral agreements. In this scenario, we also assume that infrastructure projects and financial requirements would manage at the national level.

Infrastructure

The lack of internal cohesion will not facilitate the creation of an independent European body for the implementation of major infrastructure projects. In this context, infrastructure planning and financing will be managed at national level. The lack of investment cooperation would increase the risk of not achieving emission reduction targets. The role of the EU would focus on basic functions of coordination. The EU could also co-finance some strategic infrastructure.

Target setting

Only a strong EU can set specific targets and national targets. Thus, in a decentralised scenario we do not expect that the EU can set binding targets on the GHG emissions of Member States. The compliance of emission reduction objectives would be a national competence. Each Member State would have the freedom to choose the pathway to achieve their climate targets. In this context, the EU would not be able to set targets on renewables and energy efficiency neither at national level nor at EU level.

Table 2 EU governance scenarios

	Carbon pricing	Energy Union	Infrastructure	Target setting
EU centralised scenario	Structural reforms are possible. Other mechanisms for carbon pricing could be implemented.	An Energy Union is created.	A European body is created or adapted for infrastructure planning and financing.	The EU could set binding national targets on emissions and other specific targets.
EU decentralised scenario	A structural reform of the EU ETS is not possible	There are no major changes from current energy market.	Infrastructure planning and financing is managed at national level.	The EU role is limited to providing recommendations to member states.

3 Assessment of Instrument Packages in each Governance Scenario

3.1 Instrument packages

Based on a bottom-up approach, Huppes (2015) presents four options for the development of current climate policy instrumentation in the four main sectors: electricity, industry, buildings and transport. The set of instruments are linked to four basic options of emission pricing: no emission pricing, pure cap-and-trade, price stabilized cap-and-trade and pure emission tax. The four sectoral instrument mixes linked to each pricing system are added to come up with four climate policy pathways.

This section presents the key features of these four climate policy pathways. A more complete analysis can be found in Huppes (2015).

3.1.1 Technology-specific pathway

Electricity sector

- Emission standards and subsidies, as feed-in premiums and capacity payments, are implemented to promote renewables and stimulate storage facilities.
- The implementation of emission standards, which are specified in terms of emissions per kWh, leading to the phase out of coal and later gas.
- In principle, electricity sectors remain national.
- The EU ETS is phased out.

Industry sector

- Emissions are regulated by standards. For some new and innovative low emission industries, technology subsidies are implemented.
- Standards are based on BAT (Best Available Technology) and are specified by the EU and implemented nationally.
- CCS technology may be subsidized in basic industries for primary iron and steel production and cement production.
- The EU ETS is phased out and there is no generic carbon pricing.

Buildings sector

- Energy use in buildings is reduced through standards. There are also information measures and subsidies.
- New buildings are subject to insulation standards. A combination of standards and subsidies is implemented for retrofitting the existing building stock.
- The efficiency of appliances is improved through information measures and product standards.

- Decarbonizing buildings may follow two routes: electrification or hydrogen delivery replacing natural gas in distribution systems. Both seem mutually incompatible and cost development may determine the winner.
- Initially, a hydrogen infrastructure may partly replace the natural gas infrastructure. There are demonstration projects on heat pumps and heat storage systems, and new multifunctional fuel cell systems.
- Instruments are implemented at national level. The international hydrogen infrastructure would require the active support but not ownership by the European Commission.

Transport sector

- Fleet standards are implemented for all vehicle categories. The set-up of fleet standards is based on emissions only.
- Similarly to buildings, there are different options for decarbonisation: electricity and hydrogen. It is induced the development of all relevant infrastructures to keep options open.
- There are subsidies on electric and hydrogen fuel cell drives.
- There is no carbon pricing. Fuel taxes rise modestly and there are taxes on combustion motors.
- Air and sea transport are mostly left out of climate policy, but taxed normally.

3.1.2 ETS pure-cap pathway

Electricity sector

- The EU ETS is the main driver of decarbonisation. The emission cap is set at a fixed reduction path of 8% per year.
- Current subsidies on the promotion of renewables are phased out. However, there are learning curves subsidies for some renewables.
- There are two options to counteract the high uncertainty on investment paths: (i) subsidizing stabilization technologies and (ii) developing and open electricity market.
- In addition to the EU ETS, there are R&D subsidies for electricity storage system.

Industry sector

- The EU ETS covers all industrial emissions.
- BAT specifications are implemented as an information instrument, to help industries reduce emissions actively.

- In order to overcome price uncertainty, technology specific instrumentation could be implemented, but more modestly than in the Stimulation and Forcing Mix. Some subsidies can be introduced with a focus on BAT.

Buildings sector

- The EU ETS is expanded to cover the buildings sector. This implies that the administrative implementation is moved upstream. The cap includes all primary production and imports of fossils and fossil energy products, also covering hydrogen production.
- Similarly to industry sector, technology specific instrumentation could be implemented to counteract price uncertainty and encourage investment on low carbon technologies. These instruments cannot too ambitious and their contribution in terms of emission reduction should be taken into account, otherwise EU ETS price will plummet.
- Additional technology specific measures could be refurbishing subsidies on the worst performance buildings and are implemented at national level. New technologies are subsidies to create learning curves.
- Hydrogen infrastructure is developed by EU in parallel to natural gas piping.

Transport sector

- The EU ETS is expanded to cover the transport sector. As mentioned above, this implies that the administrative implementation is moved upstream.
- The EU ETS domain is also expanded to include emissions in air and sea transport.
- Fleet standards are phased out. National excise taxes on fuels lose importance under the pure cap.
- In order to avoid technology lock-ins, new technologies are subsidized (e.g. electric and hydrogen fuel cell drives).
- Member states are required to build refuelling electric and hydrogen network.

3.1.3 ETS price stabilized pathway

Electricity sector

- The EU ETS is the main driver of decarbonisation. The EU ETS is reformed, setting a price floor and ceiling. The cap volume is adjusted to keep the EU ETS price between these values.
- Subsidies are offered at different administrative levels. EU funding is focused on R&D. The creation of learning curves for upcoming technologies is co-funded by the EU and Member States.

- There are also national subsidy schemes to promote renewables. National technology subsidies are implemented for resolving regional and national intermittency.

Industry sector

- All industrial emissions are covered by the EU ETS, which keeps the price within a determined range.
- There is no risk of making the price of the EU ETS price irrelevant, as in the pure cap mix, and therefore, a more active industrial policy is developed.
- There are EU subsidies for R&D. National efforts are focused on demonstration projects and implementation of highly relevant but slightly expensive technologies.
- The EU develops hydrogen infrastructure.

Buildings sector

- The EU ETS covers all fossil fuels used in buildings. The administrative level is upstream.
- Buildings standards remain to protect rental homes from underinvestment. In the long-term information measures support market functioning.
- In the medium-term, national subsidies are implemented to finance buildings insulation.
- There is the EU electricity market and the EU international hydrogen transport.
- EU funds for R&D are focused on integrating seasonal energy storage in buildings.

Transport sector

- The EU ETS is expanded to cover the transport sector, including air and sea transport. The cap is administered upstream beyond the refinery level.
- Current fleet standards are abolished in the medium-term.
- There may be limited subsidies for market creation of novel technologies, for instance, subsidizing zero emission cars.
- Standardization is limited and coordinated by the EU. Fossil fuels are press out of most heavy transport domain by standards and subsidies.
- There is a public transmission grid for electricity and hydrogen, which is owned by the EU and Member States.
- Development of transport infrastructure is focused at model shifts.

3.1.4 Emission tax pathway

Electricity sector

- The EU ETS is stepwise transformed into an emission tax. The tax level could increase 10€ per year, reaching for example €200 per tonne CO_2 in 2040 and €300 in 2050.
- The administrative implementation is first with electricity producers, but then moves to fossil fuel producers and importers.
- There is a Single European Electricity Market.
- The international electricity grid is owned and operated at EU level. The national electricity grids and distribution grids are owned and operated publicly at national level.
- Standardization plays a limited role.
- Public funds for R&D are focus on basic research.

Industry sector

- Firstly the EU ETS is broadened to cover all industrial emissions, and then a single emission tax is fixed. There is upstream administration to cover smaller firms.
- The pure emission tax would lead to more emphasis on a stricter public-private separation and more focus on purely public tasks.
- There are few subsidies for high risk high potential technologies.
- The hydrogen option may require public provision of hydrogen transmission and storage infrastructure.

Buildings sector

- The emission tax covers all emission in buildings.
- Additional climate measures are abolished. There are no technology specific subsidies and no standards. Insulation standards are replaced by information measures.
- Lon-term markets may not function in some cases and, therefore, public intervention may be required exceptionally. This can be the case for the development of energy storage systems. Public funding on R&D is focused on energy storage in housing.
- Public infrastructure is developed for delivering electricity and hydrogen. Use options are managed by private parties.

Transport sector

- The emission tax also covers all fossil fuels used in the transport sector. It covers aviation and shipping.
- Public intervention is minimized. Current fleet standards are abolished and there are limited public funds for R&D.

- The main infrastructures are developed publicly. Electricity and hydrogen infrastructures and markets are set up publicly to make zero emission drives in transport possible.

3.2 Implications of the international governance context

International Governance will be a key aspect to determine the effectiveness, cost-effectiveness and feasibility of EU's climate policy. In this section, we analyse how EU's decarbonisation strategies would be affected by the international context.

González-Eguino et al. (2015) analyse the effectiveness of the EU climate policy in a wide range of possible international contexts[6]. The scenarios considered range from the case where the EU goes alone for an emission reduction target of 80% by 2050, to the case where most of the countries participate in an international agreement. In the scenario where the EU goes alone, they find that the global mean temperature increase would be reduced just by 0.1˚C at the end of the century compared to the business-as-usual scenario. In the business-as-usual scenario temperature increase would be 3.8˚C above preindustrial level in 2100, while EU's action would limit global warming to 3.7˚C. An ambitious global climate action, on the other hand, would be much effective in reducing GHG emissions. According to their results, when an ambitious carbon tax is implemented in most countries, global warming could be limited to 2.4˚C.

These results show that, in the absence of ambitious global actions, the impact of the EU climate policy would be very weak. Thus, we should expect that the effectiveness of the EU climate policy would be higher in a Non-global-deal scenario than in a middle-of-the-road scenario. However, we should also consider the risk of breaching the pledges. Although the Non-global-deal scenario assumes that national pledges will be ambitious enough for limiting global warming to 2˚C, the lack of any binding commitment may reduce the credibility of national pledges, especially during periods of economic difficulty or of exceptional growth. When national pledges cannot be verified or enforced, free-riders may surge.

Another important aspect of the international context is carbon leakage. The effectiveness of the EU climate policy will depend on the level of ambition the rest of the world. Unilateral EU action may result in higher emissions abroad. Kuik (2015) use a dynamic Computable General Equilibrium model to study the determinants of carbon leakage in the long run, with a focus on the European iron and steel industry. In the absence of anti-leakage measures (e.g. free allocation of allowances in the EU ETS), when the EU acts alone carbon leakage rate would be of 44%. In addition to the price channel, they decompose carbon leakage in competitiveness channel and investment reallocation channel. The results show that the price channel is main driver of carbon leakage in short and medium term. However, from 2025 the competitiveness

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[6] The tool used for the analysis is GCAM, a dynamic recursive economic partial equilibrium model driven by assumptions about population size and GDP growth.

and especially the investment channel gain importance. In 2050, almost 60% of carbon leakage is determined by the investment channel. González-Eguino et al (2015) reckon that the carbon leakage rate would be about 28% when EU acts alone[7]. This means that the rest of the world would increase emissions by 0.28 tCO_2 for each ton of CO_2 avoided in the EU. They find that carbon leakage is mainly triggered by land use changes. The lower energy demand in the EU The leakage rate declines as the size of the coalition implementing the international climate regime increases.

International governance is also crucial for the cost-effectiveness of EU climate policies. Several studies have assessed how global climate action, or inaction, will have an impact on the cost of meeting the EU targets. De Cian et al. (2013) show how EU's decarbonisation strategies would be affected by the international context. They use eight different models[8] to analyse four international scenarios. When the EU reduces emissions by 80%, and the rest of the world remains less ambitious, global GDP would decline between 0% and -10%, with a median value of -4.1%. Most of the economic losses take place in the EU and mainly from 2030 onwards. Not all sectors would be affected in the same way, while production of energy-intensive industries would decline up to -40%, the maximum decline in non-energy intensive industries would be -15%. When the rest of the world implements climate policies of similar stringency as in the EU, mitigation costs are reduced considerably. European energy-intensive industries would gain market share and total value added in Europe would be higher. In 2050 global consumption would increase up to 5% compared to the scenario with asymmetry between the efforts of the EU and the rest of the world. De Cian et al. (2013) also detect the importance of harmonizing climate policies. They find that linking emission trading markets could increase GDP up to 6% compared to a non-coordinated scenario. In the same vein, Antimiani et al. (2015) find that the EU economy would benefit and carbon leakage would decrease when similar mitigation efforts are carried out by other countries. They also highlight the positive effects of linking emission trading markets across countries. Meyer et al. (2014) find that the GDP average annual growth rate of the EU would be reduced less than 0.1% when there is global cooperation.

Political feasibility could also be affected by the international context. As argued by Munaretto and Walz (2015), the international climate debate plays a major role on the EU climate policy development. Climate actions in the rest of the world will influence decisions at the EU level. They carry out an analysis based a multi-method approach[9] and observe that

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[7] This study considers two sources of carbon leakage: one due to the different fuel prices in countries with a carbon target as opposed to countries without one, and the other resulting from a shift of biomass/food production that is carbon intensive out of regions with a carbon target to regions without one.

[8] The set of models includes three Computable General Equilibrium models (EPPA, PACE, FARM-EU), three Energy System Models (POLES, TIAM-UCL, TIMES-VTT) and two Optimal Growth Models (WITCH, MERGE-CPB).

[9] The multi-method approach includes semi-structured in-depth interviews, focus groups, an on-line survey and a policy simulation with relevant stakeholders in the EU climate policy domain.

interest groups would not agree on the EU to take ambitious actions when the rest of the world does not cooperate.

3.2.1 Climate instrumentation under a Non-global-deal scenario

Based on the analysis in previous section, we summarize the key aspects to consider when evaluating the EU climate instrumentation under a Non-global-deal scenario:

- The degree of global ambition is high. The efforts of the EU are similar to those of other countries.
- There are not binding international agreements which increase the risk of non-compliance.
- There is a low degree of convergence among national/regional climate instruments.

This international governance scenario would result in several challenges and opportunities for the EU climate policy. Probably the most important challenge is the one related with the risk of carbon leakage. As mentioned above, carbon leakage can occur through two channels: the price channel and the competitiveness channel (Kuik, 2014). The price channel works reducing the demand for fossil fuels in regulated countries and, thus, induces a drop in international prices, which could increase the demand in non-regulated countries. The competitiveness channel affects the competiveness of some sectors, especially the energy-intensive and trade-exposed (EITE) industries that could be relocated to non-regulated countries. In the short term, this would imply a change of the utilization rate of existing capacities (operational leakage), while in the long-term, it would imply a change in production capacities (investment leakage).

In this scenario, the main risk of carbon leakage should occur through the competitiveness channel. Although high global ambition is assumed, the lack of international coordination can create divergences of the climate regulation in energy-intensive and trade-exposed industries. Some countries/regions may implement ambitious climate targets for most sectors of the economy, but protect those industries exposed to international competition. Or even if all countries implement ambitious regulation in trade-exposed industries, asymmetrical mitigation instruments can cause carbon leakage. As argued by Marcu et al. (2013), climate instruments impose a visible and a 'shadow' price for carbon. When the shadow price is not taken into account, asymmetric carbon constraints can be created, affecting industrial competitiveness. Thus, the lack of convergence between countries/region would increase the risk of carbon leakage in some EU industries.

Another challenge for the EU climate policy stems from the lack of binding international agreements. This scenario foresees an international commitment to reduce emissions and limit global warming to 2˚C. However, there is no international authority to sanction non-compliant parties. This increases the uncertainty related the actions of other countries/regions. In this context, flexibility and capacity for modification as new information emerges would become a valuable feature of the EU climate instrumentation.

On the other hand, this scenario presents an opportunity derived from the ambitious climate actions in the rest of the world. More stringent regulation should lead to a higher demand of low carbon technologies. Several EU industries could benefit from this international context.

Challenges:

- The lack of international coordination and harmonization is a risk for carbon leakage, particularly through the competitiveness and the investment channel.
- The EU should deal with high uncertainty regarding the climate actions of other countries.

Opportunities:

- Higher global demand of low carbon technologies.

Technology-specific pathway

In this section we assess the performance of a technology-specific pathway under a Non-global-deal scenario which is characterized by high international ambition to reduce GHG emissions but without international cooperation and harmonization of climate policy instruments.

The international context will be a key determinant of the environmental effectiveness of the EU climate policy, since carbon leakage is determined by the different climate regulations across countries. A more stringent climate policy in the EU compared to the rest of the world could lead to a high carbon leakage rate, reducing the environmental effectiveness of the EU climate policy. As argued above, in a non-global-deal scenario there is a risk of carbon leakage through the competitiveness and the investment channel.

The effects of a technology-specific pathway on carbon leakage are ambiguous. In this policy instrumentation, climate regulation is implemented by subsidies and emission standards. The EU ETS is phased out. Thus, those industries exposed to a risk of carbon leakage benefit from a lower carbon price; however the effects of non-market based instruments on carbon leakage are ambiguous. Emission standards, for instance, work as implicit emission taxes on the input side where the fictitious tax revenues are recycled as implicit subsidies on the output side (Holland et al., 2009). While an emission tax induces emissions reduction through substitution effects, an output subsidy induces inefficiently high output. This mechanism may imply that, in a fragmented international scenario, emission standards can prevent carbon leakage and increase cost-effectiveness compared to carbon pricing (Holland, 2012). However, using a computable general equilibrium model, Böhringer et al. (2015) find that emission standards may increase rather than decrease carbon leakage compared to emission taxes or tradable emission allowances. Inappropriate stringency levels may impose a high burden on energy-intensive and trade-exposed industries, reducing international competitiveness and increasing carbon leakage.

Therefore, in the absence of international harmonization of climate policies, implementing non-market based instruments, which reduce (or eliminate) carbon pricing, may not reduce the risk of carbon leakage. In order to tackle the risk of carbon leakage and thus increase environmental effectiveness, additional anti-leakage measures should be included in this instrument package. Given that this climate instrumentation pathway avoids carbon pricing, granting exemptions to energy-intensive and trade-exposed industries could be implemented as an anti-leakage measure. This measure exempts those industries exposed to a risk of carbon leakage from emission regulation. Although less effective than border tariffs, Böhringer et al. (2012) find that exemptions are effective in reducing carbon leakage. However granting exemptions to some industries prevents equating marginal abatement cost across sectors, which may even increase rather than decrease emission reduction cost.

The lack of coordinated global actions not only may affect environmental effectiveness but also cost-effectiveness. Several studies find that the harmonization and coordination of national/regional climate policies reduces considerably mitigation costs (De Cian et al., 2013; Antimiani et al., 2015). These studies generally analyse the effects of linking market-based instruments such as emission taxes and emission trading systems and, although there is not empirical evidence on the global harmonization of non-market based instruments, we suspect that similar conclusions could be drawn.

In addition to the costs derived from non-coordinated global actions, implementing technology-specific instruments rather than market-based instruments in a scenario without cooperation can negatively affect the EU economy. Based on the standard economic postulate, which states that emission taxes or emission trading systems achieve emission reduction at lowest cost, technology-specific instruments may impose a high burden on local industries. Governments have limited information and their intervention may increase mitigation costs (Helm, 2010). Given that there are no coordinated global actions and competitors abroad may have a less costly regulation, European industries may face higher costs of compliance than their international competitors and this would lead to a comparative disadvantage for European industries. The electricity sector may also face a more costly regulation, increasing electricity prices and reducing the competitiveness of the EU economy.

On the other hand, in a scenario with high uncertainty regarding the climate actions of the rest of the world, a technology-specific pathway may create a stable framework for investment. As pointed out by IPCC (2014), uncertainty about the performance of new technologies is a major factor in their deployment. For instance, technology support policies such as feed-in-tariffs have been effective in promoting renewables in Germany and other countries. In this scenario, all emitting industries would also benefit from low carbon technology paths which would be developed and implemented through subsidies and standards. This regulatory framework can be more stable than a marked-based pathway, attracting low carbon investment to Europe.

The global ambition to reduce emissions would increase the demand of low carbon technologies, creating business opportunities for many industries. The development of the right technologies will be crucial to gain market share in the world economy. In this context, research, technology development and innovation should play a crucial role. Given that there are several market failures associated with RD&D investment (IPCC, 2014), public intervention can be particularly convenient in this scenario. The technology-specific pathway which proposes the creation of learning curves and the public support for RD&D in most of the sectors can be superior to a pure market pathway.

In an uncertain international scenario, flexibility and capacity for modification are advantageous features of an instrumentation pathway. This may represent a disadvantage for a technology-specific pathway because some technology support instruments (e.g. emission standards) have been considered less flexible than market-based instruments (Burtraw et al., 2010).

This international governance scenario should not decrease the feasibility of this instrument package. However, the lack of a price signal may reduce the feasibility of this policy pathway. Most stakeholders consider that carbon pricing is an appropriate way of reducing GHG emissions and, thus, in the absence of a price signal, the acceptability of the instrument package would be lower. Moreover, the implementation of a technology-specific pathway is perceived too organizationally complex, which could reduce its administrative feasibility (Munaretto and Walz, 2015).

Summary:

- The implementation of technology-specific instruments would reduce carbon price; however this may not lead to a lower risk of carbon leakage. Inappropriate stringency levels may reduce the competitiveness of energy-intensive and trade-exposed industries.
- In this scenario, the instrument package would require additional anti-leakage measures such as exemptions.
- The lack of international harmonization on technology deployment increases the risk caused by picking up winners. Wrong regulatory policies may lead to high economic costs, reducing the competitiveness of European industry.
- In an international scenario with high uncertainty, technology-specific policies may encourage low-carbon investment.
- This international governance scenario should not decrease the feasibility of this instrument package. However, the lack of a price signal may reduce the feasibility of this policy pathway.

ETS pure-cap pathway

In this section we assess the performance of an ETS pure-cap pathway under a Non-global-deal scenario which is characterized by high international ambition to reduce GHG emissions but without international cooperation and harmonization of climate policy instruments.

As argued by Huppes (2015), this instrumentation pathway will have an average carbon price higher than the other two market-based pathways. This is because limited price predictability makes investment decisions more difficult. The carbon price must be higher to compensate for the higher uncertainty.

Therefore, this scenario is characterized by uncertain and non-coordinated international climate actions, and by an instrument package with a volatile and high carbon price. In this context, the risk of carbon leakage is very high. EU industries should deal with high and volatile carbon prices, and different international regulations. Energy-intensive and trade-exposed industries may move and/or invest in other countries/regions laxer and more stable regulation. This scenario would require anti-leakage measures.

The current mechanism for supporting those EU industries at risk of carbon leakage is free allocation of emission allowances[10]. The free allocation of allowances should not threaten the environmental effectiveness of the instrument package. Regardless of how allowances are allocated, an established cap should achieve a fix emission reduction level. This mechanism works as a production subsidy to recover (part of) losses in comparative advantage (Böhringer et al., 2012). Given that production is indirectly subsidised, it is not as effective as other anti-leakage measures such as border tariffs. In terms of dynamic efficiency, free allocation rewards encourage the emission-intensive installations to catch up the best available technologies (Turcea and Kalfagianni, 2015). However there is no evidence free allocation has induced technological innovation.

Carbon leakage can also be addressed through other anti-leakage measures such as border adjustments. Monjon and Quirion (2011) compare the performance of both border-adjustments and output-based allocations[11] to tackle carbon leakage in the EU ETS. They find that border-adjustments are more efficient in reducing carbon leakage. However, although output-based allocation is generally less effective in reducing carbon leakage, production losses affected by the EU ETS are lower. Moreover, when output-based allocation is properly implemented[12], carbon leakage remains very limited. Turcea and Kalfagianni (2015) note that border-adjustment measures would require multilateral negotiations and, given that in this scenario international coordination is low, the political feasibility of border-adjustments is lower than that of output-based allocations. Therefore, the current mechanism of free allocation of emission allowances would be the best option to address carbon-leakage in this scenario.

The cost-effectiveness of this instrument package would be also affected by the high uncertainty of this scenario. As mentioned above, uncertainty can discourage RD&D

[10] Turcea and Kalfagianni (2015) offer a complete analysis of this anti-leakage measure.

[11] This measure is equivalent to the free allowance allocation (Böhringer et al., 2012).

[12] According to Monjon and Quirion (2011), this would imply auctioning allowances in the power sector and output-based allocation in the cement, steel and aluminium sectors, covering both direct and indirect emissions.

investments in low carbon technologies, which may prevent reduce mitigation costs in the long-term. In order to increase the cost-effectiveness, additional technology support policies should be included in this instrument package. Public RD&D funding should be included to promote innovation in low carbon technologies. Other instruments such as subsidies on emission reducing investment should also encourage the development and deployment of new technologies. In addition to increasing cost-effectiveness, these instruments could also increase the international competitiveness of some EU industries, which could take advantage of the business opportunities identified in this scenario. However, as argues by Huppes (2015), successful technology-support instruments may erode the role of the pure cap system, and diminish the carbon price and make it irrelevant. Hence, when implementing additional measures, their impact on the EU ETS should be considered and emission cap should be set accordingly.

Although it is generally accepted that the EU ETS is not working properly, its political feasibility would be higher than that of other climate instruments because the EU ETS is already in place (Munaretto and Walz, 2015). Complementing the EU ETS with additional instruments could increase the acceptability of this instruments package. Munaretto and Walz (2015) find that industry and governmental officers tend to favour market based instruments, such as the EU ETS, complemented with technology-specific instruments.

Summary:

- Under high and volatile carbon prices, and non-coordinated international regulations, the risk of carbon leakage is very high.
- Anti-leakage measures would be required. The free allocation of allowances should be implemented to minimize the risk of carbon leakage.
- The high uncertainty could discourage investment in low carbon technologies and, thus, reduce the cost-effectiveness.
- Additional technology-support instruments could improve the performance of the instrument package. However, an inappropriate setting may erode the role of the pure cap system, increasing the risk of failure of this instrument package.
- Complementing the EU ETS with additional instruments could increase the acceptability of this instruments package.

ETS price stabilized pathway

In this section we assess the performance of an ETS price stabilized pathway under a Non-global-deal scenario, that is, a scenario with high international ambition to reduce GHG emissions but without international cooperation and harmonization of climate policy instruments.

In contrast to a pure cap system, this pathway would deliver a stable carbon price, keeping permit prices between a floor and a ceiling. Besides, the longer predictability of the carbon price would allow carbon price set by the EU ETS to be reduced (Huppes, 2015).

Carbon price stabilization would be very beneficial to reduce the risk of carbon leakage. Not only is the carbon price path set by the EU ETS lower than that of the pure cap system, it also reduces uncertainty. Both aspects are key factors to reduce the risk of carbon leakage in an uncertain international context without non-coordinated climate actions. A price stabilization mechanism would reduce uncertainty for industry and allow permits supply to adjust to changing international circumstances (UK Government, 2015). Transparent rules and a predictable carbon price would provide a stable framework and dissuade energy-intensive industries reallocate production capacities in non-EU countries.

However, in a non-coordinated international scenario, a stabilized carbon price might not be enough to prevent carbon leakage. Additional anti-leakage measures should be included in the instrument package. The current mechanism of free allocation of allowances could be the most politically feasible anti-leakage measure. As mentioned above, the free allocation of allowances does not affect environmental effectiveness, but it can reduce the cost-effectiveness of the instrument package. Given that the price stabilized pathway involves lower risk of carbon leakage than a pure cap pathway, those industries exposed to carbon leakage should be less and, therefore, the list of sectors receiving free allowances should be more targeted.

A price stabilization mechanism could also reduce the cost of emissions reduction, particularly, improving the dynamic efficiency of the EU ETS. The degree to which the EU ETS encourage low-carbon investment depends on the stability of the carbon price (Neuhoff et al., 2015). A price stabilization mechanism is a useful way to manage expectations of future prices. Keeping permit prices between a floor and a ceiling would incentivize investments in innovations that are required for cost-effective long-term decarbonisation (Knopf and Edenhofer, 2014). Moreover, this scheme is not incompatible with technology-support instruments, which in a pure cap system can make the carbon price so low as to become irrelevant. The subsidies proposed in this pathway would not undermine the EU ETS. This can be particularly important in this international scenario where ambitious climate actions would generate business opportunities for EU industries. Thus, subsidies and other technology-support instruments may incentivize innovation and increase the international competitiveness of EU industries.

In terms of flexibility, in an uncertain international environment, capacity for modification as new information emerges is a valuable feature of an instrument package. The price stabilization mechanism proposed in this policy pathway would allow permits supply to adjust to changing circumstances.

Although there is a general agreement that the EU ETS should be reformed, Knopf and Edenhofer (2014) consider that the political feasibility of a price stabilisation mechanism would be limited. A price collar is outside the structural reform proposed by the European Commission, which recommends a market stability reserve.

Summary:

- The risk of carbon leakage would be reduced with predictable carbon prices.

- Still the free allocation of allowances might be necessary in some specific sectors.
- Lower uncertainty would increase the dynamic efficiency of the EU ETS.
- This instrument package would be compatible with technology-support instruments, which could be implemented to incentivize innovation and increase the international competitiveness of EU industries.
- The political feasibility is limited.

Emission tax pathway

In this section we assess the performance of an emission tax pathway under a Non-global-deal scenario which is characterized by high international ambition to reduce GHG emissions but without international cooperation and harmonization of climate policy instruments.

The EU ETS reform, which stabilizes allowance prices between a floor and a ceiling, could eventually lead to an emission tax. The price path set by the emission tax would rise linearly, and could reach €400 per tonne in 2050. According to Huppes (2015), the higher long term predictability of an emission tax would reduce the carbon price level compared to the price path set by the EU ETS.

Theoretically, emission taxes should not be superior to a trading system to address carbon leakage. In a first-best world both instruments are identical (Norregaard and Reppelin-Hill, 2000). However, there exist markets failures and barriers which discourage private investment. An important barrier is uncertainty; the lower predictability of the carbon price may induce energy-intensive and trade-exposed industries to move and/or invest in other countries and, thus, increase the risk of carbon leakage. Consequently, emission taxes should be superior to emissions trading in order to avoid carbon leakage.

Although emission taxes may induce lower carbon leakage than the EU ETS, this pathway may also require additional anti-leakage measures. This can be a disadvantage for emission taxes compared to a trading system. In the EU ETS the free allocation of permits can easily implemented. On the other hand, emission taxes would require other anti-leakage measure whose feasibility might be lower. An alternative anti-leakage measure is border carbon adjustment, which is the most effective instrument in cutting carbon leakage and reducing global costs (Böhringer et al., 2012). They can aggravate regional inequality but, given that this is non-cooperative international scenario, this might not be a problem. Besides, border adjustment measures would compatible with WTO law (Turcea and Kalfagianni, 2015). The feasibility of output-based allocation is also limited and exemptions may increase mitigation cost (Böhringer et al., 2012).

The higher predictability of carbon prices would also benefit the cost effectiveness of an emission tax pathway. First, carbon prices would be lower because there is no need to compensate for greater uncertainty. Second, lower uncertainty increases investment into low-carbon technology and makes technological learning easier (IPCC, 2014), increasing dynamic efficiency. Moreover, similarly to carbon price stabilization mechanisms, emission taxes can be implanted with other instruments without the risk of making them irrelevant. Although this instrument package is a pure market pathway, without technology-support instruments, in an uncertain international scenario, public subsidies on low-carbon technologies may convenient to make EU industries more competitive.

Regardless of the international scenario, the main obstacle for an emission tax pathway is political feasibility. Munaretto and Walz (2015) find that taxation is considered as politically infeasible by most stakeholders.

Summary:

- An emission tax pathway would deliver lower and more predictable carbon prices than the EU ETS, reducing the risk of carbon leakage.
- Although the feasibility is low, a border carbon adjustment would be beneficial to reduce the risk of carbon leakage.
- In an uncertain international scenario, public subsidies on low-carbon technologies may convenient to make EU industries more competitive.
- The political feasibility of emission tax is very limited.

3.2.2 Climate instrumentation under a Middle-of-the-road scenario

Based on the analysis in previous sections, there exist key aspects to consider when analysing the EU climate instrumentation under a Middle-of-the-road scenario:

- The degree of global ambition is low. This leads to a strong asymmetry between the efforts of the EU and the rest of the world.
- Although emission reduction targets are low, the compliance of the targets is guaranteed by binding agreements.
- The high degree of convergence makes possible the harmonization and coordination of climate policy instruments.

This international governance scenario would result in several challenges and opportunities for the EU climate policy. The most important challenge stems from the lack of international ambition to reduce GHG emissions. Given that the EU's targets are assumed to be met regardless of the climate actions of other countries, this would create large asymmetries between the EU and the rest of the world. The EU accounts for around 10% of global emissions and its actions would have little impact on limiting global warming. High mitigation costs with no effects would reduce legitimacy and political feasibility.

In this context, the EU climate policy should focus on strengthening the non-climate benefits of mitigation measures. The co-benefits of reducing emissions are generally realised in the short-term and in those countries that implement mitigation measures (New Climate Economy, 2014). This increases the feasibility of an ambitious EU instrument package in an asymmetric international scenario.

There is extensive literature assessing the non-climate benefits of reducing emissions[13]. The health benefits, for instance, could account for \$55-420/tCO_2 due to avoided mortality (West et al., 2013). Another important co-benefit is higher energy security. The deployment of renewables would increase national energy sufficiency and resilience. The lower dependence on fossil fuels would alleviate future energy price volatility which characterizes these energy sources. IPCC (2014) enumerates other non-climate benefits such as energy access, employment, biodiversity conservation and water use. Parry et al. (2014) calculate the carbon price for the top twenty emitting countries which should be set to maximize own national interest due to domestic co-benefits (e.g. health, traffic congestion). Co-benefits vary across countries depending on several factors (e.g. population density), but on average a carbon price of \$57.5/tCO_2 could be justified on co-benefits alone, suggesting that there is no need for global actions to set such a carbon price because the domestic benefits.

In this international scenario, the convergence and harmonization of climate instruments would minimize the risk of carbon leakage through the competitiveness and investment channel. We assume that there is an international agreement which coordinates climate actions and, thus, energy-intensive and trade-exposed industries would be faced with similar climate regulation in all countries. However, the higher ambition of EU climate policy may increase the risk of carbon leakage through the price channel. The lower demand for fossil fuels in the EU would imply a fall in prices, which could increase the demand in the rest of the world. The CO_2 capture and storage (CCS) may be one of the few measures that can address the risk of carbon leakage caused by the price channel. In contrast to other climate instruments, CCS does not reduce the demand for fossil fuels and, consequently, does not affect international prices. Quirion et al. (2011) analyse the effects on carbon leakage of implementing CCS in OECD countries. They find that CCS may halve carbon leakage, even if it can increase abatement costs.

Higher international coordination would represent an opportunity to harmonize and link climate instruments across countries. Although EU's climate targets are more ambitious than in other countries, this is not an impediment to implement a set of coordinated instruments. This is particularly important for energy-intensive and trade-exposed industries, which would not deal with the risk of carbon leakage. The efficiency gains from globally coordinated actions have been widely analysed in the literature. De Cian et al. (2013) calculate the benefits of linking the EU ETS to a global carbon trading scheme. Although they analyse a scenario in which both the EU and the rest of the world implement ambitious targets, the efficiency gains from linking climate instrument are remarkable. They find that coordinated instruments could increase consumption and GDP by up to 8% and 6%, respectively.

Challenges:

- The lack of international ambition is a risk for carbon leakage, particularly through the price channel.

[13] Chapter 6 of IPCC (2014) reviews all the non-climate benefits of mitigation measures.

- Low international ambition may reduce the political feasibility of EU climate policy.

Opportunities:

- The EU climate instruments could be harmonized with other instruments across borders.

Technology-specific pathway

In this section we assess the performance of a technology-specific pathway under a Middle-of-the-road scenario which is characterized by low international ambition to reduce GHG emissions but with international cooperation and harmonization of climate policy instruments.

In this scenario, international cooperation allows participating countries to harmonize national/regional climate instruments. From the effectiveness perspective, this could prevent carbon leakage through the competitiveness and investment channel. Energy-intensive and trade-exposed industries would face similar regulation across countries, discouraging the reallocation of production capacities.

However a technology-specific pathway may hinder the harmonization of climate instruments. This pathway assumes that the EU ETS price would be very low and irrelevant which could finally lead the EU ETS to phase out. In the absence of a carbon price, it would be difficult to harmonize policy instrument between countries/regions. In this context, coordination policies should focus on those industries exposed to the risk of carbon leakage. The EU could implement carbon standards which limit the amount of emissions per unit of output, and negotiate the introduction of similar instruments in other countries. As an alternative to emission standards, international coordination could lead to the introduction of technology standards which impose specific abatement technologies on emitters. Thus, those industries exposed to the risk of carbon leakage should have a similar cost of compliance across countries. This would avoid the comparative disadvantage for regulated EU industries.

The higher international coordination will not reduce the risk of carbon leakage through the price channel. As mentioned above, the promotion of the CCS technology is one of the few measures that the EU could adopt to reduce this risk. The technology-specific pathway is particularly suitable for creating learning curves. The EU could implement feed-in tariffs or feed-in premiums which incentives the use of CCS technology. In addition to these subsidies, there should be public funding for R&D to promote innovation and reduce production costs of CCS.

In this pathway, the inability to cover most sectors under the same policy instrument and, thus, to link this instrument to other instruments across countries will reduce the cost-effectiveness. Marginal abatement costs will vary across sectors and across emitters. This will prevent emitters to cut emissions where it costs least to do so. Additional measures to increase the cost-effectiveness of this instrument package would be convenient. For example, if possible, a single instrument such as feed-in premiums should cover the entire EU electricity sector. This will allow renewable generators to site the capacity where the resource is highest.

The low international ambition to reduce emissions will be an obstacle for the feasibility of the EU climate policy. Emissions reduction should focus on those sectors which deliver high non-climate benefits of reducing emissions. A technology-specific pathway, which is more interventionist than other pathways, is particularly suitable for this purpose. Given that most co-benefits (e.g. health, energy security, traffic congestion) are related to the transport sector, technology regulation and subsidies should be particularly high in this sector. Emissions should be reduced drastically in cities. Hence, in addition to the fleet standards proposed for this pathway, a modal shift to cycling and walking should be incentivised. The construction of new infrastructure and subsidies for public transport should complement energy standards.

Summary:

- A technology-specific pathway may hinder the international harmonization of climate instruments across countries/regions.
- International coordination should lead to the introduction of emission standards which impose the same burden on energy-intensive and trade-exposed industries across countries.
- The promotion of CCS technology through feed-in premiums could reduce the risk of carbon leakage through the price channel.
- Marginal abatement costs would vary across sectors and across emitters, reducing the cost-effectiveness.
- Technology regulation and subsidies should focus on the transport sector to increase the non-climate benefits of emissions reduction.

ETS pure-cap pathway

In this section we assess the performance of an ETS pure-cap pathway under a Middle-of-the-road scenario which is characterized by low international ambition to reduce GHG emissions but with international cooperation and harmonization of climate policy instruments.

Although the EU climate policy is more ambitious than in the rest of the world, international cooperation would allow the EU ETS to be linked to compatible emission trading systems[14]. Linking emission trading markets creates political, administrative and economic benefits (Kachi el al., 2015). In terms of effectiveness, when systems link, the risk of carbon leakage through the competitive and investment channel is reduced, given that carbon price will converge across countries. Thus, all emitters covered by the emission trading system would face the same price signal. This will eliminate the comparative disadvantage of EU firms, and alleviate reallocation pressures.

[14] See Kachi et al. (2015) for a complete literature review related to linking emissions trading systems.

A priori, larger linked markets would also increase liquidity and reduce price volatility (Ranson and Stavins, 2015). Given that uncertainty is one of the main drawbacks of the EU ETS, linking markets would involve a notable improvement for this policy pathway. Higher price predictability would make investment decision easier and boost innovation in low-carbon technologies. In the short term, the efficiency gains of linked markets would depend on the heterogeneity of abatement options (Kachi et al., 2015). When the EU ETS is linked to other systems with similar abatement costs, the potential for efficiency gains are limited. More heterogeneity, on the contrary, would expand mitigation options and reduce abatement costs.

The main weakness of the policy pathway is the political feasibility. This scenario assumes that EU ambition is higher than in the rest of the world. In principle, linking emission trading systems with different stringency levels is feasible. However, a different ambition level is one of the main barriers to linking emission trading systems (Green et al., 2014). When two systems with different ambition levels (and different level of carbon price) are linked, carbon price declines in the more stringent system and rises in the less stringent system, until it becomes equal. This implies a money flow from the more stringent system to the less stringent system which can result in a political barrier (Zetterberg, 2012). Therefore, linking heterogeneous emission trading systems (i.e. with different abatement costs and carbon prices) benefits efficiency but may constitute a political barrier. Burtraw et al. (2013) state that linking emission trading systems may have political benefits because signals a common effort to reduce emissions.

Another disadvantage of the EU ETS pure-cap pathway under this international scenario is that EU climate policy could not focus on non-climate benefits of GHG emission reduction. When the EU ETS covers most emitters, including the transport and buildings sector (as proposed for this policy pathway), there is no room for sectoral discrimination. It would not be possible to reduce emissions in those sectors which deliver more non-climate benefits without affecting the performance of the EU ETS. Additional measures to reduce emissions in cities, for instance, will reduce allowance price, affecting the (dynamic) cost-effectiveness of the scheme.

In order to increase the feasibility of the EU ETS pure-cap pathway under this international scenario, the domain of application of the EU ETS could be limited to certain sectors. The EU ETS would cover those sectors exposed to the risk of carbon leakage and/or have similar ambition levels across countries. Although this will imply lower efficiency, it could increase political feasibility. Moreover, excluding the transport sector from the EU ETS, it would be possible to implement a relatively higher stringency level to this sector, and take advantage of the non-climate benefits due to emission reduction in this sector.

Summary:

- The EU ETS could be linked to compatible emission trading systems and, thus, reduce the risk of carbon leakage and improve the cost-effectiveness.

- A larger emission trading market could reduce the high volatility associated to a pure-cap system. Higher price predictability would make investment decision easier.
- Linking emission trading systems with different stringency levels is feasible, but may constitute a political barrier.
- It might not be desirable to expand the EU ETS and cover all sectors.
- The transport sector could face relatively a higher stringent regulation to take advantage of the non-climate benefits.

ETS price stabilized pathway

In this section we assess the performance of an ETS price stabilized pathway under a Middle-of-the-road scenario which is characterized by low international ambition to reduce GHG emissions but with international cooperation and harmonization of climate policy instruments.

International cooperation would allow the EU to link the EU ETS to similar trading systems. As mentioned above, there are plenty of advantages associated to linking emission trading systems. In terms of effectiveness, it would reduce the risk of carbon leakage through the competitive and investment channel. Besides, from the cost-effectiveness perspective, it would expand mitigation options and, thus, reduce the cost of meeting the emission reduction target.

The main challenge is to align the EU ETS with other emission trading systems in the presence of a price floor and ceiling. Stavins (2007) highlights the difficulties of linking two trading systems when there are cost containment measures. For instance, when the supply of allowances is restricted if the price falls below a price floor, linked programs would be affected as well (Burtraw et al., 2013). Recently, the UK has introduced a carbon price floor in the power sector which is already covered by the EU ETS (UK Parliament, 2013). This action will reduce the demand for EU allowances and, consequently, the carbon price, but it will not achieve further emission reductions. A unilateral price floor causes the effective marginal cost of emissions reductions to differ across participants, reducing the efficiency of the system (Burtraw et al. 2014). Therefore, the efficiency gains of linking emission trading systems may vanish in the presence of a price floor and ceiling. Given the different international ambitious levels, in the short-term it may be best to use the Kyoto Protocol's Clean Development Mechanism (CDM). As pointed out by Stavins (2007), savings potential is larger, given the low-cost emissions reduction opportunities in developing countries. Besides, the EU ETS could set a price floor and ceiling, without reducing the efficiency of the scheme.

Thus, an ETS price stabilized pathway would not take full advantage of potential international agreements. Without linking emission trading systems, energy-intensive and trade-exposed industries, which are covered by the EU ETS, may face a more stringent climate regulation than their competitors abroad. Hence, it should be necessary to implement anti-leakage measures such as the free allocation of allowances.

In contrast to the ETS pure-cap pathway, this pathway could implement additional measures to focus its efforts on non-climate benefits of GHG emission reduction. Additional measures will not affect allowances price, as this should be fluctuate between the carbon price floor and ceiling. The EU climate instrument mix could focus on the transport sector and minimize emission in cities with high population density. Subsidies for the deployment of zero emission cars could be implemented. The public sector should play an active role on the development of new infrastructure for a modal shift. In order to reduce the risk of carbon leakage through the price channel, CCS technology could be promoted by subsidies and public funds for R&D.

The difficulties in harmonizing the EU ETS with other emission trading systems would reduce the feasibility of this instrument package in this international context. There is a trade-off between stabilizing allowances price and linking the EU ETS with other trading systems. Given the low international ambition in reducing emission, EU climate policy should focus on the non-climate benefits of emission reduction. This could increase the public acceptability of emission reduction measures, even if the ambition in rest of the world is lower than in the EU.

Summary:

- Although the international context would facilitate international agreements, setting a price floor and ceiling, the EU ETS could not be aligned with other emission trading systems abroad.
- In the short-term, it may be best to use the CDM to reduce emissions abroad and increase the efficiency of the scheme.
- Setting a price floor and ceiling, additional measures could be implemented with no risk of making the EU ETS price irrelevant. Thus, climate measures could be focused on maximizing non-climate benefits of emission reductions.
- Non-climate benefits of emission reductions should be highlighted to increase the public acceptability of the instrument mix.

Emission tax pathway

In this section we assess the performance of an Emission tax pathway under a Middle-of-the-road scenario which is characterized by low international ambition to reduce GHG emissions but with international cooperation and harmonization of climate policy instruments.

As in previous policy pathways, the international context would facilitate international agreements to coordinate climate policy instruments. It is generally argued that an ETS is easier to link across borders than agree on a common tax (IPCC, 2014). This would imply that the EU ETS pathway may more desirable in this international scenario. Harmonization is advantageous since it gives flexibility in reducing emissions and thereby reduces costs. However, as argued above, international linkage of trading systems may lead to a loss of control over domestic design. Thus, the link of emission trading system may also present difficulties.

In this policy pathway driven by an emission tax, the EU could harmonize the carbon price with other countries. There could be a commitment to keep tax rates within some range (Metcalf, 2009). However, the different ambition levels between the EU and the rest of the world could make harmonization difficult. The EU would like to establish an emission tax higher than in the rest of world. One option could be to harmonize an emission tax only for those sectors exposed to international competitiveness and, thus, reduce the carbon leakage. This however would imply two different emission tax rates in the EU: a less stringent emission tax on energy-intensive and trade-exposed industries and a very ambitious tax rate on the rest of the sectors. Setting two different emission tax rates, the main benefits of an emission tax are vanished. From the administrative point of view, it would not be possible to set an upstream administration which covers all primary production and imports of fossils and fossil energy products. From the cost-effectiveness perspective, marginal abatement costs would differ across sectors, increasing mitigation cost.

In this international context, the EU could set a unique and less ambitious emission tax across all sectors. The tax rate should be harmonized with the rest of the world. There should be an international commitment to keep tax rates within some range. The harmonization of carbon prices would reduce the risk of carbon leakage through the competitive and investment channel. EU industries exposed to international competition would not face more stringent regulation than their competitors abroad. The EU should meet its more ambitious targets implementing additional measures. Energy-intensive and trade-exposed industries should be exempted from additional regulation. Additional measures should focus on those sectors in which emission reductions deliver non-climate benefits. An option would be reduce emissions from the transport sector. Decreasing oil consumption in the transport sector would deliver not only health benefits but also higher energy security due to lower dependence on fossil fuels. The instrument package should include subsidies to promote new technologies (e.g. electricity and hydrogen). The transition to low carbon transportation could be also incentivised with taxes on combustion motors. A shift to cycling and walking in cities should be a priority.

In contrast to the ETS pure-cap, adding instruments to an emission tax would not affect the price signal. Moreover, implementing additional measures, which take into account non-climate benefits, could increase the cost-effectiveness of the instrument mix. In order to keep the dynamic efficiency of the instrument package, public funding on R&D projects should compensate for the lower carbon price signal. These public funds would not be only focused on basic research but also on the development of clean technologies.

A cooperative international scenario should increase the feasibility of implementing an emission tax. Private companies would offer less resistance to an emission tax when their competitors abroad have similar regulation. Moreover, implementing additional measures such as subsidies and reducing the rate of the emission tax should increase the acceptability of this instrument.

Summary:

- The different ambition levels between the EU and the rest of the world could make emission tax harmonization difficult.

- The EU could set a less stringent emission tax, which would be in line with the rest of the world. This would reduce the risk of carbon leakage.
- Additional measures should be implemented to meet the more ambitious EU targets. These measures could be focused on enlarging non-climate benefits of emission reduction.
- A cooperative international scenario should increase the feasibility of implementing an emission tax.

3.3 Implications of the EU governance

The development of the EU governance is going to be crucial for climate instrumentation. Similarly to the international governance, the EU governance will affect the effectiveness and cost-effectiveness of the EU climate policy. In addition to these, the EU governance will be particularly important for the feasibility of the different instrument packages. As argued in the analysis below, the feasibility of some instrumentation pathways will depend largely on the centralisation or decentralisation of the EU climate policy.

There is no optimal balance between centralised and decentralised climate policies (Bausch et al., 2015). Both centralisation and decentralisation trends have advantages and disadvantages. Some policy pathways may perform better in a centralised scenario while others in a decentralised scenario. Hence, it is important to first identify the general implications of the EU governance in order to then evaluate properly the instrument packages.

Firstly, the EU governance will affect the environmental effectiveness of the instrument package, that is, the likelihood of meeting the necessary emission reductions. From the effectiveness perspective, the EU governance should deal with the risk of carbon leakage. Similarly to the arguments applied to the international scenarios, the decentralisation of the EU climate policy may lead to different stringency levels of national climate instruments. This would affect the relative costs of energy-intensive and trade-exposed industries across Member States, which could eventually lead to the reallocation of production factors. In addition to the risk of carbon leakage, free-riders can arise. In the absence of legally binding agreement, some Member States may not address the challenge of climate change. On the other hand, a strong centralisation may prevent the adoption of ambitious targets. There is usually a trade-off between convergence and ambition and, therefore, higher centralisation may be at the expense of laxer mitigation targets. For example, the EU ETS is a centralised instrument; however the EU and its Member States were not able to find a sufficiently ambitious solution to solve the problem of the surplus of allowances (Bausch et al., 2015). Moreover, strong centralisation may discourage front-runners which could facilitate meeting mitigation emission targets.

Secondly, the cost-effectiveness of the EU climate policy will be affected by the centralisation or decentralisation of EU governance. Several studies have analysed the economic consequences of coordinating climate instruments such as carbon taxes and the promotion of renewables. ECP (2013), for instance, analyses the benefits from siting renewable generation where the resource availability is highest. They find that a non-coordinated deployment of renewables could require 20% more investments in the period 2020-2030. An internal electricity market may also generate economic benefits given that it would increase competition, optimize transmission investment, interconnect national markets and allow increasing the capacity of renewables (Zachmann, 2013). In a study for the European Commission, Booz & Co. (2013) estimate that market integration would generate benefits of up to €30 billion per year for the EU27. The economic benefit would come from price effects and from increased security of supply. A common market for renewables, which locates renewable generation capacity in locations that are most effective for it, would generate extra gains in the range of €15 billion to €30 billion per year by 2030. The centralization of the EU climate policy may also have negative effects on the cost-effectiveness, particularly in the long-term. Bausch et al. (2015) state that too much harmonisation may increase the risk of losing room for learning and innovation, given that it could impede some Member States serve as policy laboratories.

Finally, as mentioned above, EU governance will be a key aspect for the feasibility of the instrument packages. Some instrument packages require a very specific framework and, therefore, their feasibility will depend on the EU governance. As mentioned in section 2.2, the EU governance will determine the structural reform of the EU ETS, the harmonisation of renewable support schemes, the Energy Union, etc. When some of these conditions are not met, the feasibility of some instrument packages would very low.

3.3.1 Climate instrumentation under a EU centralised scenario

Based on the analysis in section 2.2.2, there exist key aspects to consider when analysing the EU climate instrumentation under an EU centralised scenario:

- A centralized EU creates the institutional capacity to reform the EU ETS.
- An internal energy market is created.
- A European body is created for infrastructure planning and financing.
- The EU can set legally binding national targets

A centralised scenario increases the feasibility of most instrument packages; however it will also deal with important challenges. As mentioned above, higher convergence may lead to lower ambition. A centralised scenario would involve higher competences for the EU and a loss of sovereignty of Member States. The transfer of competence should not result in less ambitious climate instruments. In other words, there is a risk of adopting the smallest common denominator (Bausch et al., 2015).

The centralisation of the EU climate policy may increase the rigidity of the instruments. It could increase the bureaucracy and make policy processes less dynamic. This is an important challenge because given the huge uncertainty associated to the technological development, flexible mechanisms are necessary. The challenge is to create a flexible enough instrument package to react as new information emerges.

Too much centralisation can discourage national initiatives. In this scenario, an optimal instrument package should leave room for front-runners. Some Member States may want more ambitious emission reduction targets than those imposed at the EU level. They should have the freedom to implement additional measures and make them effective.

A centralised instrument package may not take into account national idiosyncrasies. While some measures perform very well in some countries, they might have a negative impact on others. This has consequences on the acceptability of climate instruments. In the long-term conflicts may arise between the EU and some Member States.

We have already enumerated some of the opportunities stemming from more EU centralisation: EU ETS reform, Energy Union, etc. The harmonization of renewable energy support schemes is another opportunity in this scenario. In recent years, the promotion of renewables has been driven by national instruments. The development of new electricity grid infrastructure with more interconnections would facilitate the expansion of renewables. Moreover, the centralisation of renewable support schemes would increase efficiency, locating renewable generation capacity in locations that are most effective for it.

R&D policy can also take advantage of a centralised scenario. The EU could facilitate cooperation and coordination of national research programmes. Moreover, the development of some technologies will require abundant investment, which may not be raised at national level. In a centralised scenario, a supranational body could finance projects for capital intensive technologies such as CCS.

Challenges:

- Higher convergence should not lead to lower ambition.
- Avoid bureaucracy to make instrument package more flexible.
- Allow front-runners implement additional and ambitious instruments.
- Adapt instrument package to national idiosyncrasies.

Opportunities:

- Harmonise national policy instruments such as taxes and renewables support schemes.
- Facilitate cooperation and coordination of R&D policies.

Technology-specific pathway

In this section we will assess the performance of a technology-specific pathway under an EU centralised scenario which is characterized by high centralisation of EU climate policy.

A priori, the design of this instrument package includes both EU instruments and national instruments (Huppes, 2015). However, the centralisation of the climate policy would lead to a greater weight of EU instruments. Emissions standards and subsidies would be designed and implemented at EU level. For instance, in order to promote renewables in the electricity sector, feed-in-premiums would be implemented at EU level. The Energy Union would facilitate the centralisation of the climate policy. Current standards on vehicles and buildings would be strengthened and a subsidy scheme designed at EU level would be implemented to promote low carbon technologies.

High stringency levels on emission standards should guarantee the environmental effectiveness of this policy pathway. In principle, the likelihood of meeting EU targets should be high. Nevertheless the absence of a price signal may lead to rebound effects. The EU centralisation would facilitate the control and verification of national emissions. There are binding national targets and the EU has the competence to monitor the compliance of this targets. Moreover, a common climate policy would avoid comparative disadvantages between countries due to laxer regulation in some Member States. On the other hand, a high centralisation of the climate policy may hinder national initiatives to reduce emissions. This may prevent front-runners implement additional and more ambitious instruments. Hence, EU instruments should be flexible enough to allow national initiatives. Emission standards, for instance, should set minimum requirements to enable tougher stringency levels. Similarly, EU subsidies should be coordinated with national initiatives to allow Member States to complement these subsidies with national funds.

The centralisation of those instruments in the promotion of renewables would have some positive economic consequences. Current national schemes would phase out and a unique EU-wide instrument (e.g. feed-in-premiums) would be implemented. Thus, renewable generation would take place where it is cheaper. Investors in solar panels, for instance, would be encouraged to place their production in South Europe where the resource availability is highest. This could generate gains between €15 billion to €30 billion per year by 2030 (Booz & Co., 2013). The centralisation of technology-specific instruments may also have negative economic impact. Too much centralisation may disincentives national initiatives which could work as laboratories to enhance innovation and learning potential (Bausch et al., 2015). As mention above, the EU could set minimum requirement which should be complemented with national measures. This could increase not only the effectiveness but also the efficiency of the instrument package.

In comparison with other instrument packages, a technology-specific pathway may increase the cost of mitigation in some sectors. The most common argument states that governments have limited information and its intervention can increase mitigation costs (Helm, 2010). An inappropriate design of energy standards, for instance, may not lead to find the cheapest ways of reducing emissions. This could particularly important in a centralised scenario, where climate instruments are implemented at EU level. While some subsidies and/or standards may be appropriate for a country, the same measure can have negative effects on others. There are, however, some positive economic impacts of technology-specific instruments. In the buildings and transport sector, there is evidence that energy efficiency policies (e.g. appliance standards and fuel economy standards) have negative private costs (IPCC, 2014).

Efficiency standards have been proved to be efficient in presence of information asymmetry and other market failures.

A technology-specific pathway requires high public intervention and public spending. Although this governance scenario assumes high EU centralisation, some Member States may be reluctant to increase the budget of the EU. This can be a disadvantage of a technology-specific pathway compared to a market-based pathway, where investment funds stem mainly from the private sector. Centralisation may also lead to higher bureaucracy, which reduces the capacity for modification as new information emerges.

Summary:

- More centralization should not hinder the implementation of this policy pathway.
- High stringency levels on emission standards should guarantee the environmental effectiveness of this policy pathway.
- In the absence of a price signal, the risk of rebound effects increases.
- EU instruments should be flexible enough to facilitate national initiatives. This could increase not only the effectiveness but also the efficiency of the instrument package.
- This policy pathway would require a considerable increase in the EU budget, which could face opposition from some Member States.
- Centralisation could increase bureaucracy and reduce the capacity for modification as new information emerges.

ETS pure-cap pathway

In this section we will assess the performance of an ETS pure-cap pathway under an EU centralised scenario which is characterized by high centralisation of EU climate policy.

This policy pathway is in line with current instrument mix. More centralisation would allow increasing the coverage of the EU ETS, including the transport and the buildings sector. The administrative implementation is moved upstream. The cap includes all primary production and imports of fossil fuels. The environmental effectiveness of this pathway would depend on the stringency level of the emission cap. According to Huppes (2015), a substantial increase in yearly emission reduction rate would be required. From 2030 emissions cap should be reduced by 8.5% per year, which would lead to very substantial price rises.

Expanding the coverage of the EU ETS, the cost-effectiveness of the scheme should increase. Marginal abatement costs would become equal across sectors and, thus, emission cuts would take place where it is cheapest. Apart from that, the EU ETS should face the same weaknesses shown in the first trading periods. One of the most important is the limited price predictability which makes long-term investment decisions very difficult. The price of allowances depends on several external factors such as the economic situation; an economic downturn as in 2008 could lead the carbon price to collapse. The expansion of the EU ETS should help to reduce volatility. As pointed out by Ranson and Stavins (2015), larger trading markets reduce volatility. However, substantial price fluctuations could remain. In order to promote investment in low carbon technologies, a higher carbon price should compensate for the higher uncertainty (Huppes, 2015). This could face high opposition from emitters.

The performance of an ETS pure-cap could be improved implementing additional climate instruments. This should be addressed carefully because the first trading periods of the EU ETS shown that the interactions with other climate instruments may affect the price signal. When other instruments performance is above expectations, the price of the EU ETS declines. In recent years the effectiveness of national policies in promoting renewable energy is a main cause of the low carbon price of the EU ETS (Point Carbon, 2013). Hence, when implementing additional instruments, the impact of other instruments on the EU ETS should be considered. An EU centralised scenario could facilitate the coordination between instruments. Most of the measures would be designed and implemented at the EU level, which would make coordination easier. These additional instruments should focus on reducing uncertainty for investors and overcoming market failures. An EU-wide feed-in-premiums scheme could be implemented in the electricity sector to make investment revenues in renewables more predictable. Subsidies and BAT specifications as an information instrument could help industry sector to deal with high uncertainty. In the buildings and the transport sector, energy sufficiency standards would complement the EU ETS, as it has been proved that they reduce information asymmetries and other market failures (IPCC, 2014).

As argued above, too much centralisation discourages front-runners and national initiatives which could improve efficiency in the long-term. However, uncoordinated national measures may affect the functioning of the EU ETS. Thus, this pathway may face a trade-off between the benefits of national initiatives and a proper functioning of the EU ETS. Given the poor performance of the EU ETS in recent years, it seems more appropriate to limit national initiatives. Additional measures could be implemented when they are designed at EU at level and their impact on the EU ETS is assessed.

The proposed instrument package is not very different from the existing package and, therefore, its feasibility should be high. This pathway implies a loss of national sovereignty but, given that we assume the centralisation of the EU governance, this should not be an obstacle. To be effective, emission cap should be reduced considerably, which could be rejected by emitters and reduce its social feasibility. Additional instruments may help to reduce the carbon price.

Summary:

- Expanding the coverage of the EU ETS, the cost-effectiveness of the scheme should increase.
- The EU ETS should face the same weaknesses shown in the first trading periods.
- This pathway may face a trade-off between the benefits of national initiatives and a proper functioning of the EU ETS.
- Additional measures could be implemented when they are designed at EU at level and their impact on the EU ETS is assessed.

- The proposed instrument package is not very different from the current one and, therefore, its feasibility should be high.

ETS price stabilized pathway

In this section we assess the performance of an ETS price stabilized pathway under an EU centralised scenario which is characterized by high centralisation of EU climate policy.

The centralisation of the EU climate policy would allow a structural reform of the EU ETS. In this pathway, a price floor and ceiling would be set, so that, the cap volume would be adjusted to keep the carbon price of the EU ETS between these two values. The coverage of the EU ETS is expanded to include the transport and the buildings sector. The administrative implementation is moved upstream. The cap includes all primary production and imports of fossil fuels. The environmental effectiveness of this pathway would depend on the stringency level of the emission cap. According to Huppes (2015), in order to achieve the same emission cuts, the carbon price would be lower than that in an ETS pure-cap scheme, given the higher predictability of the carbon price.

Although setting a floor and a ceiling may alter the nature of the current EU ETS (i.e. a quantity-based market instrument), there are several arguments in the literature in favour for having a price management mechanism. Price floors may have advantages for technological innovation, price volatility and management of cost uncertainty (Wood and Jotzo, 2011). In recent years, the EU ETS has been characterized for delivering low carbon prices. Knopf and Edenhofer (2014) argue that the EU ETS has not incentivised optimally mitigation efforts and innovation over time. According to them, the problem is the low credibility of the long-term scarcity. A price stabilization mechanism would deliver a stable and sufficiently high carbon price, which could improve the dynamic efficiency of the EU ETS. In a quantitative analysis, Philibert (2009) confirms that price floors and ceiling can reduce uncertainty caused by unpredictable economic growth and energy prices. As a consequence, a price stabilization mechanism improves welfare and the performance of an emission trading system (Burtrow et al. 2009). But not only the effectiveness and the efficiency would increase but also the political feasibility (Knopf and Edenhofer, 2014). A price ceiling would prevent unsustainable economic costs, raising the acceptance by private companies.

One of the challenges in this governance scenario is to take into account national interests in a centralised framework. Unlike an ETS pure-cap, this pathway could make the EU ETS compatible with national initiatives, without affecting the price signal. Even if the EU ETS would cover most of the emissions, adding other instruments may improve the performance of the instrument package. A stable price pathway should make private investment decisions easier and, therefore, additional measures should focus on overcoming market failures, particularly for households. Information asymmetries could be alleviated with energy efficiency standards in the transport and the buildings sector. Member States should have the possibility to set more stringent standard levels and/or include other measures which mean additional emission cuts.

As argued above, a stabilized carbon price path may increase the acceptability of the climate instrument mix by private companies. Higher predictability would facilitate their investment decisions. Besides, a price ceiling would prevent unbearable economic costs. The main weakness could be the administrative feasibility. A well-functioning EU ETS may require huge and complex administrative task. Too much bureaucracy may reduce the flexibility of the instrument package and reduce the capacity for modification as new information emerges.

Summary:

- The centralisation of the EU climate policy would allow a structural reform of the EU ETS, setting a price floor and ceiling.
- Price floors may have advantages for technological innovation, price volatility and management of cost uncertainty.
- Not only the effectiveness and the efficiency would increase but also the political feasibility.
- Unlike an ETS pure-cap, this pathway could make the EU ETS compatible with national initiatives, without affecting the price signal.
- A well-functioning EU ETS may require huge and complex administrative task.

Emission tax pathway

In this section we assess the performance of an emission tax pathway under an EU centralised scenario which is characterized by high centralisation of EU climate policy.

In this pathway, there is a structural reform of the EU ETS, which is facilitated by the centralisation of the EU climate policy. Initially a price stabilization mechanism is introduced to fix the allowance price between a floor and a ceiling. The EU ETS would eventually evolve into an emission tax. The price path set by the emission tax would rise linearly, and could reach €400 per tonne in 2050. According to Huppes (2015), the higher long term predictability of an emission tax would reduce the carbon price level compared to the price path set by the EU ETS. In addition to an emission tax, this pathway requires the development of a single European electricity market. Electricity will become more central in primary energy production and throughout the use chain.

The effectiveness of the instrument mix will depend on the stringency level of the emission tax rate. This pathway does not consider implementing technology-specific instruments. Thus, emission reduction would be driven by the emission tax. In presence of market failures or barriers, a single emission tax may not lead to the expected emission reduction. Information asymmetry, for instance, may result in underinvestment in energy efficiency (Gillingham et al., 2009). Goulder and Parry (2008) also point out that consumers may underestimate future gains from purchasing more energy efficient automobiles and appliances. Due to the principal-agent problem, Murtishaw and Sathaye (2006) find that energy use is above the social optimum. All this cases show that a single emission tax may not be as effective in reducing emissions as theoretical models predict.

Not only the environmental effectiveness but also the cost-effectiveness could be negatively affected by market failures. The cost of reducing emissions is minimized equating marginal abatement costs across sectors and emitters. In principle, this is achieved when all emitters face a common price, for example, through an emission tax. Hence, in presence of rational consumers, firms, and complete markets, tax emissions are generally considered the most cost-effective way of reducing emissions (IPCC, 2014). In reality, there are market failures and barriers which reduce the efficiency of emission taxes. Energy efficiency measures, for instance, are generally considered as the most cost-effective ones. However, the level of investment on these measures is below the levels which would correspond to such benefits (Linares and Labandeira, 2010). In this context, the interaction of emission taxes with other instruments may be beneficial for reducing mitigation costs. The combination of an emission tax and an energy efficiency standard may overcome the market failure associated with consumer purchases of more energy efficient durables (e.g. vehicles and appliances) and, thus, promote cost-effectiveness (IPCC, 2014). Dynamic efficiency could also be improved addressing the innovation market failure[15]. Combining an emission tax and R&D subsidies can promote innovation of low-carbon technologies (IPCC, 2014), which would reduce mitigation costs in the future.

From the feasibility perspective, administrative costs are reduced given that they are moved upstream. The emission tax covers all primary production and imports of fossil fuels. The administrative implementation is at member state level and existing revenue collection systems could be used. New administrative machinery would not be required. Compared to an emission trading system, an emission tax may meet more opposition from industry (IPCC, 2014). Besides, the 1990s attempt to establish an emission tax at EU level shows the difficulties of implementing. However, in this governance scenario with high centralisation, the political feasibility of implementing an emission tax should be high.

Summary:

- The EU ETS would eventually evolve into an emission tax. Given the higher predictability, the price path of an emission tax would be lower than that in the EU ETS.
- The effectiveness of the instrument mix will depend on the stringency level of the emission tax rate. However, in presence of market failures, a single emission tax may not lead to the expected emission reduction.
- Market failures and barriers could also affect the static and dynamic efficiency of an emission tax. The implementation of additional measures should be considered.
- The centralisation of the EU climate policy should facilitate the administrative and political feasibility of the policy pathway.

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[15] When innovators cannot capture all social benefits from their new clean technologies, the level of investment in innovation might be below the optimum.

3.3.2 Climate instrumentation under a EU decentralised scenario

Based on the analysis in section 2.2.3, there exist key aspects to consider when analysing the EU climate instrumentation under an EU decentralised scenario:

- National interests dominate the development of the EU ETS, which cannot be reformed.
- There are no major changes from current energy market which is ruled at national level.
- Infrastructures and main investment projects are planned and financed at national level.
- The EU cannot set binding technology standards.
- There are not specific targets for Member States.

In the absence of a centralised authority, climate policy is stablished at national level. This scenario presents many challenges for the feasibility of instrument packages. Most of the initiatives are implemented without a formal status in European law and the main challenge for the EU would be the coordination of national instruments. Both market-based instruments and technology support measures are implemented at national level. Thus, the EU can establish the mechanism to facilitate agreements on coordination between national pricing systems. Technology standards could be implemented but for guidance only.

Uncoordinated national policies may increase the risk of carbon leakage between Member States. The EU would face the challenge of keeping the EU single market without affecting the effectiveness of national climate policies. The coordination of those instruments affecting energy-intensive and trade-exposed industries would be essential for the effectiveness of the climate policy.

In this scenario, the regulatory framework is more uncertain given that national government have the competence to implement climate instruments. Political change in a country can lead to amend existing climate regulation and loss of credibility.

A decentralised scenario also presents some opportunities. Instruments are designed at national level which allows policy-makers to adapt them to national circumstances. More local regulation can increase the acceptability of the instrument package. This could also facilitate the implantation of more ambitious targets.

Decentralisation will also increase the variety of instruments. There will be different mitigation schemes across countries. This can serve to learn from good practices. Thus, successful national initiatives can be emulated in other countries.

Challenges:

- Coordinate national climate instruments.
- Keep the EU single market without affecting the effectiveness of national climate policies

- Policy uncertainty and regulatory instability. National policies tend to be more unstable because of government changes.

Opportunities:

- Climate instruments could be adapted to national circumstances.
- Higher acceptability may allow for more ambitious targets.
- Successful national initiatives can be emulated in other countries.

Technology-specific pathway

In this section we assess the performance of a technology-specific pathway under an EU decentralised scenario which is characterized by high decentralisation of EU climate policy.

The basis of this policy pathway is on national climate instruments and thereby the decentralisation of the EU governance should not be a problem for its feasibility. The role play by market-based instruments is irrelevant and emissions reduction is driven by technology-specific instruments. The higher decentralisation and the predominance of technology-specific instruments would hasten the phase out of the EU ETS. The development of an Energy Union would not be possible and, therefore, there are no major changes from current energy market. Each Member State would have its own regulatory framework and the energy mix would be determined at national level.

In the absence of binding emission reduction targets, the environmental effectiveness of this policy pathway would depend on the national efforts to reduce emissions. The role of the EU would focus on coordinating national policies and recommending effective pathways in emission reduction. An emission standards system is proposed by the EU to cover all sectors. Member States would be free to implement emission standards and set the stringency level. The EU should harmonise emission standards in some sector, particularly energy-intensive and trade-exposed industries, to avoid comparative disadvantages between Member States. Otherwise, the different regulations between Member States may lead some companies to move production capacities to those countries with laxer regulation (i.e. carbon leakage).

This governance scenario allows Member States to implement their own instruments. Thus, more ambitious countries could serve as role models for the rest of the countries. The EU should facilitate a forum to share national practices. The most successful measures could be imitated by other countries. This could encourage investment and innovation in low carbon technologies. On the other hand, in a fragmented EU the risk of free riders is very high. In the absence of binding targets, some Member States may not address the challenge of climate change. They could implement measures with very lax stringency levels. In general, Member States could be focused on maximizing non-climate benefits of emission reductions. This would eventually reduce the effectiveness in mitigation actions.

In a decentralised scenario, the coordination of national climate policies would be important to promote cost-effectiveness. Even if there is not an Energy Union, bilateral agreements to connect national electricity market may reduce mitigation costs. In order to deal with the intermittency in most renewables, the role of the EU could be focused on reducing barriers to international trade in electricity. National instruments in the promotion of renewables would be benefited from EU coordination.

The decentralisation of the climate policy could help to increase its acceptability by the general public. Climate instruments would be more flexible to take into account national characteristics. The design of instruments would be made according to national circumstances. In contrast to market-based pathways, the political and administrative feasibility of this policy pathway should not be reduced by the decentralisation of the climate policy.

Summary:

- The higher EU decentralisation and the predominance of technology-specific instruments would hasten the phase out of the EU ETS.
- The EU should facilitate a forum to share national practices. The most successful measures could be imitated by other countries.
- The EU should harmonise emission standards in energy-intensive and trade-exposed industries to avoid comparative disadvantages between Member States.
- In contrast to market-based pathways, the political and administrative feasibility of this policy pathway should not be reduced by the decentralisation of the climate policy.
- In order to deal with the intermittency in most renewables, the role of the EU could be focused on reducing barriers to international trade in electricity.

ETS pure-cap pathway

In this section we assess the performance of an ETS pure-cap pathway under an EU decentralised scenario which is characterized by high decentralisation of EU climate policy.

In a decentralised scenario, it looks unrealistic that the EU ETS could play a leading role. When a stringent cap is set to keep high the price of allowances, national measures would lose their influence. It makes no sense to implement national measures because their environmental effectiveness would be very limited. On the other hand, when national instruments are successful, they would reduce the price of allowances and make the EU ETS irrelevant. Thus, without a centralised coordination, the combination of a pure cap scheme and national instruments would be ineffective.

A structural reform of the EU ETS would be very unlikely. It would not be possible to include other sectors or make the emission cap level more stringent. In this governance scenario the EU ETS could remain to keep an emission reduction track, but it would be irrelevant. Emission reduction would be driven by national instruments. A carbon price floor, such as the one introduced by the UK in the power sector (UK Parliament, 2013), could be implemented to keep the price signal of the EU ETS meaningful. However, these initiatives would be promoted at national level.

Summary:

- Without a centralised coordination, the combination of a pure cap scheme and national instruments would be ineffective.
- The EU ETS could remain to keep an emission reduction track, but it would be irrelevant.
- Member States could introduce a carbon price floor to maintain the price signal of the EU ETS meaningful.

ETS price stabilized pathway

This policy pathway would be infeasible in a decentralised scenario.

Emission tax pathway

This policy pathway would be infeasible in a decentralised scenario.

Table 3 Key results for each supranational governance scenario

		International Governance		EU Governance	
		Non-Global-deal scenario	Middle-of-the-road scenario	EU centralized scenario	EU decentralized scenario
Features		• The degree of global ambition is high. • There are not binding international agreements and convergence is low. High international uncertainty. • High risk of carbon leakage, through the competitiveness and the investment channel. • The higher demand of low carbon technologies would create business opportunities for many industries.	• The degree of global ambition is low. • The compliance of the targets is guaranteed by binding agreements. • Climate instruments are harmonized across borders. • Risk of carbon leakage through the price channel. • Low feasibility of ambitious climate instruments because of the laxer regulation abroad.	• Institutional capacity to reform the EU ETS. • An internal energy market is created. • Infrastructure are planned and financed at the EU level. • The EU can set legally binding national targets.	• The EU ETS cannot be reformed. • Energy markets are ruled at national level. • Infrastructures are planned and financed at national level. • The EU cannot set binding technology standards, it should limited to recommendations. • There are not specific targets for Member States.
Policy Pathways	Technology-specific	• Inappropriate stringency levels may reduce the EU competitiveness. • Additional anti-leakage measures such as exemptions are required. • The risk caused of picking up winners may lead to high economic costs. • A stable regulatory framework may encourage low-carbon investment. • The lack of a price signal may reduce the feasibility	• With technology-specific instruments, international harmonization may be more difficult. • The promotion of CCS technology could reduce the risk of carbon leakage through the price channel. • Technology regulation should focus on the transport sector to increase the non-climate benefits of emissions reduction.	• High stringency levels on emission standards should guarantee the environmental effectiveness. • EU instruments should be flexible enough to facilitate national initiatives. • Technology-specific instrument and higher centralisation could increase bureaucracy and reduce the capacity for modification as new information emerges.	• Higher nationalization and the predominance of technology-specific instruments would hasten the phase out of the EU ETS. • The EU should harmonise emission standards to avoid comparative disadvantages between Member States. • The EU should facilitate a forum to share national practices. • The EU could reduce barriers to link national electricity markets.
	ETS pure-cap	• The risk of carbon leakage is very high; free allocation of allowances should be implemented.	• The EU ETS could be linked to compatible emission trading systems and, thus, reduce the risk	• Expanding the EU ETS the cost-effectiveness should increase. • Technology-specific measure may	• The combination of a pure cap scheme and national instruments would be ineffective.

		• The high uncertainty could discourage investment and reduce the cost-effectiveness. • Additional technology-support instruments could improve the performance of the instrument package. • Complementing the EU ETS with additional instruments could increase the acceptability.	of carbon leakage. • A larger emission trading market could reduce the high volatility associated to a pure-cap system. • It might not be desirable to expand the EU ETS and cover all sectors. • The transport sector could face relatively a higher stringent regulation to take advantage of the non-climate benefits.	be required to encourage investment. • Additional measures could be implemented when they are designed at EU at level and their impact on the EU ETS is assessed. • The instrument package is not very different from the current one and, therefore, its feasibility should be high.	• The EU ETS could remain to keep an emission reduction track, but it would be irrelevant. • Member States could introduce a carbon price floor to maintain the price signal of the EU ETS meaningful.
	ETS price stabilized	• The risk of carbon leakage would be reduced with predictable carbon prices. • Lower uncertainty would increase the dynamic efficiency of the EU ETS. • The EU ETS would be compatible with technology-support instruments, which could incentivize innovation and increase the international competitiveness of EU industries. • The political feasibility is limited.	• A price collar may be incompatible with linking the EU ETS to other trading systems abroad. • It may be best to use the CDM to reduce emissions abroad and increase the efficiency of the scheme. • Additional measures could be implemented to maximize non-climate benefits of emission reductions.	• The centralisation of the EU climate policy would allow setting a price collar. • With a price collar, not only the effectiveness and the efficiency would increase but also the political feasibility. • The EU ETS would be compatible with national initiatives, without affecting the price signal. • A well-functioning EU ETS may require huge and complex administrative task.	• This policy pathway would be infeasible in a decentralised scenario.
	Emission tax	• Predictable carbon price would reduce the risk of carbon leakage. • Although the feasibility is low, a border carbon adjustment would be beneficial to reduce the risk of carbon leakage. • Public subsidies on low-carbon technologies may convenient. • The political feasibility of emission tax is very limited.	• The different ambition levels between the EU and the rest of the world could make emission tax harmonization difficult. • The international harmonization should focus on some sectors. • Additional measures should be implemented to meet the more ambitious EU targets and maximize non-climate benefits.	• The higher predictability of an emission tax would reduce the carbon price level. • In presence of market failures, a single emission tax may not lead to the expected emission reduction. • The implementation of additional measures should be considered to increase the efficiency and feasibility	• This policy pathway would be infeasible in a decentralised scenario.

4 Conclusions

The aim of this document is to investigate different options for EU climate policy in four supranational governance scenarios. We analyse climate instrumentation in two international governance scenarios:

i. No-global-deal scenario, which assumes very ambitious international commitments but without legally binding agreements and a low degree of convergence and harmonization of climate instruments, and
ii. A middle-of-the-road scenario, which assumes a high degree of policy convergence but a lack of ambition in emission reduction.

We also analyse climate instrumentation in two EU governance scenarios:

i. An EU centralised scenario, which assumes most of the climate decisions are established at the EU level and, therefore, where there is a centralisation of EU governance structure, and
ii. An EU decentralised scenario, which assumes a re-nationalisation of climate policy and thereby climate instruments that are designed and implemented at national level.

These are the key results of the report:

Non-global-deal scenario

- In a non-global-deal scenario, carbon leakage remains as a big challenge for EU climate policy. The lack of international coordination and harmonization of climate instruments may create divergences between countries.
- A technology-specific pathway may not be superior to market-based pathways in order to avoid carbon leakage. Inappropriate stringency levels of standards may reduce the EU competitiveness. The volatility and uncertainty associated to a pure cap ETS system is also an obstacle to reduce carbon leakage.
- Regardless of the policy pathway, additional anti-leakage measures should be implemented in the energy-intensive and trade-exposed industries. The free allocation of allowances is the most effective and feasible option to avoid carbon leakage in those sectors covered by the EU ETS. Exemptions could be applied to those sectors subject to standards. When an emission tax is implemented, border carbon adjustment is the best option, but its feasibility may be low.
- In presence of market failures (e.g. principal agent problem), market-based pathways could be benefited from technology-specific instruments, which could promote investment and innovation in low carbon technologies. This is particularly important

in the ETS pure-cap pathway, where the price signal may be very uncertain and volatile.

- A price stabilization reform of the EU ETS would decrease price uncertainty. Moreover, the reform would allow implementing additional instruments without affecting the price signal. However, a price collar is outside the structural reform proposed by the European Commission and its political feasibility may be low. Likewise, an emission tax could also face feasibility problems.

Middle-the-road scenario

- The low international ambition may reduce the political feasibility of EU climate policy. In this international context, EU climate policy should focus on maximizing non-climate benefits of emissions reduction.
- The static efficiency of market-based pathways is generally high because marginal abatement cost is equal across sectors and emitters. However, emission price may not internalise non-climate benefits. Emissions are reduced regardless of the co-benefits. Hence, a technology-specific pathway may be superior to market-based pathways in this international context. Market-based pathways could be improved adding technologic-specific instruments to those sectors which can deliver high non-climate benefits.
- Although International coordination offers the opportunity to harmonize climate instruments across borders, some pathways may have difficulties to take advantage of this international context. For instance, there is a trade-off between stabilizing allowances price and linking the EU ETS with other trading systems.
- Regardless of the specific policy pathway taken, non-climate benefits of emission reductions should be highlighted to increase the public acceptability of instrument mixes.

EU centralised scenario

- This scenario would increase the political feasibility of all pathways. The centralisation of the EU climate policy would allow a structural reform of the EU ETS and expand the coverage of the EU ETS, including the transport and the buildings sector.
- The effectiveness of the instrument packages will depend on the stringency levels. However, in the absence of a price signal, a technology-specific pathway may subject to rebound effects. Likewise, market failures (e.g. principal agent problem) may reduce the effectiveness of market-based pathways.
- A price stabilization reform may be beneficial to reduce price uncertainty and encourage investment and innovation in those sectors covered by the EU ETS. Besides, the EU ETS could compatible with national initiatives, without affecting the price signal. Although this scenario assumes a centralisation of climate policy, national

and/or sub-national measures could be useful to take into account national idiosyncrasies. Moreover, they could encourage front-runners and increase the feasibility of the instrument package.

- In a technology-specific pathway, higher centralisation could increase bureaucracy and reduce the capacity for modification as new information emerges.

EU decentralised scenario

- This scenario would limit the number of pathways that the EU climate policy could take. The most feasible pathway would be the technologic-specific pathway.
- The role of the EU would focus on coordinating national policies and recommending effective pathways in emission reduction. The EU should harmonise emission standards in some sector, particularly energy-intensive and trade-exposed industries, to avoid comparative disadvantages between Member States.
- In order to deal with the intermittency in most renewables, the role of the EU could be focused on reducing barriers to link national electricity markets.
- In a decentralised scenario, it looks unrealistic that the EU ETS could play a leading role. The EU ETS could remain to keep an emission reduction track. Member States could introduce a carbon price floor to maintain the price signal meaningful.
- A price stabilization reform and emission tax pathway would require a high centralisation of EU climate policy and, therefore, they are infeasible in this scenario.

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Annex

Challenge 1

Establish a Meaningful Carbon Price in the Short, Medium and Long Term

Gjalt Huppes & Paul Drummond

Challenge 2:

Tackle the Energy Consumption and Climate Emissions of the Housing Stock

Philippe Quirion

Challenge 3

Non-CO_2 Emissions, particularly from Agriculture

Onno Kuik & Agni Kalfagianni

Challenge 4

Make Sound Infrastructure Choices despite Technological Uncertainty

Paul Drummond

Challenge 5

Electricity market reform and EU-wide integration of energy markets

Katharina Umpfenbach, with contribution Gjalt Huppes)

Challenge 6

Provide finance and mobilise the investments necessary for a low-carbon economy

Massimiliano Mazzanti

Challenge 7

Stimulate Innovation in Industry

Bernd Meyer, with contributions from Massimiliano Mazzanti and Philippe Quirion

Challenge 8

Transport and Mobility

Gjalt Huppes

Challenge 9

Low-Carbon Lifestyles

Gjalt Huppes