FORMULATION OF SECTORAL STUDIES
(ELECTRICITY, FUEL, INDUSTRY AND AGRICULTURE)
AND PROPOSITION OF DESIGN OPTIONS FOR CARBON PRICING INSTRUMENTS

COMPONENT 1 OF THE PMR IMPLEMENTATION PHASE

INTERNATIONAL EXPERIENCE OF CARBON PRICING IN THE FUEL SECTOR

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INTERNATIONAL EXPERIENCE OF CARBON PRICING IN THE FUEL SECTOR

This report presents **International Experience regarding Carbon Pricing and the Fuel Sector** prepared by Ricardo Energy & Environment and Vivid Economics for the Ministry of Finance under Brazil's PMR Programme.

The international experience has been aggregated in this ***Carbon Pricing in the Fuel Sector*** report, focusing on analysing the policy interactions between carbon pricing and fuel sector policies for the following four themes:

1. **Interaction of Fuel Price Policy and Carbon Taxes**
2. **Interaction of Fuel Pricing Policy with Emission Trading Schemes**
3. **Carbon pricing and biofuel policies**
4. **Reducing GHG emissions from in road transport in Brazil**

Themes 1-3 were prepared according to a common analytical framework, and have a cross-jurisdictional approach, drawing on international experience from multiple jurisdictions of relevance for Brazil. They begin by describing why this theme is of interest to Brazil, by referring to the Brazilian Context. Following this, the policy landscape of the case study jurisdictions is prepared.

The policy interaction analysis focuses on expected interactions between the carbon pricing instruments (CPI) and underlying fuel sector policies. Subsequently, the corrections to policies made by governments as a result of expected interactions are presented.

Following this, the actual impacts of the introduction of the CPI are presented. Impacts include the impacts on the effectiveness of the CPI, impacts on the effectiveness of the underlying policy, and distributional impacts on stakeholders such as households and industries. Finally, the lessons learnt and key implications for Brazil are presented.

Theme 4 has a different structure, as it is a broader study of the possible role of carbon pricing in the road transport sector. Apart from policy interactions, this also covers the feasibility constraints of such instruments and alternative carbon pricing instruments for the sector.

EXECUTIVE SUMMARY: INTERNATIONAL EXPERIENCE OF CARBON PRICING IN THE FUEL SECTOR

For each of the four themes, this executive summary presents an overview of the cases studied as well as the lessons learnt from this international experience, before presenting some of the key implications for Brazil.

THEMES 1 AND 2: INTERACTION OF FUEL PRICE POLICY AND CARBON PRICING INSTRUMENTS

This section summarises the key points of themes 1 and 2, which studied the interaction between fuel price policy and carbon taxes and ETS.

THEME 1: INTERACTION OF FUEL PRICE POLICY AND CARBON TAXES

Table 1 provides an overview of the jurisdictions and the chosen, the CPI adopted, the interaction studied, and key impacts of these policies.

Table 1 – Overview of Theme 1: Interaction of Fuel Price Policy and Carbon Taxes

Country	Mexico	Ireland	Canada British Columbia
CPI	Tax	Tax	Tax
Start Year	2014	2010	2008
Current Rate[1]	US$2.50/$tCO_2e$	US$25.88/$tCO_2e$	US$21.61/$tCO_2e$
Interaction of focus	Liberalisation of fuel sector	Support for low income groups	Support for low income groups
Implementation Agency	Tax Administration Service (SAT)	Office of Revenue Commissioners	Ministry of Finance
How Implemented	– Planned rate reduced due to potential impact on competitiveness and inflation	– Tax phased to allow population to adjust	– Tax made revenue neutral due to business and distributional

[1] Partnership for Market Readiness (PMR) (2017), Carbon Tax Guide: A Handbook for Policy Makers. Appendix: Carbon Tax Case Studies, World Bank, Washington. Available at: https://openknowledge.worldbank.org/bitstream/handle/10986/26300/Carbon%20Tax%20Guide%20-%20Appendix%20web%20FINAL.pdf?sequence=7&isAllowed=y)

	– Natural gas used as baseline to support domestic gas industry		concerns
CPI Impacts	– 1.5m tCO_2e reduction – Revenues below expectations	– Decrease in use of carbon intense fuels – Significant increases in revenue	– Emission reductions between 5-15%
Other Impacts	– Removal of price stabilisation outweighs tax impact resulting in protests	– National Fuel Allowance (fuel subsidy) take up increased	– Revenue neutrality mitigated distributional impacts

Source: Ricardo Energy & Environment.

LESSONS LEARNT INTERACTION OF FUEL PRICE POLICY AND CARBON TAX

Some jurisdictions took advantage of wider energy market reforms to introduce the carbon tax. In particular, the removal of fuel price stabilisation policies may be a necessary precondition for an effective carbon price signal. Mexico introduced the carbon tax within the context of wide ranging reforms of energy markets. There were several elements to this reform, including the liberalisation of oil and gas markets so others could compete with Pemex, and changes to floating excise taxes which were designed to stabilise fuel prices, toward a fixed rate. In particular the removal of the price stabilisation policy is a necessary pre-condition for the introduction of a carbon tax, since otherwise the price signal may not be passed through to final consumers.

However, in some cases the price impact of these reforms (such as removing price stabilisation) may dwarf the impact of the carbon price. The removal of the price stabilisation in Mexico contributed to a sharp increase in fuel prices, which appear to dominate those which occurred as a result of the carbon tax. The fuel price increases were very unpopular and resulted in protests. Sudden price changes are therefore met with hostility by the public used to subsidised fuel. Therefore, any shifts from offering fuel subsidies to a regime which taxes fuel consumption should be implemented gradually to let consumers and especially those most exposed to any change adjust to the new price level.

In designing the tax, a number of concessions may be necessary due to inflationary pressure and industrial competitiveness. In Mexico, concerns about the fuel price increase after the tax introduction, potential impact on general inflation levels and competitiveness of Mexican firms resulted in the carbon tax rate set at a limit of 3% of the price of the fuel. As part of a wider strategy to foster the natural gas industry, natural gas was determined as the reference fuel (the baseline) against which the carbon content of all other fuels was compared. Similarly, in B.C. despite the public support for the tax a number of concessions were made to industry. Originally, no exemptions were provided for specific industries, but in 2012 greenhouse growers were allowed an exemption from the carbon tax in response to competitiveness concerns. This was extended in 2013, and in 2014 all fuels used in agriculture were exempt from the carbon tax (Murray & Rivers, 2015). In Ireland, the carbon tax was implemented in phases to let industry and households adapt to the change. Jurisdictions have addressed distributional impacts on low income groups in a number of ways, including using revenue neutral tax policies and tax credits / allowances. Ireland conducted various studies prior to the introduction of the carbon tax to determine expected impacts on low income groups, and provided further assistance to these through a fuel allowance. Similarly, B.C. introduced a tax credit scheme aimed at low income households alongside the carbon tax. Further, the B.C. carbon tax was set up as a revenue neutral policy tool, meaning that every dollar collected as part of the tax is returned to the society through reductions elsewhere in the tax system. Earmarking carbon tax revenues to offset to the carbon tax can support low income populations and make the tax politically acceptable.

Theme 2: Interaction of Fuel Price Policy and ETS

Table 2 provides an overview of the jurisdictions chosen, the CPI adopted, the interaction studied, and key impacts of these policies.

Table 2 - Overview of Theme 2: Interaction of Fuel Price Policy and ETS

Country	UK Industrial Sector	UK Electricity Generation Sector
CPI	UK ETS and EU ETS	UK ETS and EU ETS
Start Year	2002 and 2005	2002 and 2005
Current Rate[2]	€4.93/ tCO_{2e}	€4.93/ $tCO_{2}e$
Interaction of focus	Fossil fuel pricing policy: Climate Change Levy (CCL) and Climate Change Agreements (CCA), introduced 2001	Fossil fuel pricing policy: Carbon Price Support, created carbon price floor for the EU ETS introduced 2013
Implementation Agency	UK ETS: Department for Environment, Food and Rural Affairs EU ETS: The European Commission – Directorate General Clima	
How Implemented	UK ETS • Government held incentive auction offering up to £300m for emission reduction projects EU ETS – Reset the ETS cap for each phase based on expected renewable energy generation from domestic policies – Excluding traded sectors that have obligations beyond ETS obligations	

[2] Partnership for Market Readiness (PMR) (2017), Carbon Tax Guide: A Handbook for Policy Makers. Appendix: Carbon Tax Case Studies, World Bank, Washington. Available at: https://openknowledge.worldbank.org/bitstream/handle/10986/26300/Carbon%20Tax%20Guide%20-%20Appendix%20web%20FINAL.pdf?sequence=7&isAllowed=y)

	– Design of market stability reserve that can release and absorb permits
CPI Impacts	• 1.6MTCO_2e emission reductions in the UK between 2005-2010, as a result of EU ETS sales, electricity price effects, and allowance cutbacks[3]
Other Impacts	– Electricity prices of the household sector have risen by 61% between 2004 and 2016, with 25 percentage points due to the impact of climate policies.[4] – Low-carbon policies have increased energy prices, and hence costs, but have only a limited impact on the total costs of production for the majority of businesses. A study suggests that the costs for businesses associated with low-carbon policies are expected to rise to about 0.5% of operating costs for the commercial sector, 1.0% for manufacturing and 1.6% for energy-intensive sectors by 2030

Source: Ricardo Energy & Environment.

LESSONS LEARNT: INTERACTION OF FUEL PRICE POLICY AND ETS

INDUSTRIAL SECTOR

The introduction of the EU ETS on top of the existing UK policy scenario (CCL/CCA) was expected to overlap since both impose GHG and energy efficiency targets on the same participants and energy vectors (fuels combusted and electricity consumed). However, despite this overlap, these policies may have not identical and complementary objectives. As such, there is certain rationale to have overlapping policies, however, this results in increased administrative complexity and regulatory burden for the obligated entities and, consequently, increased costs for the final energy consumers.

Policy makers should seek to design the two instruments to try to minimise the regulatory burden and unnecessary double regulation on industrial operators. If direct incentives for energy efficiency are provided through levies on fuel and electricity consumption at the industrial level, it should be recognised that an ETS would similarly impose a direct incentive to reduce fuel combustion. Following the experience of the UK government, it may be necessary to reduce the created burden on industries, for example through discounts offered through participation in the energy efficiency scheme.

Policy makers should consider whether it is appropriate to have both upstream and downstream regulation in the case of electricity consumption. There may be an advantage in having a downstream incentive (energy levy) in addition to the upstream carbon price (ETS on electricity generation), which is passed through in electricity prices. The UK government has opted for both up and downstream incentives as the view was that price signals are less effective than downstream targets in incentivising electricity efficiency.

[3] Carbon Trust, The UK Climate Change Programme: Potential evolution for business and the public sector,

[4] Committee on Climate Change (2017), Energy Prices and Bills – impacts of meeting carbon budgets

The level of administrative costs resulting from overlapping policies should be considered. As the UK experience has demonstrated, the question of reducing the administrative burden and costs for the participating entities is crucial for successful policy operation.

ELECTRICITY SECTOR

Fossil fuel levies can be used as a mechanism to support the ETS price, through the creation of a carbon price floor, as the UK government did with the introduction of the CPS. The objective was to provide robust and reliable incentive that the EU ETS failed to deliver, and therefore incentivise investments in low-carbon electricity generation technologies. However, there is a risk that if the ETS price does not behave according to expectations, the floor price may need to be adjusted.

If such carbon price floor is adopted, policy makers should acknowledge the risk that the ETS carbon price may not behave according to expectation. Therefore, an in-depth analysis of potential ETS scenarios is required to ensure that the established carbon price floor is set at the appropriate level.

COMPENSATORY MEASURES

Compensatory measures for businesses, households and industries can also be considered in order to minimise the cost of the climate change and energy efficiency policies. This is particularly relevant in case of overlapping policies. A number of compensation mechanisms have been introduced in the UK to support energy intensive industry, beyond the introduction of the CCA (as a response to the cost of CCL) and capping carbon price floor rates. These compensations were implemented to address both the introduction of EU policies, such as the EU ETS compensation scheme, and UK legislative measures, such as CCA compensating for the effect of CCL.

Regarding EU policies, free allocation under the EU ETS became more stringent for the industrial sectors as the phases ensued. In Phase I and Phase II, most allowances were freely allocated, and auctioning was introduced in Phase III for those not deemed at risk of leakage (for the latter, free allocation according to benchmarks was introduced). The power sector however was subject only to auctioning as of Phase III.

Second, the UK government also developed a national compensation mechanism. As a result of national and EU climate policies, wholesale electricity prices were expected to increase in short to medium term. Indeed, electricity prices of the household sector rose by 61% between 2004 and 2016, and 25% of this increase was due to these climate policies. The compensation scheme allows businesses to claim compensation for the indirect costs, in line with EU state aid rules. As of October 2014, 53 companies had been paid over £44 million, mitigating around 65% of these costs. Evaluation shows that this scheme has been successful in limiting the impact on the final energy costs.

Finally, exemptions from the CCL were granted to selected energy intensive industry sectors. The mineralogical and metallurgical industries were granted exemptions based on their process types, and did not require committing to any energy efficiency targets.

IMPLICATIONS FOR BRAZIL: INTERACTIONS OF FUEL PRICE POLICY AND CPIS

Current policy priorities of inflation containment through intervention in fuel pricing may not be in line with the introduction of a CPI in the fuel sector in Brazil. Mexico introduced the carbon tax on fuels as a small part of a much wider energy sector reform, which focused on liberalising the energy market, increasing competition and introducing cost reflective pricing. The introduction of a carbon tax in Mexico was complementary to the policy goal of cost reflective fuel pricing. It is not clear that the same is true of the policy context in Brazil, which is still prioritising inflation containment over cost reflective pricing.

In this interventionist policy context, it is unclear whether the carbon price signal would be effective. Although recent years have seen the Brazilian government allowing Petrobras more autonomy in setting cost reflective fuel prices, the CIDE excise duty is still being used as a lever to contain inflationary pressure of fuel prices. In this policy context, one should question whether the carbon price signal will reach consumers at all, or whether it will be ineffective. In Mexico, the removal of fuel price stabilisation policies was a necessary precondition for an effective carbon price signal. In fact, the carbon tax was included as small part of a much wider energy sector reform.

Nonetheless, Mexico's case demonstrates that the carbon tax can be designed in a manner which is sensitive to inflationary pressure concerns, and uses an interesting "reference fuel" approach. In Mexico, concerns about the fuel price increase after the tax introduction, potential impact on general inflation levels and competitiveness of Mexican firms resulted in the carbon tax rate set at a limit of 3% of the price of the fuel. In addition, in Mexico natural gas was determined as the reference fuel (the baseline) against which the carbon content of all other fuels was be determined. In a similar way, biofuels could be set as the reference fuel in the Brazilian road transport sector.

In two cases studied, protection of low income households was a key part of fuel policy which was extended as a result of introducing the carbon tax. Protection of low income households was a key policy priority in Ireland and B.C., and in both cases the regressivity of the carbon tax was an issue which had to be addressed. Ireland conducted various studies prior to the introduction of the carbon tax to determine expected impacts on low income groups, and provided further assistance to these through a fuel allowance. Similarly, B.C. introduced a tax credit scheme aimed at low income households alongside the carbon tax. Further, the B.C. carbon tax was set up as a revenue neutral policy tool, meaning that every dollar collected as part of the tax is returned to the society through reductions elsewhere in the tax system. Earmarking carbon tax revenues to offset to the carbon tax can support low income populations and make the tax politically acceptable.

Finally, a number of design elements and compensatory measures can be adopted to protect industrial competitiveness, a key policy priority in the Brazil. The UK provides a good example of such measures, to address both the introduction of national climate policies, such as CCA compensating for the effect of CCL, as well as wider EU policies, such as the EU ETS compensation scheme. As mentioned above, free allocation was introduced in initial phases of the EU ETS, and gradually this moved to auctioning for most sectors, except those at risk of leakage. Second, the UK government also developed national compensation mechanism, to compensate for wholesale electricity price rises. The compensation scheme allows businesses to claim compensation for the indirect costs, and as of October 2014, 53 companies had been paid over £44 million, mitigating around 65% of these costs. Finally, exemptions from the CCL were granted to selected energy intensive industries (mineralogical and metallurgical industries) based on their process types.

THEME 3: INTERACTION OF CARBON PRICING AND BIOFUEL POLICY

Table 3 provides an overview of the jurisdictions chosen, the CPI adopted, the interaction studied, and key impacts of these policies.

Table 3- – Overview of Theme 3: Carbon Pricing and Biofuels

Jurisdiction	California	EU	British Columbia
CPI	ETS	ETS	Tax
Start Year	2012	2005	2008
Current Rate	US$12.78/$tCO_2e$ [2016 average[5]]	US$5.91/$tCO_2e$ [2016 average]	US$30.00/$tCO_2e$ [2012]
Policy Interaction	the Low Carbon Fuel Standard (LCFS)	Renewable Energy Directive (RED) and the Fuel Quality Directive (FQD)	Renewable & Low Carbon Fuel Requirements Regulation
Implementation Agency	California Air Resources Board (CARB)	European Commission	Province of British Columbia, Ministry of Finance
How Implemented	Transparent legislative process	Regional collaboration and increasing stakeholder engagement.	Tax made revenue neutral to mitigate distributional impacts.
CPI Impacts	Biofuel mandates and fuel standards could	Biofuel mandates and fuel standards could	Carbon taxes are complementary to fuel

[5] Up to October 2016

	reduce the allowance price	reduce the allowance price	standards but may increase system costs
Other Impacts	The impact of a carbon price on the competitiveness of biofuels depends on whether the transport sector is covered; how biofuel emissions are treated; and the existence of fuel standards and biofuel mandates.		

Source: Vivid Economics.

Lessons learnt Interaction of Carbon Pricing and Biofuel Policy

Lifecycle fuel intensity standards and biofuels blending mandates overlap with each other and the carbon price. Biofuels mandates overlap with the carbon pricing signal in the same way that renewable energy targets do, in that they stipulate minimum shares of biofuels in transport fuels. A fuel emissions intensity standard can interact negatively with the carbon price signal by lowering the allowance price (if an ETS), as seen in California, which can reduce the effectiveness of the carbon pricing signal in other sectors in exchange for potentially higher cost transport sector abatement.

Fuel intensity standards and biofuels blending mandates can interact to increase the costs of compliance. Fuel intensity standards effectively redistribute emissions credits from emission intense fuel producers to less emissions intense fuel producers based on a pre-determined threshold. These credit prices can be volatile and lead to highly varied costs of abatement. Similarly, mandates pick winning fuels, which can reduce the cost-effectiveness of the instrument by reducing the options available for compliance with fuel intensity standards. This entails that the compliance with the mandate is either redundant or excessively costly. Increasing the regulatory costs for the transport sector can have significant knock-on effects on other sectors, due to the interlinkages between transport and other sectors in an economy. Furthermore, biofuels mandates can erode the carbon tax base (if a tax).

A CPI may benefit the inter-fuel competitiveness of biofuels, depending on the transport sector coverage and point of obligation. A CPI affects the cost of refined fuels (liquid transport fuels) by taxing the emissions from refining or by taxing the carbon content of the refined fuel itself (as in Mexico and British Colombia). If the CPI covers only stationary emissions from refining, domestic mineral transport fuels become costlier than both imported mineral transport and biofuels, which are advantaged. If the CPI covers combustion emissions, then biofuels may benefit depending on whether the design incorporates point of obligation on combustion emissions or only production emissions.

Fuel intensity standards can interact with a CPI to accelerate fuel switching, but at potentially high(er) cost. California's fuel standard (LCFS) imposes a carbon price only on fuel emissions exceeding the annual emissions intensity benchmark. Biofuels benefit by generating credits for having a lower lifecycle emissions intensity than the benchmark. The LCFS and ETS have potentially large health impacts and local co-benefits: cumulative societal economic benefits in California were estimated at $274 billion by 2020. However, the benchmark fuel intensity determines the cost of compliance and mineral transport fuels are often above the benchmark. Producers above the benchmark level need to purchase credits from more efficient producers to comply with the fuel standard and these transfers create a discrepancy between fuel prices and increase the inter-fuel competitiveness impacts. Compliance costs can be volatile as credit prices can be unstable and result in comparatively high cost per tCO_2e abated, for example LCFS credit prices varied between less than US$ 10 in 2013, to over US$ 120 in 2017.

A well-designed CPI may fulfil the objectives of a biofuels policy without some of the downsides of biofuel-specific policies. Levying a carbon price against the full carbon content of fuels avoids the distortionary impacts that fuel emissions intensity standards entail due to the use of emissions intensity thresholds. Imposing a carbon price on the full carbon content of a fuel ensures incentives are aligned to reduce this content by as much as possible. CPIs also do not exhibit any preference for particular fuels as they are market-based measures. Table 4 summarizes five common key objectives of biofuels policies and the design elements of CPIs that can be used to achieve them.

Table 4 - CPI design can ensure that the objectives of biofuels policies are achieved

Key objectives of biofuels policies	CPI design element
1. cost-efficient abatement	full carbon content priced, flexible compliance
2. promote biofuels consumption	transport sector coverage and point of obligation
3. minimise distributional impacts on consumers	carbon revenue recycling, tax reform
4. minimise competitiveness impacts on other fuel producers	allow cost pass-through in liberalised fuel sector, carbon revenue recycling, tax reform, allow trading
5. allocate revenues to tax payers	carbon revenue recycling, tax reform

Source: Vivid Economics.

A carbon price can also be designed to encourage biofuels. If the carbon price covers only stationary emissions, lower refining emissions from biofuels gives them a cost advantage; but if combustion emissions are also covered then the benefit to biofuels will depend on whether they are considered to have combustion emissions or if these emissions are attributed to the production stage.

A carbon tax provides greater cost certainty than an ETS and/or biofuels mandates and it can be separate from CPIs in other sectors. As discussed above, a carbon price can achieve greater cost-efficiency in abatement than mandates and emissions-intensity standards while also supporting biofuels production. A carbon tax provides greater cost certainty to producers and consumers than an ETS and/or biofuels mandates, due to fixed prices on emissions. Using a carbon tax in the fuel sector also avoids the unintended effect that promoting biofuels can have on lowering allowance prices in an ETS, which would reduce emission reduction incentives across the entire economy. Implementing a carbon tax in the fuel sector does not necessitate that the carbon pricing instrument in other sectors also be a tax, as the international experience of hybrid instruments illustrates. France, Ireland, Portugal, and Sweden all apply carbon taxes to selected non-EU ETS sectors (Wang-Helmreich et al., 2017).

Policy barriers to implementing fuel standards are the compliance costs and extra-jurisdictional obligations. The fuel standards of both California and the EU ETS were challenged by fuel producers outside the jurisdictions on the grounds of WTO contraventions. Domestic regulations reduce the margins of producers of higher emissions-intensity fuels by lowering the competitiveness of their product. Extra-jurisdictional producers claim these regulations attempt to regulate entities beyond their remit. To overcome these barriers, affected stakeholders should be engaged from the beginning of the implementation of the policy and feedback should be considered for revisions. Furthermore, jurisdiction-wide scale regulations are preferable to regional policies and may create less friction and legal concerns between states. California's LCFS is subnational and, as a result, has experienced legal challenges from ethanol producers in the different US states, who perceived the policy as regulating them beyond its jurisdiction.

Implications for Brazil: Interactions of Carbon pricing and biofuel policy

RenovaBio is effectively a carbon pricing instrument in road transport. It incentivizes biofuels in the same way a carbon pricing instrument would. The tradeable compliance units (CBios) provide an incentive across covered fuels (gasoline), and mandates for biodiesel cover the remainder. As such, additional carbon pricing instruments covering transport may create unintended interactions and/or replicate the effort and direction given by the RenovaBio policy.

The design of RenovaBio will determine the impact of additional carbon pricing instruments in transport. Particularly, what emission reduction target will be chosen will influence the price of CBios and the impact of the RenovaBio policy. Future amendments or current design details of RenovaBio could be guided by the lessons learnt from successful biofuels policies and carbon pricing policies.

Theme 4: International Experience of Carbon Pricing in the Road Transport Sector

This theme studies the role of carbon pricing in the road transport sector, and adopts a different analytical approach to the other themes. First, the role of carbon pricing in road transport and feasibility challenges of implementing such instruments are presented. Following this, the considerations regarding the interactions of CPIs and the existing policy landscape are explored, before presenting some alternative carbon pricing instruments for the sector. Finally, the implications for Brazil of this study are presented.

Role of carbon pricing in the road transport sector

Carbon pricing has a role to play as part of a portfolio of measures to reduce GHG in the road transport sector. ETS and CT are most effective to incentivise low to mid cost abatement measures, for example affecting vehicle or fuel pricing, and cost of circulation, in order to reduce private vehicle ownership, support congestion management and a switch to biofuels. However, the effectiveness of carbon pricing depends on the elasticity of demand of vehicles and fuels to changes in price signals.

There are limitations on the role of carbon pricing in mitigating GHG emissions from transportation. Typically carbon prices are too low to incentivise abatement measures with high up-front costs. CPIs can only provide supplementary incentives for modal shift and alternative vehicles. In addition, there are a number of policy objectives which cannot be achieved through carbon pricing. These include policy objectives to support biofuels or improving carbon efficiency of vehicles, where command and control (CAC) regulation is preferable.

Feasibility challenges

The diffuse nature of emissions sources in the road transport sector poses a challenge for choosing the point of regulation (POR) for ETS and CT systems. The choice of which point of regulation involves a trade-off between the strength of the carbon efficiency incentive and the administrative costs.

The experience of the EU highlights some of these tensions. While an ETS was considered for road transport in the EU, their commitment to the principle of direct emissions and a downstream point of regulation meant it was not implemented due to feasibility challenges. At the time (2000), this was recognised as a key weakness.

Subsequently, a number of EU states have chosen to implement carbon taxes in order to complement the ETS as a means of introducing carbon pricing in un-traded sectors. For example, Ireland introduced carbon taxes from 2009 to cover emissions in non-traded sectors (mainly transport, heat in buildings and heat and process emissions by small enterprises).

California however was able to include road transport in the ETS by adopting an upstream approach for transport fuels. In order to cover the transport sector, the 2nd phase of the ETS was expanded to cover fuel distributors, although policy makers were aware of the trade-offs implied, since placing the obligation on fuel suppliers missed the opportunity to incentivise technological improvements in car manufacturing.

Policy interactions: considerations for introducing CPIs into the existing policy landscape

There are a number of examples of successful combination of carbon pricing and command and control (CAC) policies for the road transport sector. A number of EU states have successfully combined CAC (such as fuel economy standards) with fiscal measures such as carbon taxes. While such standards are low cost and effective means of increasing vehicle efficiency, combining these with taxes reduces the rebound effect.

However, the combination of CPIs and CAC is effective only under certain conditions. A landscape already congested with CAC regulations may limit the effectiveness of the CPIs, as well as increase the regulatory and administrative burdens. Pre-existing policies may reduce the level of effort required to meet emission targets, and leave participating entities with less choice over what abatement options to adopt. This reduces the demand for emission allowances, and lowers the carbon price signal. This was the finding of the EU when considering the introduction of an ETS in the sectors already covered by similar regulation.

In addition, the carbon price signal can be affected by existing energy pricing policies. Harmonising energy and carbon taxation is necessary to ensure that contradictory incentives are not being created. When considering the interaction with fuel pricing policies, the experience of the EU in trying to adopt carbon taxes on fuels demonstrates that the energy taxation policy has to be analysed as whole, to ensure the different components are not contradictory. A carbon tax cannot be imposed without considering the overall effect of other taxes and subsidies on the final prices which consumers face, and the relative attractiveness of competing fuels.

Alternative carbon pricing instruments for the road transport sector

Carbon pricing in the form of ETS or CT may not be appropriate for a particular jurisdiction. In light of this, jurisdictions worldwide have been using carbon pricing in transport in innovative ways.

Colombia proposes to combine a carbon levy with an offsetting system, to incentivise high cost abatement measures and limit fuel price rises. In Colombia's case, a carbon tax would be too expensive and would not achieve the emission reductions desired. Instead, a carbon levy combined with an offsetting mechanism, which could also be funded internationally through NAMAs, was proposed.

Guangdong has implemented an up-scaled crediting mechanism alongside its ETS aiming to fund high-cost abatement, and provide climate financing to project developers. The CDM programme of activities is aimed at funding the replacement of buses. Since such mitigation options have high up-front costs, they usually cannot be incentivised by a carbon price signal alone.

Finally, jurisdictions have been using market based approaches for imposing standards and incorporating carbon taxation in vehicle ownership. Colombia and the EU have adopted market approaches to imposing GHG performance standards on vehicle manufacturers and fuel suppliers. The obligations have been innovatively combined with trading and offsetting elements, to reduce burden on entities. Also noteworthy is the experience of a number of European countries introducing carbon taxation on vehicle registration or ownership, in order to influence the purchasing decision. In France this approach has shown positive results.

Implications for Brazil: Carbon pricing in road transport

Priority mitigation options in Brazil

As stated in Section 1, Brazil's priority mitigation options in the Road transport sector are:

- Urban transportation. Shift to bus rapid transit and metro, implanting traffic management measures.
- Regional transportation. Modal shift for passenger and freight transport, such as expansion of high-speed passenger trains between Sao Paulo and Rio de Janeiro to replace the use of planes, cars, and buses, or increased use of water and rail transit for freight.
- Fuel switching. Increasing the switch from gasoline to bio-ethanol fuels. The key challenge is to ensure that market price signals are aligned with this objective. In addition, financial mechanisms to absorb oil price shocks are also recommended.

Of the options outlined above, modal shift in urban and regional transportation are characteristically large capital intensive infrastructure projects, with high up-front costs. Fuel switching however is focused on ensuring the correct price signal is sent so that biofuels become relatively attractive compared to fossil alternatives. Transport demand management may be achieved by a combination of pricing signals and regulation.

Potential effectiveness of carbon pricing

Carbon pricing may play a role in supporting these mitigation options, but as shown is most effective at incentivising low to mid cost abatement measures. For example it can be used to influence vehicle or fuel pricing, and cost of circulation, in order to reduce private vehicle ownership, support traffic management and a switch to biofuels.

Fuel switching. **In a context such as Brazil's, where there is already the widespread use of biofuels, the carbon price signal could play a role in supporting switching to biofuels.** Nonetheless, an analysis of the elasticity of demand of these fuels would be necessary, in order to determine how costly such a fuel switch would be for consumers and the economy as a whole. In addition, further support may be required, for example in the form of complementary regulation to support biofuel production, and importantly, harmonising energy price signals. This is dealt with in the interaction analysis section below.

Modal shift through transport infrastructure projects. Such projects have high upfront costs, requiring high carbon prices to incentivise the project (although this is not the critical investment factor). The World Bank study (Gouvello, 2010) estimates a marginal abatement cost of approximately U$40 / tCO_2e for BRTs, and a break even carbon price of between U$200-300/ tCO_2e for the project to become attractive to the private sector. However, such projects usually have enormous co-benefits, and indeed are being implemented in most major cities in Brazil (and in Latin America more generally), so the carbon price would not be the critical investment factor.

Some jurisdictions have developed alternative carbon mechanisms in order to support large transport projects. This is the case of Colombia, which proposed to implement a carbon levy and offsetting scheme which recycle revenues into transport projects. In addition, Guangdong provides an example of up-scaled crediting mechanisms which can be could be designed to raise funds for these projects. Offsets generated could be sold into other capped sectors of an ETS.

FEASIBILITY CHALLENGES

The diffuse nature of emissions sources in the road transport sector poses a challenge for choosing the point of regulation (POR) for ETS and CT systems, which involves a trade-off between the strength of the carbon efficiency incentive and the administrative costs. The cost of administering a downstream scheme in the road transport sector is potentially prohibitive given the number of car users in Brazil. There were 36 million vehicles in Brazil in 2014, and according to the National Energy Plan for 2050, this is expected to rise to 130 million by this date (Diário do Transporte, 2014). In this sense, regulating upstream may be more feasible, as Brazil has a concentrated fuel supply market. 60% of the market share for distribution of automotive gasoline is controlled by 3 distributors in 2016 (Agência Nacional de Petróleo Gas Natural e Bicombustíveis, 2013). However, the trade-off is that the end-user is not being regulated, and the effectiveness of the measure depends on the strength of the passed through carbon price signal.

Brazil may wish to learn from some jurisdictions such as California, whose cap and trade programme covers the fuel supply, by having adopted a mixed regulatory approach (up and downstream), or the case of many EU states such as Ireland, which adopt an carbon tax alongside the EU ETS.

POLICY INTERACTIONS.

While this review shows that there are a number of examples of successful combination of carbon pricing and command and control policies for the road transport sector, the combination is effective only under certain conditions. A landscape already congested with CAC regulations (fuel and vehicle standards, transport demand measures) may limit the effectiveness of the CPIs, as well as increase the regulatory and administrative burdens. In particular, the price signal of an ETS may be weakened by the existence of such complementary overlapping policies.

Although not the remit of this chapter, one area of further study will be the interaction of a possible CPI and planned mechanisms to support biofuels. Brazil was one of the first countries to implement policies to stimulate biofuel consumption. Currently, flexible fuel vehicles are eligible for federal value-added tax reductions ranging from 15–28%. In addition, all gasoline should meet a legal alcohol content requirement of 27%. Moreover, the planned RenovaBio mechanism aims to introduce a biofuel supply obligation and permit trading mechanism, which will stimulate the supply market. The question will be whether additional support for biofuels will be necessary in light of this existing regulation.

Regarding interactions with contradictory policies, the carbon price signal may be affected by existing energy pricing policies. Although Brazilian fuel pricing policy has been formally liberalised to be reflective of costs conditions, there has been a history of intervention in prices to control distributional impacts and inflationary pressures. Harmonising energy and carbon taxation is necessary to ensure that contradictory incentives are not being created, as the example of the EU demonstrated. These policy interactions are covered in greater detail in *Chapter 2- Interaction of Fuel Price Policy and Carbon Taxes*.

The same is true if carbon taxation for vehicle circulation or ownership is considered in Brazil. The price signals sent through existing regulation for vehicle circulation and ownership must be reviewed prior to introducing a carbon price.

TABLE OF CONTENTS

1 BRAZIL CONTEXT

This section provides a short overview of key points in the Brazilian context which have served to guide the selection of the jurisdictions studied, and apply some of the lessons learnt from international experience to Brazil.

1.1 FUEL PRICING POLICY IN BRAZIL

Fuel prices are a sensitive issue in Brazil, given the economy's dependence on fuels and a history of extreme inflationary pressure. Fuel prices are a particularly sensitive issue since much of the economy depends on road transport (Financial Times, 2016b). In addition, Brazil has a history of extreme inflationary pressure with inflation rates in the early 1990s rising above 2000%(The Economist, 2015). Brazil is currently under pressure to ensure that inflation in administered prices (a price not set by market forces) does not spread to other areas of the economy, although this is a particularly difficult task with fuel and electricity as they are critical inputs into production (Reuters, 2015).

Although fuel prices have been formally liberalised, Brazil has historically adopted an interventionist approach to fuel pricing. Fuel prices have been formally deregulated since 2002, but have been controlled indirectly by the government through the dominant energy firm Petrobras, of which the government holds a controlling stake. As part of this approach, fuel prices have been capped to shield domestic energy prices, and inflation rates more generally, from global shocks affecting international markets (Oliveira & Almeida, 2015).

However, as this approach has resulted in significant debts for Petrobras the government has increasingly allowed greater independence in setting fuel prices, despite inflationary pressure. This price smoothing activity has resulted in huge debts for Petrobras. In light of these losses, the fiscal crisis and requirements to finance capital expenditure, Brazil's Energy Ministry has changed its approach and is now backing full independence for Petrobras in setting fuel prices, which are therefore more likely to be reactive to the fluctuations on the international energy markets (Reuters, 2015). Nonetheless, year-on-year inflation reported in December 2015 was 10.7% (World Bank, n.d.), which has been in part caused by the fuel prices being allowed by the government, through Petrobras, to rise in response to the fiscal crisis and the depreciation of the currency(The Wall Street Journal, 2015).

Alongside these interventions, an excise duty, Contribuição sobre Intervenção no Domínio (CIDE), is also applied to fossil fuels in Brazil. It was introduced in 2001 to stabilise domestic fuel prices despite the general price fluctuations (OECD, 2015). In this way, although fuel prices were allowed to increase between 2012 and 2013 (through Petrobras), the CIDE was set to zero for petrol and diesel between 2012 and 2015 to offset this increase. Following this, positive tax rates were introduced for diesel and petrol in 2015 to further support fuel prices. Apart from stabilising fuel prices, CIDE's tax revenues also aimed at financing environmental projects in the oil and gas industry as well as transport infrastructure projects.

1.2 BIOFUEL POLICY IN BRAZIL

Brazil has been a world leader in liquid transport biofuels production since the Pro-Alcool programme was launched in 1975 to foster ethanol production. The policy was a response to the first oil crisis with the aim to increase energy security and lower transport fuel cost in Brazil (Leite & Leal, 2007).The ethanol-use mandate has been mandatory since 1977, starting with a requirement blend of 4.5% ethanol to gasoline and reaching 27% in 2015 (USDA FAS, 2016). The average world volume share of ethanol in gasoline over 2012-14 was 10.1% (OECD-FAO, 2015). In 2002, with a new increase in oil prices, the vehicle industry started to develop the Flex Fuel Vehicle, with a flexible motor that can operate with gasoline, ethanol or any mixture of these two fuels (Leite & Leal, 2007). Climate incentives, such as the opportunity to generate CDM credits, and the compliance with the National Plan for Climate Change have also supported biofuel production (USDA FAS, 2016).

. In 2015 road transport fuels in Brazil resulted in significantly greater levels of GHG emissions than both the industry and electricity sectors, as shown in Figure 1. The System Study Greenhouse Gas Emissions Estimates show that, in 2015, the emissions from freight transportation were 105.22 $MtCO_2e$ and from passenger transportation, 99.13 $MtCO_2e$.

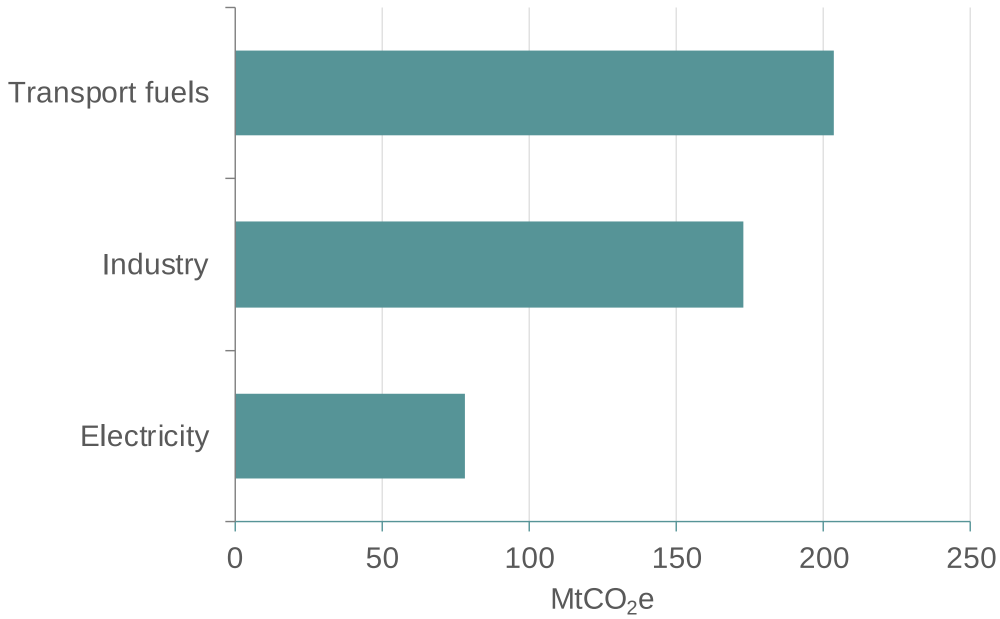


Figure 1 - Brazil's transport fuels GHG emissions were greater than the industry and electricity sectors emissions in 2015

Source: SEEG (2016).

Biofuels comprise almost a fifth of road transport fuels consumption. As shown in Figure 2, diesel comprised 53 m^3 (46%) of transport fuel sales in Brazil in 2015, with hydrated ethanol and biodiesel together comprising almost a fifth of total sales.

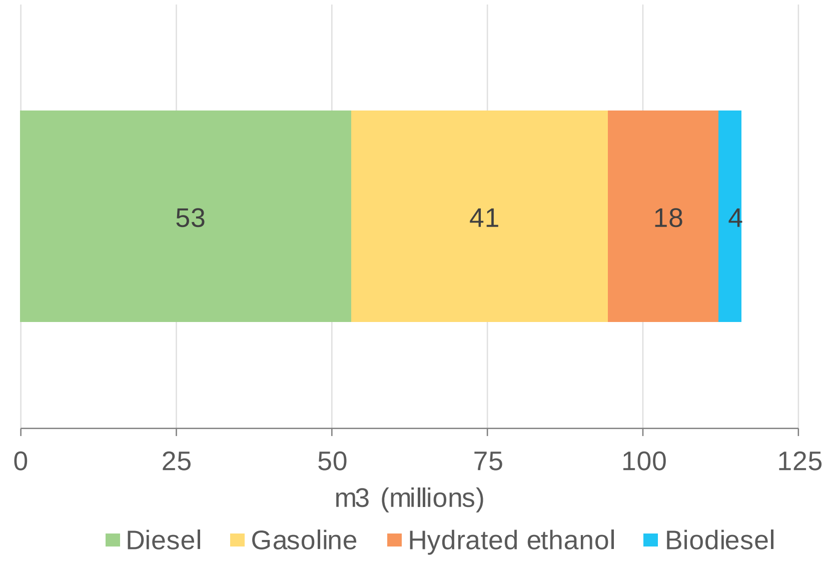


Figure 2 - Biofuels comprised almost a fifth of total fuel sales in Brazil in 2015

Source: ANP (2017).

Sugarcane bioethanol (anydrous and hydrated) and biodiesel from soybeans are the primary biofuels in Brazil and are partly mandated in the fuel mix. The National Biodiesel Production Programme established a mandate of a 2% biodiesel blend to regular mineral diesel in 2004 (Leite & Leal, 2007). In 2010, the National Council for Energy Policy raised this mandate to 5%. The same Council increased the mandate to 8% from March 3rd 2017, and for the following two years, it will reach 9% and 10%, in March 2018 and 2019 respectively. The average world volume share of biodiesel in diesel over 2012-14 was 3.5% (OECD-FAO, 2015).

Although the focus of this theme is on biofuels in transport, the production of biofuels has interactions with electricity generation. The production of ethanol generates bagasse that is used to generate electricity. The bagasse is the major by-product of the sugar cane industry, a lignocellulosic material providing an abundant renewable energy source. Bagasse is currently responsible for 79% of the biomass thermal electricity generation in Brazil and 7% of the total electricity generation. With a total installed capacity of 10.88 GW, it's Brazil third energy source, after hydropower, with 61%, and natural gas, with 8% (ANEEL, 2017). There are currently 395 bagasse thermal power plants, and, according to the National Sugar Cane Industry Union (UNICA, 2017), in 2016, 56% of bioelectricity generation was used as auto-consumption of industrial units, and 44% went to the grid. UNICA (2017) estimates that this sugar cane bagasse electricity directed to the grid has provided energy for 11 million households and avoided the emission of 9.3 $MtCO_2$ in 2016.

1.3 Mitigation in road transport in Brazil

Below is an overview of Brazil's priorities in the transport sector, both in terms of emission sources and mitigation measures.

Reducing emissions from road transport is a priority for Brazil. According to the Third National Communication (Brazil MCTI, 2016), transport was responsible for 35.94% of final energy consumption in Brazil in 2010. Transport related fuel emissions comprise 13.8% of total CO_2e emissions in 2010. Regarding CO_2 emissions, 45.5% of Brazil's total CO_2 emissions come from road transport (mainly from gasoline and diesel), with much smaller proportions coming from other modes of transport (railways, civil aviation and navigation comprise 5% together).

As for the national policies and plans, Brazil has developed a Sectoral Transport and Urban Mobility Plan for the Mitigation and Adaptation to Climate Change (PSTM). *"Based on the elaboration of emission scenarios and mitigation measures, the PSTM includes … highways for the carriage of cargoes (road transport by heavy, medium and light trucks), rail and waterway, specifically, inland and coastal waterways (shipping or coastal navigation); and in the case of passenger transport, the individual transport (for light vehicles and motorcycles), public transport on wheels as bus corridors, LWT (light wheeled vehicles), BRT (Bus Rapid Transit), and public transport on rails, like subway, urban train, monorail, LVR (light vehicle on rails) and air-mobile*" (Brazil MCTI, 2016).

In addition to this, a Growth Acceleration Program (Programa de Aceleração do Crescimento – PAC) regarding Big Cities Mobility was launched in 2011. It aimed at upgrading and deploying structured public transportation systems in order to expand the capacity and the promotion of mobility system's inter-modal, physical and toll integration in large urban centres.

The World Banks' Brazil - low carbon country case study (Gouvello, 2010), proposes that the main mitigation options for Brazil's transport sector are a shift to BRT and metro, traffic management in urban transport, modal shift in regional transport, and fuel switch from gasoline to biofuels. The study estimates that significant GHG savings can be achieved compared to a reference scenario based these promising mitigation options:

- *Urban transportation*. Shift to **bus rapid transport** and metro, **implanting traffic management** measures, can reduce emissions by 26% in 2030. However, policy, coordination, and financing issues for capital intensive mass transit options often prevent and/or delay their implementation. In addition, decentralised administration, makes the mobilization of resources difficult. Public private partnerships could be an option.
- *Regional transportation*. Modal shift for passenger and freight transport, such as expansion of high-speed passenger **trains** between São Paulo and Rio de Janeiro to replace the use of planes, cars, and buses, or increased use of water and rail transit for freight—can reduce emissions by 9% in 2030. However, inadequate infrastructure for efficient intermodal transfer and a lack of coordination among public institutions present barriers. This requires adequate

coordination between the public sector between regions, and oversight of the private sector which implements these transport projects, whether road or rail.

- *Fuel switching*. Increasing the **switch from gasoline to bio-ethanol fuels** from 60 percent in the reference scenario to 80 percent in 2030 could deliver more than one-third of total emissions reduction targeted for the transport sector over the period (nearly 176 Mt CO_2). Here, the key challenge is to ensure that market price signals are aligned with this objective. The report recommends that a financial mechanism be designed and implemented to absorb oil price shocks and maintain the attractiveness of biofuels.

2 INTERACTION OF FUEL PRICE POLICY AND CARBON TAXES

2.1 INTRODUCTION

A wide array of policy instruments can be implemented in the energy and climate change areas in order to stimulate the national energy efficiency improvement and GHG emission reduction. While being closely linked, these policies interact in various ways which can result in beneficial synergies or burdensome policy overlaps depending on how the instruments are applied. To consider such instances in more detail, this theme will explore the interaction between energy and carbon pricing objectives of the policies implemented in selected countries.

Interventions in fuel pricing and energy markets are generally focused on protecting consumers from high or sudden changes in fuel prices, as well as protecting the wider economy from inflation. While a variety of levers can be pulled to regulate the fuel markets, most policies applied in this area can be classified as subsidies. Implementing a subsidy regime which reduces consumers' exposure to high fuel prices or shocks creates a significant pressure on the fiscal resources of a country. This type of intervention in the fuel market is therefore expensive and supports environmentally harmful behaviour by indirectly stimulating fuel consumption. For this reason, countries are undertaking energy policy reforms focusing on minimising intervention in the fuel price market.

Considering the global experience in this area, there are not many regimes that adopt the same price stabilisation programme as Brazil in conjunction with a carbon tax. Therefore, in order to draw the most relevant conclusions, this theme will look at countries that either 1) have introduced a carbon tax into an environment where fuel pricing is being reformed or 2) there has been some action to reduce the impact of the carbon tax on vulnerable groups. Based on these criteria, the countries listed in Table 5 will be explored.

Table 5 - Case Studies Summary

Country	Summary
Mexico	Mexico had operated an interventionist policy through price smoothing in fuel markets to protect consumers. A carbon tax was introduced as part of wide ranging energy reforms.
Ireland	A carbon tax was introduced into a constrained fiscal environment where there was considerable concern about impacts on low income households. Subsidies were expanded in response to the introduction of the carbon tax
Canada (British Columbia)	A 'textbook' approach to a carbon tax where revenue neutrality provides support to consumers while maintaining the price signal. Concern about low

	income groups was alleviated by adopting revenue neutrality which reduced taxes elsewhere in the system and maintained the price signal on the fuel.

Source: Ricardo Energy & Environment.

2.2 Mexico

This case study will focus on the implementation of the carbon tax in Mexico which was introduced as part of a wider fiscal reform package along with other energy landscape changes in a price sensitive environment.

2.2.1 Policy Landscape

The Mexican energy market is dominated by the state-owned corporation Petróleos Mexicanos (Pemex). Pemex's revenues, arising from the monopoly in production of hydrocarbons, natural gas and oil refining markets, have been a large source of income for the government, providing 35% of budget revenues in 2013 (Muñoz Piña, 2015). Given that Mexico has significant reserves of oil and natural gas, Pemex has become the tenth largest net-exporter of oil in the world (OECD, 2016).

Prior to the market reform implemented in 2013, gasoline and diesel prices were set by the federal government using excise taxes through *Impuesto Especial sobre Producción y Servicios por Enajenación de Gasolinas y Diesel* (IEPS) (OECD, 2016). Due to political and public sensitivity to any sharp fuel price changes (Muñoz Piña, 2015), maintaining the fuel prices stable has become a policy priority. Since IEPS has a floating excise rate, it allows to level the price fluctuations and was implemented across the period 2006-2014 to ensure fuel price stability. The IERS formula determining the rate is dependent on the administered and international fuel prices and applies in a countercyclical way. This implies that when international prices go above a certain level, the tax rate reduces and when they go down, it grows, by which IEPS provides an implicit subsidy (Green Fiscal Policy, 2017).

In December 2013 Mexico enacted wide ranging reforms of energy markets encompassing electricity and fuel markets, which included the introduction of a carbon tax. The key change introduced by the reform package was that private firms were permitted to compete with Pemex (OECD, 2016) on oil and gas markets in order to increase supply and create market competition forcing efficiency improvements. This liberalisation of the energy market was expected to boost growth and create 1.8 million jobs by 2018 (Green Fiscal Policy, 2017).

Another focus area of the market reform was to address energy pricing and the function of IEPS. In 2016, changes to excise taxes and price determination made its way through the congress (Muñoz Piña, 2015). Whereas IEPS was previously a floating excise designed to stabilise fuel prices, the reform moved the tax towards a fixed rate per litre of fuel. The excise quota is being regularly adjusted to ensure that fuel prices remain within +/-3% of the 2015 price level (Rennhack et al., 2015; World Bank Group, 2017), while the currently existing maximum price cap will be abolished from 2017.

2.2.2 Analysis of Carbon Pricing Instrument (CPI): Carbon Tax

The carbon tax was not a standalone measure, but a part of a wider package (Wooders et al., 2016) and was primarily introduced as a way to increase fiscal revenue. A carbon tax was introduced in 2013 as part of the energy market reform and came into force in 2014 (Rennhack et al., 2015).

The carbon tax covers a range of fuels which are responsible for 40% of Mexico's emissions (World Bank Group, 2017). These include propane, butane, gasoline, kerosene and other jet fuels, fuel oil, petroleum coke, carbon coke, and coal and is levied on fuel sales and imports. The tax is applied upstream to producers and importers (as opposed to downstream final consumer taxation) and is administered by the Tax Administration Service (SAT). The tax can be paid in cash or in carbon credits via Clean Development Mechanism framework. The tax is currently set at US$3.2/t$CO_2$e and is applied on the difference between the GHG emissions associated with each taxed fuel and a baseline of natural gas emissions (Wooders et al., 2016).

2.2.3 Effectiveness Impact Analysis

2.2.3.1 *Impact on the effectiveness of CPI*

From the outset, the carbon tax was controversial and appeared to act counter to the government's plans and president Nieto's promise to lower the cost of fuel. Initial expectations were that the tax would not make it through the Mexican congress. There were also reports of the futility of the carbon tax since the government was subsidising fuel consumption (through IEPS) at the same time (Reuters, 2013). But such analysis discounted the fact that the carbon tax in Mexico was introduced as part of a wider reform of the energy market which would, gradually, move from providing net 'subsidies' to fossil fuels to net taxes on fuel.

Albeit gradual, the removal of subsidies and the introduction of a carbon tax is expected to increase prices of fossil fuels. Therefore, both taxes introduced by the government, CIDE and IEPS, 'pull' in the same direction, potentially reducing fuel demand and, therefore, can be considered overlapping.

Liberalisation of the energy market and removal of the monopoly power of Pemex opened the energy markets up to competition, changing the dynamics on the energy market. Since fuel markets are unlikely to compete on quality, competitive pressure tends to make markets more responsive to price signals with more substitutes available. As a result, the markets become more responsive to carbon taxes - this is often cited as a key reason for the introduction of a carbon tax as opposed to any command and control mechanisms. In addition to this, liberalisation of the energy markets is expected to result in fuel prices fluctuations in response to global and local demand and supply. This, in turn, will emphasise the price signal associated with fuel consumption and reinforce the effect of the carbon tax. On the other hand, liberalisation could also reduce fuel prices by increasing supply, thereby increasing demand for fossil fuels. Given all these factors affecting the market with different intensity, the overall impact of the dynamic between the removal of subsidies and increasing supplies remains uncertain.

2.2.3.2 Impact on the effectiveness of the existing policies

The energy market reform, specifically introduction of fixed excise rates and removal of the floating excise rate, was a necessary pre-condition for the introduction of a carbon tax, as otherwise the price signal would not be passed through to final consumers. The carbon tax is supportive of the energy market reform objective as it moves from subsidising fuel use to a regime which taxes consumption of fuels based on their environmental impacts and, as a result, encourages exploration of alternative more environmentally friendly fuel sources.

2.2.4 Policy Harmonisation

2.2.4.1 Carbon tax changes

The carbon tax was changed several times as it passed through Mexican congress in response to potential impacts on competitiveness. The initial proposal for the carbon tax was that it would be levied on all fossil fuels with a uniform price of US$5.7/t$CO_2$e, with this tax rate determined as a weighted average of the rates in international carbon markets. The carbon content of fuels in this initial proposal was to be determined by IPCC default values.

Concerns about the fuel price increase after the tax introduction, potential impact on general inflation levels and competitiveness of Mexican firms resulted in the carbon tax rate set at a limit of 3% of the price of the fuel. As part of a wider strategy to foster the natural gas industry, natural gas was determined as the reference fuel (the baseline) against which the carbon content of all other fuels was be determined. As a result of these changes and negotiations, the rate of carbon tax was lowered to US$3.2/t$CO_2$e. It appears that these changes were primarily caused by the industry competitiveness concerns, rather than concerns about the interaction between energy market reform and the carbon taxation.

2.2.4.2 Energy policy changes

The energy reform was not adjusted in response to the introduction of the carbon tax because the considered carbon tax was part of the same fiscal package.

2.2.5 Policy Impacts

2.2.5.1 Impacts on emissions and carbon pricing signal

The carbon tax was designed to achieve two primary goals: bring fiscal revenue and contribute to reduction of the national GHG emission. As for the first objective, fiscal revenues from the carbon tax appeared to be considerably lower than initially expected by the Mexican government. However, the government sources claim that a reduction of 1.5 million tCO_2e was caused by the introduction of the carbon tax. As discussed above, the carbon tax was only one element of the fiscal and energy sector reform and some other elements of the reform package made industry more responsive to fuel price signals contributing to the same objective (e.g. removal of price subsidies).

2.2.5.2 UNDERLYING POLICY IMPACT

Considering the overall energy policy landscape, it is likely that removal of the price stabilisation mechanism will dominate the price signal associated with the carbon tax. Deregulation which began in 2017 and due to finish in 2018 is expected to lead to *"remarkably large"* (OECD, 2017a) increases in effective tax rates.

The carbon tax was only one aspect of an extremely complex environment with political, regulatory, supply and demand factors interacting. It can be seen from Figure 1 that the carbon tax, introduced in 2014 had little impact on energy focused CPI. Sharp increases are seen in energy inflation in 2017 in Mexico and across the OECD. As can be seen, this is the first time that Mexican consumers are exposed to sharp changes in energy prices experienced elsewhere in OECD countries.

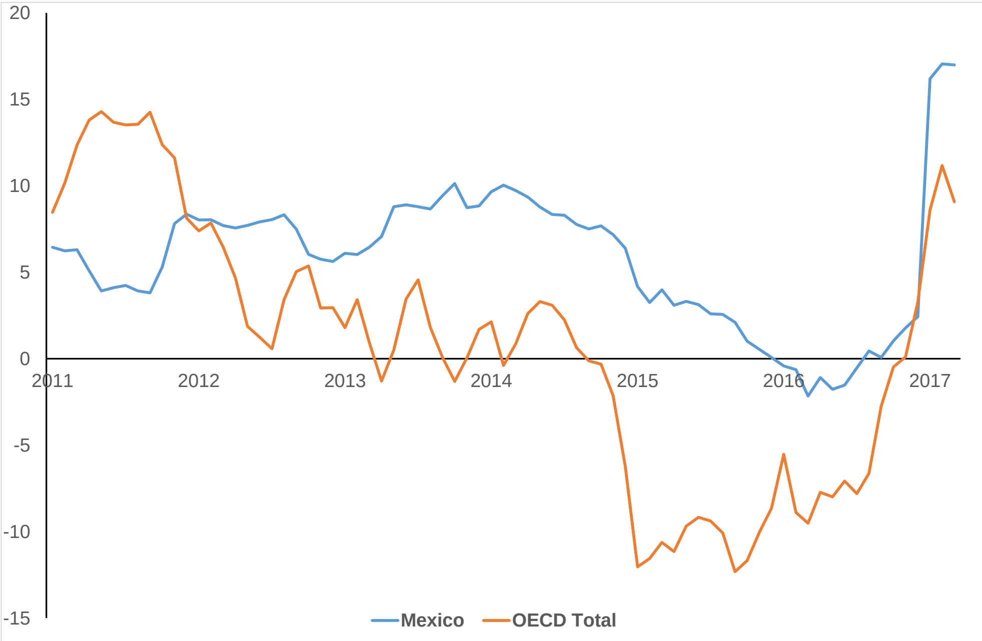


Figure 3 - Energy in Mexico and across OECD - annual growth (%) January 2011- April 2017)

Source: (OECD, 2017b).

2.2.5.3 DISTRIBUTIONAL IMPACTS ON HOUSEHOLDS

As a result of the removal of subsidies, the fuel prices in Mexico increased by up to 20% which led the country to sometimes violent protests. The increase in fuel prices is known colloquially as *gasolinazo* (Okeowo, 2017) meaning *"a fuel price slam"* (E. Martin, 2016). At present, there seems to be a strong negative reaction to the market reforms. However, the carbon tax did not have any significant effect on the public reaction, since it was the removal of the subsidies which caused major dissatisfaction among Mexican population.

2.3 Ireland

The Ireland case study will analyse implementation of the carbon tax primarily as a fiscal revenue stream and its interaction with fuel poverty alleviation policies.

2.3.1 Policy Landscape

The carbon tax was introduced in Ireland in the midst of a fiscal crisis and was one of the measures introduced to address the shortage of fiscal revenues. The country had experienced strong economic growth in the years preceding the introduction of the tax, but much of this growth happened due to a credit and property price boom. In 2008, after the global financial crises, Ireland faced a fiscal failure and a banking crisis, which made taxation decision particularly sensitive (F. J. Convery, Dunne, & Joyce, 2013). At that time, substantial financial support was provided to Ireland by the 'Troika' (European Central Bank, the European Commission, and IMF) but this support was conditional on fiscal reform, primarily reducing public spending and increasing fiscal revenues.

Support to low income households for fuel costs was introduced prior to the implementation of the carbon tax and was kept in place after introduction of the tax. Launched in 1998, it is provided in the form of the National Fuel Allowance and is designed as a subsidy for low income households. This subsidy effectively reduces the price of fuel for vulnerable groups, in line with the aim of the programme to help low income households with heating costs. The scheme operates during a 'fuel season' when heating costs are higher and the need for an adequately heated home is more acute. Two key subsidy eligibility criteria include being an Irish resident and in receipt of welfare payments, however, other conditions apply (Department of Employment Affairs and Social Affairs, n.d.).

2.3.2 Analysis of the Carbon Pricing Instrument (CPI): Carbon Tax

The tax was introduced primarily as a revenue generating measure alongside more general fiscal reform required by the Troika to reduce the national public deficit (OECD, 2013). It gradually applied in different areas and covered transport fuels in 2009, non-transport fuels in 2010 and solid fuels in 2013.

The carbon tax was introduced in Ireland into those areas of intensive energy consumption not covered by the European Union Emission Trading Scheme (EU ETS) and applied to 38.51% of all GHG emissions in Ireland in 2011 (F. Convery, Dunne, & Joyce, 2014). Since large manufacturing and energy generating facilities are already covered by the EU ETS, the carbon tax covers mainly combustion for heating in the residential sector, transport and small industry. The tax applies to a range of fuels, namely, petrol, heavy oil, auto diesel, kerosene, LPG, fuel oil, natural gas, coal and peat (OECD, 2013). Agricultural sector was excluded from the tax coverage despite being responsible for 44% of GHG emissions because of the difficultly in measuring emissions including methane and nitrous oxide (F. J.

Convery et al., 2013). While the tax is applied to fuel suppliers which are required to pay it, the costs are passed on to final consumers (OECD, 2013).

The tax rate was increased over time in the following phases (World Bank Group, 2017, OECD, 2013):

- 2010 - The carbon tax was introduced at a rate at €15/tCO_2e for selected fuels;
- 2012 – The rate of carbon tax on a selection of fuels was increased to €20/tCO_2e
- 2013 - A carbon tax was introduced on peat and coal at a rate of €10/tCO_2e;
- 2014 – The rate of carbon tax on all fossil fuels was increased to €20/tCO_2e.

2.3.3 Effectiveness Impact Analysis

2.3.3.1 *Impact on the effectiveness of CPI*

The existence of fuel subsidies in the form of the fuel allowance provides support to the most vulnerable groups resulting in discussion about the compatibility of the implemented mechanisms. Arguments can be made that this subsidy undermines the pricing signal associated with the carbon tax, but, conversely, a reduction in demand for fossil fuel could occur as long as the subsidy is not directly tied to a specific fuel consumption (which does not appear to be the case in Ireland), and low carbon substitutes are available or reduction in demand is possible. Few analyses focused on the extent to which the pricing signal of the carbon policy instruments would be undermined by the existing financial support. Instead, focus for analysis was primarily placed on the regressive nature of the tax and impacts on low income groups.

2.3.3.2 *Impact on the effectiveness of the existing policies*

Various studies were conducted prior to the introduction of the carbon tax to determine expected impacts on low income sections of society, which concluded that further support might be required for the most affected groups. As a result, a number of schemes aimed at limiting the impact of the carbon tax on low income groups were introduced or expanded in response to the implementation of the carbon tax and its expected regressive nature. These schemes used the revenue from the tax to minimise its regressive nature. In this way, the National Fuel Allowance, which is a means tested payment to help with cost of home heating, was extended, increasing the subsidy amount (additional €2 a week) as well as the duration of the scheme. Alongside the National Fuel Allowance, the Warmer Homes Scheme and the Better Energy Homes Scheme were introduced to support energy efficient improvements in the residential sector.

2.3.4 Policy Harmonisation

2.3.4.1 *Carbon Tax Changes*

The carbon tax was implemented in phases to let industry and households adapt to the change. At the outset, the Commission on Taxation established in 2009 recommended an initial carbon tax rate of €20/tCO_2e. However, the tax rate was initially set at a lower rate to phase in the tax, presumably to let the population adjust to price changes. The carbon tax on solid fuels (coal and peat) was intended to be applied at a rate of €15/tCO_2e in 2010, it was instead introduced three years later in 2013, at €10/tCO_2e with an increase to €20/tCO_2e in 2014. This change can be explained by the sensitive situation which unfolded around peat consumption in Ireland. Peat fuel is indigenous and it is harvested by rural communities and generally used to heat low income households. Even though peat cutting has negative consequences for the provision of habitat as well as carbon sequestration, previous efforts to reform this industry have been resisted. In order to address the situation, meetings were and still are being held with the public and industry to alleviate and address concerns.

2.3.4.2 *Energy Policy Changes*

Ireland undertook an extensive analysis on the potential impacts of the carbon tax and enacted policies which support low income households either before or just after the introduction of the policy. The cost of support to low income groups increased after introduction of the tax, and there were moves by the Department of Social Protection to reduce it. The costs of providing the National Fuel Allowance rose by 200% across the period 2005 to 2011. The carbon tax, falling incomes and increases in the number of the unemployed could have driven the increased costs of the governmental support under National Fuel Allowance, and, as a consequence of all these factors, the duration of the scheme was reduced in 2013.

2.3.5 Policy Impacts

2.3.5.1 *Impacts on emissions and carbon pricing signal*

The carbon tax level was set based on the forecasted trajectory of the EU ETS prices, which resulted in a carbon price gap due to the EU ETS price drop. The price of the carbon tax was set under the expectation that the future EU ETS price would lie in the 15-30€ per tCO_2e range. This was not the case with the EU ETS falling to €3 per tCO_2e, way below the initial expectation. Therefore, a considerable difference has emerged between carbon prices of the tax and EU ETS.

Between the period 1990 and 2013 the use of fossil fuel in Ireland decreased considerably, with coal consumption decreasing by 16.4%, peat - by 9.5% and natural gas - by 8.3%. However, the factors leading to this decline in consumption are not clear. The application of the carbon tax to peat and coal led to a significant increase on the price of these fuels (24% increase in peat prices in 2014[6]). Although energy and carbon policies had certain effect on the fuel use reduction, the context of the economic decline and warmer weather has to be accounted for.

The primary purpose of the carbon tax was to increase tax revenues in a time of fiscal constraints. By placing an additional tax pressure on an environmentally unfriendly fossil fuel burning, the government managed not to raise taxes on those activities which are considered beneficial, such as economic and social taxes[16]. Although the carbon tax provides a relatively small amount of total tax revenue (approximately 1% of total tax revenues), it provided a substantial part (21.5% to 24.6%) of the increase in tax revenue required by the Troika between 2010 and 2012.

2.3.5.2 *Impacts on effectiveness of the underlying policy*

There appears to be no ex post analysis on the impact of the carbon tax on low income groups. But the take up of the National Fuel Allowance was greater than anticipated, with efforts made to reduce expenditure associated with the programme.

2.3.5.3 *Distributional impacts on households*

There appears to be no ex post analysis on the impact of the carbon tax on low income groups.

2.4 Canada

The case study of the carbon tax introduction in British Columbia, Canada, became one of the world's key examples of revenue neutral taxes and balanced environmental fiscal policy focusing on taxing negative externalities as opposed to economic or social value creation.

2.4.1 Policy Landscape

The key elements of the policy landscape in British Columbia which will be considered in this study are the introduction of a carbon tax and the support provided to low income groups as a result of this. In Canada, all provinces and territories have the authority to regulate fuel prices, but not all provinces do so. Some of them set maximum retail prices, but British Columbia does not regulate fuel prices and adopts a market based approach. Fuel prices in British Columbia are made up of the base price defined by the market, which is then taxed via a federal excise tax, GST/HST, the carbon tax, and provincial fuel tax (Petro-Canada, n.d.).

[6] RTE (2014), Carbon tax pushes up coal and briquette prices, Available at: https://www.rte.ie/news/2014/0501/614162-carbon-tax-pushes-up-coal-and-briquette-prices/

2.4.1.1 Analysis of Carbon Pricing Instrument (CPI): Carbon Tax

In 2008 British Columbia introduced North America's first carbon tax, which went through a number of adjustments as the system matured. The tax was set at a rate of US$10 per tCO_2e and increased to reach US$30 per tCO_2e in 2012. This increase over time was phased to let families and businesses adjust. Rates were frozen in 2013 until 2018. Exempt from the tax were fuels exported from British Columbia, aviation fuel, fuels used in agriculture, emissions from sources other than fossil fuels (e.g. forestry and agriculture), and 'fugitive' emissions of methane. The tax covered three quarters of all GHG emissions in the province (Murray & Rivers, 2015).

The carbon tax was set up as a revenue neutral policy tool, meaning that every dollar collected as part of the tax is returned to the society through reductions elsewhere in the tax system. This is the application of tax that is favoured by economists, because it shifts the tax system from taxing 'goods' (for example income) towards taxing 'bads' (pollution).

To address concerns about potential regressive nature of the tax, a Low Income Climate Action Tax Credit was introduced (World Bank Group, 2017). Launched in 2008, it was designed to offset the impact of carbon taxes on individuals and families. In addition, a Northern and Rural Homeowner benefit was provided to citizens in north and rural areas of British Columbia because they argued they had higher heating and transport costs. British Columbia's experience with the carbon tax provides an example of economists' favoured approach to distributional concerns and alleviating impacts of fuel price increases through revenue neutrality.

2.4.2 Effectiveness Impact Analysis

2.4.2.1 Impact on the effectiveness of the CPI

The carbon tax was introduced as a fiscally neutral instrument meaning that the potential increase in fuel prices as a result of the tax can be offset elsewhere in the tax system. Tax relief provided in the form the Low Income Climate Action Tax Credit, or the Northern and Rural Homeowner would not impact the price signal associated with the carbon tax.

2.4.2.2 Impact on the effectiveness of the existing policies

Due to the nature of energy spending among households of different income groups, the question of tax regressivity arose. Households in the lowest income decile in British Columbia spent 10% of their income on carbon based energy goods, while those in the top half of the income decile spent only about 4% of their income on the same goods category. Therefore, any carbon tax is likely to be regressive in nature (Murray & Rivers, 2015).

British Columbia had no fuel pricing policy prior to the introduction of the carbon tax with a liberalised energy market in place. But concerns about the regressive nature of the carbon tax meant that tax credits were introduced to low income and particularly exposed sections of society. Tax credits were introduced instead of any form of fuel price support in order to maintain the price signal associated with the carbon tax.

2.4.3 Policy Harmonisation

2.4.3.1 *Carbon tax changes*

Despite the favourable environment for the introduction of the tax, its implementation was not simple. In British Columbia, the public was particularly concerned about climate change and the presiding government had the support of business, which facilitated introduction of the carbon tax. However, despite the favourable socio-political circumstances, the introduction of the tax was not straightforward. Particularly, the carbon tax was introduced as a revenue neutral fiscal tool because of the concerns about disproportionate impacts on business and households that would be 'unfairly' burdened. Originally, no exemptions were provided for specific industries, but in 2012 greenhouse growers were allowed an exemption from the carbon tax in response to competitiveness concerns. This was extended in 2013, and in 2014 all fuels used in agriculture were exempt from the carbon tax (Murray & Rivers, 2015).

2.4.3.2 *Underlying policy changes*

No evidence suggests that existing excise taxes on fuel have been adjusted in response to the carbon tax. But other taxes including business taxes and personal income tax have been reduced as part of the revenue neutrality of the carbon tax.

2.4.4 Policy Impacts

2.4.4.1 *Impacts on emissions and carbon pricing signal*

The carbon tax has been found to reduce fuel consumption and GHG emissions, with reductions between 5-15% of a baseline level. Empirical evidence suggests that impacts on the economy are minimal. There may have been some negative impact on particularly carbon intensive industries, but this has been offset by gains elsewhere in the economy (Murray & Rivers, 2015).

2.4.4.2 *Underlying Policy Impact*

Any regressive impacts of the tax were mitigated by the introduction of tax credits for low income groups.

2.4.4.3 *Distributional impacts on households*

Any regressive impacts of the tax were mitigated by the introduction of tax credits for low income groups

2.5 Lessons learnt

Some jurisdictions took advantage of wider energy market reforms to introduce the carbon tax. In particular, the removal of fuel price stabilisation policies may be a necessary precondition for an effective carbon price signal. Mexico introduced the carbon tax within the context of wide ranging reforms of energy markets. There were several elements to this reform, including the liberalisation of oil and gas markets so others could compete with Pemex, and changes to floating excise taxes which were designed to stabilise fuel prices, toward a fixed rate. In particular the removal of the price stabilisation policy is a necessary pre-condition for the introduction of a carbon tax, since otherwise the price signal may not be passed through to final consumers.

However, in some cases the price impact of other reforms (such as removing price stabilisation) my dwarf the impact of the carbon price. The removal of the price stabilisation in Mexico contributed to a sharp increase in fuel prices, which appear to dominate those which occurred as a result of the carbon tax. The fuel price increases were very unpopular and resulted in protests. Sudden price changes are therefore met with hostility by the public used to subsidised fuel. Therefore, any shifts from offering fuel subsidies to a regime which taxes fuel consumption should be implemented gradually to let consumers and especially those most exposed to any change adjust to the new price level.

In designing the tax, a number of concessions may be necessary due to inflationary pressure and industrial competitiveness. In Mexico, concerns about the fuel price increase after the tax introduction, potential impact on general inflation levels and competitiveness of Mexican firms resulted in the carbon tax rate set at a limit of 3% of the price of the fuel. As part of a wider strategy to foster the natural gas industry, natural gas was determined as the reference fuel (the baseline) against which the carbon content of all other fuels was to be determined. Similarly, in B.C. despite the public support for the tax, a number of concessions were made to industry. Originally, no exemptions were provided for specific industries, but in 2012 greenhouse growers were allowed an exemption from the carbon tax in response to competitiveness concerns. This was extended in 2013, and in 2014 all fuels used in agriculture were exempt from the carbon tax (Murray & Rivers, 2015). In Ireland, the carbon tax was implemented in phases to let industry and households adapt to the change.

Jurisdictions have addressed distributional impact on low income groups in a number of ways, including revenue neutral tax policies and tax credits/ allowances. Ireland conducted various studies prior to the introduction of the carbon tax to determine expected impacts on low income groups, and provided further assistance to these through a fuel allowance. Similarly, B.C. introduced a tax credit scheme aimed at low income households alongside the carbon tax. Further, the B.C. carbon tax was set up as a revenue neutral policy tool, meaning that every dollar collected as part of the tax is returned to the society through reductions elsewhere in the tax system. Earmarking carbon tax revenues to offset the carbon tax can support low income populations and make the tax politically acceptable.

3 INTERACTIONS OF FUEL PRICING POLICY WITH EMISSION TRADING SCHEMES

3.1 INTRODUCTION

Energy intensive industrial sectors have potential for significant energy savings, which has brought them into the focus of energy efficiency and climate change programmes all around the world. A number of policy and fiscal instruments have been applied to reduce industrial GHG emissions, which offers a variety of examples for the analysis of policies' effectiveness and their interaction.

While there are multiple countries which have implemented carbon and energy policy tools in the industrial sector, this study focuses on the UK, as it presents a very rich example of the interaction between fuel pricing policies and emissions trading schemes (ETS). In particular, this study will analyse the application of the UK Climate Change Levy (CCL) (UK Government, n.d.-c), a linked scheme of Climate Change Agreements (CCA), a specific form of the CCL implementation in the energy generation sector through the Carbon Price Support (CPS) as well as its interaction with the European Union Emission Trading Scheme (EU ETS).

Recognising the differences between the electricity generation sector and non-residential energy consumers, the CCL was applied differently to these sectors. The analysis provided in this chapter will focus on the (1) industrial and (2) electricity generation sectors, providing separate case studies, with each of the two sectors analysed in depth[7].

3.2 CCL IN THE UK INDUSTRIAL SECTOR

3.2.1 OVERVIEW OF THE INDUSTRIAL SECTOR. CCA INTRODUCTION AS A RESPONSE TO CCL.

CCL Overview

The CCL is a levy on energy used by the non-domestic sector which was introduced as an incentive to increase energy efficiency. It applies to electricity, natural gas, LPG and solid fuel consumption. By increasing the effective price of energy, the levy intends to encourage greater energy efficiency and lower energy use. In addition, the CCL aims to help the UK meet its legally binding climate change commitments to reduce its GHG emissions at the national (through the UK Carbon Budget) and EU levels (through the Nationally Determined Contribution). When introduced, the CCL was expected to reduce the UK carbon dioxide emissions by at least 2 MtC by 2010, whereas some assessments forecasted the expected savings at 3.5 MtC in the same period (Seely & Ares, 2016).

[7] Note that while these sectors are the focus of this study, the CCL applies to all non-domestic energy consumption in the UK.

The CCL was first introduced on the 1st April 2001 and is collected by the UK government via energy suppliers at fixed rates. It is applied at various rates per unit of consumption to a range of fuels. These rates are revised and announced by the government every year. In the industrial sector, the main rates of the CCL apply (see Table 6).

Table 6 - Main rates of CCL 2016 – 2019

Taxable commodity	Rate from 1 April 2016	Rate from 1 April 2017	Rate from 1 April 2018	Rate from 1 April 2019
Electricity (£ per KWh)	0.00559	0.00568	0.00583	0.00847
Natural gas (£ per KWh)	0.00195	0.00198	0.00203	0.00339
LPG (£ per kg)	0.01251	0.01272	0.01304	0.02175
Any other taxable commodity (£ per kg)	0.01526	0.01551	0.01591	0.02653

Source: HMRC (UK Government, n.d.-b).

CCA Overview

In order to ease the tax burden after the introduction of the levy and soften its effects on the international competitiveness of the UK industry, alongside the implementation of the CCL, in 2001, the government designed a voluntary support mechanism called the Climate Change Agreement (CCA). The CCAs allowed energy intensive companies in the industrial sector claim a discount on the levy if they committed to emission reduction targets. Thus, the CCA was expected to reinforce the objective of the CCL and encourage energy efficiency supporting the UK in meeting its binding climate change commitments. As voluntary agreements between the industry and the government, and administered by the trade associations, the CCAs were initially available only a limited number of industrial activities. These included aluminium, cement, ceramics, chemicals, food and drink, foundries, glass, non-ferrous metals, paper and steel. As time has passed, the number of sectors and facilities has expanded. [8] At present, 54 energy intensive sectors are eligible to become party to a CCA (UK Government, n.d.-a).

8Today sector coverage is much larger and includes less energy intensive sectors such as motor manufacturing and laundries, and most recently, sectors such as milling and Data Centres

The CCAs are set up in a way requiring companies to regularly assess their performance. By signing up to a CCA, companies adopt binding energy efficiency targets on their energy consumption for a period of 10 years broken down into 2-year milestone periods. While being a party to a CCA, they receive a significant discount on the CCL rate: up to 90% (increased from 80% in 2012) on electricity and up to 65% on other combustion fuels. At the end of each two-year target period, the actual energy efficiency performance is being compared to the target for that period. If the energy performance outperforms the set target, the operator will receive surplus credits which can be used in the following target periods and keep the eligibility to claim the CCL discount further. If the target, however, is not met and the operator does not have surplus credits to use, a penalty (called a "buyout") is imposed, based on how far from target the performance has been. In case a company decides not to pay the buyout fee, it loses the right to claim CCL discount.

Types of target under CCA

The CCAs set up energy efficiency targets for each facility joining the scheme. The targets can be **relative**, i.e. energy consumption assessed per unit of output, or **absolute**, i.e. energy consumption assessed irrespective of the production level. The targets are set on the sectoral level and their type has been agreed upon as a result of the initial negotiations. The ambition of the negotiated energy (or carbon) efficiency targets was based on the assessment of the energy saving potential and possible energy saving opportunities available to each specific sector.

All but two sectors have opted for relative targets as they prevent fluctuations in the future output level from affecting performance level and compliance efforts. However, absolute targets may be interesting for sectors anticipating a decrease in production.

EU ETS Overview

The EU ETS is one of the major EU-wide climate change policies. It sets a cap on the overall GHG emissions from a range of sectors in the EU and allows installations covered by the scheme to sell or buy generated emission savings.

The UK, however, introduced a pilot emissions trading scheme prior to the EU ETS. The UK Emission Trading Scheme was introduced in 2002, which is three years before the EU ETS was launched, and was designed to run until 2006, to achieve three objectives:

- to secure cost-effective GHG emissions reductions;
- to give UK companies early experience of emissions trading, with a particular view to being ready for the EU ETS;
- to encourage the establishment of an emissions trading centre in London.

Participation in the UK ETS was voluntary and open to both the public and private sectors. In order to establish a market for emissions allowances, the UK Government held an incentive auction in March 2002. That government made £300 million of funding available, and entities bid for that funding according to the level and price of emission savings that they could make. Allowances were allocated for the most cost-effective savings that could be achieved with the fund value available. The UK ETS was terminated and succeeded by the EU ETS in 2006.

3.2.2 CCL and CCA interaction with the EU ETS

The described policy instruments applied to the UK industrial sector interacted in a number of ways which can be considered overlapping or complimentary depending on the implementation aspect. A detailed analysis of their interaction is provided further.

3.2.2.1 *Policy instruments' overlaps*

Overlapping policy instruments

The CCL/CCA overlap with the EU ETS since they impose GHG and energy efficiency obligations on the same industrial entities and the same energy vectors (fuels combusted). As an example, an industrial operator which is simultaneously covered by all three instruments/policies in question will face the following options and obligations:

- CCL (mandatory): pay a tax on the consumed energy (electricity and combustion fuels);
- CCA (optional): can choose to adopt an energy efficiency target and receive discount on the energy and fuels covered by the CCL;
- EU ETS (mandatory): surrender European Union Allowances (EUAs) equivalent to the GHG emissions from fuels combusted on site. (Note there are also obligations on process emissions).

Effectively, both the CCA and the EU ETS will apply to the energy consumption already covered by the CCL, meaning that a double layer of incentives applies to the same energy consumption. In order to minimise the overlap, the energy consumption reported under the EU ETS is excluded from the CCA performance measurement, but it can enjoy the reduced CCL rate.

Double carbon pricing

An additional incentive to reduce energy consumption faced by industrial entities is the carbon cost which is imposed by the climate regulations and is then passed through in electricity prices to the final consumers. An early UK policy brief (Sorrell, 2003), made at the time of the implementation of the EU ETS, indicated that thermal electricity generators would have passed a portion of allowance costs onto electricity consumers, many of which would be either subject to the CCL or signatories to the CCAs. The impact of this double cost on electricity prices would depend in part upon the allowance price in the EU ETS – the higher the allowance price, the greater increase of the electricity price can be expected. The study also estimated the impact of the EU ETS on electricity prices by stating that even relatively low allowance prices could increase average electricity prices by as much as the level of the CCL. This results in a double carbon pricing on the electricity consumed by industrial entities, which includes both the EU ETS and the CCL carbon cost.

Table 7 summarises the regulatory incentives faced by an industrial entity that is covered by the CCL/CCA and the EU ETS and they apply per fuel.

Table 7 - Summary of incentives energy vectors faced by industrial entities through CCL/CCA and EU ETS

Energy vector	CCL	CCA	EU ETS Industry sector
Combustion fuels	✓CCL covers fuel combustion.	✓ CCL discount for entity adopting a CCA. Excludes fuels covered by the EU ETS.	✓EU ETS covers fuel combustion.
Electricity	✓ CCL covers electricity consumption.	✓CCL discount for entity adopting a CCA	✕Electricity consumption is not covered under the EU ETS. (However, carbon costs is passed through electricity price).

Source: Ricardo Energy & Environment.

3.2.2.2 Instruments' complementarity

The key question is whether the CCL/CCA and the EU ETS overlap is efficient. To assess its efficiency, it is necessary to highlight important differences in the objectives and design of the considered instruments.

Policy Objectives

Whereas the CCL/CCA and the EU ETS have similar environmental objectives, these are not identical - the table below highlights their differences (Table 8).

Table 8 - Comparison of the CCL/CCA and EU ETS objectives

Objectives	CCL/CCA	EU ETS
Absolute reduction in GHG emissions	+	++
Absolute reduction in energy consumption	++	+

Improving energy efficiency of activities	++	+[9]
Improving carbon intensity of activities	+	+
Stimulating Energy Efficiency markets	++	+
Stimulating Renewable Energy markets	-	+
Improving energy security	++	+

Source: Ricardo Energy & Environment.

While both instruments can achieve multiple objectives at once, their primary focus (++) does not lie in the same areas. The main objective of the EU ETS is to provide incentives to reduce GHG emissions, whereas the main objective of the CCL/CCA is to provide an incentive for energy efficiency. As such, these instruments allow the UK government to achieve different policy objectives, and to impose stronger incentives through double regulation.

Instrument Design

In addition to the different objectives, the instruments have a number of design differences, which result in different incentives. These can be found in three areas.

Energy vs GHG targets. Energy and GHG targets can be complementary as they focus on closely related but different aspects. While those instruments which focus on GHG reductions might not fully address energy reduction opportunities as in case of switching from fossil fuels to biofuels which reduces emissions but does not improve energy efficiency, the energy efficiency improvement alone cannot guarantee GHG emission reduction. In this way, setting a price on carbon via EU ETS is expected to deliver the cheapest form of GHG emissions abatement, but may not necessarily reduce energy consumption. Meeting an energy based target established through CCL/CCA could, on the other hand, misses the opportunity to address non-energy GHG emissions since obliged entities are merely incentivised to reduce energy consumption. The complementarity of these target types appears particularly important while making fuel choices.

[9] Whilst in most cases it is expected that reduction of GHG emissions will go in line with energy efficiency improvements, in certain instances the opposite effect can be observed. As an example, switching to biofuels, which have a lower energy content per unit of fuel than fossil fuels, will contribute to emissions reduction while also decreasing the overall energy efficiency.

***Absolute vs Relative targets**.* The target type provides another area for instrument complementarity**.** In the EU ETS, an absolute emissions cap is applied at the system level, with annual reduction targets. This approach was taken to ensure an absolute emission reduction across the EU, regardless of the economic trends. The majority of targets in the CCA, however, are relative. A relative target requires a reduction in energy per unit of output, e.g. MWh per tonne of production. This approach is primarily linked to the economic performance of the regulated companies and ensures that energy improvements take place regardless of the production volumes.

The choice of the target type is usually determined by the primary objective of the instrument. The absolute targets are chosen when the primary objective is to reduce total emissions or energy consumption, whereas relative targets are applied to incentivise improvements in efficiency. It should be noted that, for those two CCA covered sectors which adopted absolute energy targets, the link to meeting obligations under EU ETS is direct. However, the same is not always true for sectors with relative targets, where improving energy efficiency without reducing absolute GHG emissions (e.g. due to an increase in production), will not help them meet the EU ETS obligations.

In addition to this, the considered target types also have different impacts on companies' growth. The use of relative targets in the CCAs means that output and emissions could grow as long as relative emissions decrease. The EU ETS incentivises absolute reductions disregarding economic performance of the complying businesses, however, measures are in place to minimise possible negative impacts on the economic growth.

Point of regulation**.** Energy or emissions can be regulated at various points in the supply chain. In the UK, emissions associated with electricity are regulated by the EU ETS at the point of production (upstream), and the energy consumed is regulated by the CCL/CCA at the point of consumption (downstream). Together these measures allow to address both the energy generation sector, encouraging generators opt for a more sustainable fuel mix, as well as the industrial sector incentivising more environmentally friendly procurement and technical solutions.

3.2.2.3 *ASSESSING POLICY OVERLAP AND IMPACTS ON INSTRUMENT EFFECTIVENESS*

The interactions described above can have both positive and negative effects on the effectiveness of the instruments depending on how harmonised they are. Two major aspects of the interaction of the CCL/CCA and EU ETS are related to the strength of created incentives and regulatory burden.

Two-point regulation provides stronger incentives. One of the key questions in this analysis is whether it is beneficial to have both up and downstream incentives. The advantage of having both is that it allows the regulator to impose direct incentives on generators and consumers in order to alter their behaviour. At the time of implementation (Sorrell, 2003), the UK government's view was that price signals are less effective than downstream targets in incentivising electricity efficiency. While the carbon cost pass through creates an incentive for more efficient use of electricity, depending on consumption elasticity, it may be insufficient, or may not be sufficiently visible to end-users, to drive significant improvements in industrial electricity use. The direct obligation, in turn, increases this incentive. Indeed, the same study suggests that in a context of low energy prices and low ETS allowance prices, there would be some appeal in retaining some of the CCL/CCA package unchanged, in order to maintain downstream incentives to improve energy efficiency.

Double regulation increases administrative and participatory costs. While there may have been a strong rational to have overlapping policies, this situation results in increased administrative complexity and regulatory burden for the obligated entities, and consequently, increased costs for the final consumers. Policy makers sought to design the two instruments to try to minimise the regulatory burden and unnecessary double regulation on industrial entities, as for example, individual entities are not required to report, or comply with obligations, for the same energy under multiple systems. In addition, they have implemented a number of compensatory measures for households, businesses and industry.

As such, the overall impact of the policy interaction on the considered policy instruments can be summarised as follows.

Impacts on effectiveness of the EU ETS

The existence of an overlapping policy can be considered inefficient from the perspective of the EU ETS, since it creates preferential incentives for where the abatement should come from, rather than allowing entities the flexibility to determine their abatement choices, responding to the carbon price signal. This effectively contradicts the main principle of establishing an ETS. In addition, if the effect of such measures is not taken into consideration when determining the ETS cap, the cap will be set too high, which, in turn, will weaken the carbon price signal. The weaker price will have a spill-over impact on the abatement in other sectors, while the overall cap is restricted ensuring the overall emission reduction. This would not prevent the policy from meeting its original abatement levels but would prevent incentivising full emission reduction potential of the covered industry sectors.

Impacts on effectiveness of the CCL/CCA

In terms of the effectiveness of the CCL, the existence of the EU ETS is expected to reduce the revenues raised by government through the tax as a result of incentivising lower energy consumption. However, raising fiscal revenue is not the primary objective of the CCL and, indeed, the CCAs already provide a considerable discount on the levy. As for the target setting, the CCA targets are set recognising the incentives which were created under the EU ETS, in order to minimise the overlap. Otherwise, the EU ETS would make it more likely that a CCA targets were achieved, but would have only indirect impact on relative CCA targets.

3.2.3 Policy harmonisation

As the considered policies co-existed, the UK government sought to maximise synergies and minimise the burden of overlap. As part of the process of harmonisation, a number of changes have been made to both the CCL/CCA and the EU ETS. These changes will be considered further.

3.2.3.1 EU ETS changes caused by the interaction with the CCL/CCA

Exemptions for UK industry

In order to facilitate introduction of the EU emission regulations, businesses in the UK industry were granted exemption from the EU ETS in the first phase if they could demonstrate that they were achieving emissions savings through the CCA policy. While the European Commission (EC) intended for the EU ETS to be mandatory from phase one, this was opposed by the UK and Germany who were seeking to protect their existing negotiated agreements with manufacturing industry. Thus, the exemptions for well-performing CCA participants were permitted during Phase 1 of the scheme (2005-2007), but participation became mandatory from Phase 2 (2008-2012). Currently, in Phase 3 (2013-2020), only small installations and hospitals can opt out from the EU ETS in the UK (UK Government, n.d.-d).

Possible double regulation risks during Phase I EU ETS interaction with CCL/CCA

As mentioned, during Phase I the Commission allowed exemptions for certain installations and sectors. The UK industry had two options: a) opt out from the EU ETS but retain the CCA agreement or b) retain the CCA agreement and also be covered under the EU ETS. This created a range of possible double regulation risks, which are described below for illustrative purposes. Note, however, that these are hypothetical examples, and measures were applied to avoid them.

If a site opted for option b, then the interaction between EU ETS and CCA created a double counting problem. This implies that GHG emissions from energy use covered by the CCA would also have been included in the EU ETS compliance. In this case, if a site was to reduce emissions, then it would have had a surplus of allowances for sale within the EU ETS market. The same reduction in emissions may also have meant that the operator over-performs against its CCA target, so there would be an additional benefit under this scheme in the form of banked energy saving credits which can be used to comply with targets in later phases of the CCA scheme. In other words, the site would have had benefits in both EU ETS and CCA schemes for the same reduction in emissions. Conversely, if emissions were to increase, a site may find itself forced to pay a penalty under their CCA as well as purchase EU ETS allowances.

EU ETS cap accounted for the effect of CCL/CCA. In first two phases, the EU ETS, the caps were set as an aggregation of national caps. In order to ensure that the EU ETS price signal was not weakened, cap setting in the UK took into account the effect of CCL/CCA policies, and ensured that emission reductions required under the EU ETS were additional to those already expected as a result of existing policies (UK Government, 2004).

3.2.3.2 CCL/CCA CHANGES CAUSED BY THE INTERACTION WITH THE EU ETS

No changes to the CCL. Operators under that system were still required to pay the CCL on their fuel consumption, even if those fuels were reported under the EU ETS.

CCA design evolved to minimise overlap. As the CCA policy evolved, policy makers made efforts to minimise the overlap with the EU ETS, and reduce the risk of double regulation on industrial entities. The UK government decided that it would be preferable to remove the EU ETS emissions from the CCA targets, and avoid overlap of the instruments. Thus, all the energy covered by EU ETS would have been removed from the CCA performance measurement scope and the CCA reported energy consumption would be determined only by considering energy not covered by EU ETS (i.e. electricity and not EU ETS covered combustion fuels). The EU ETS covered energy consumption would still, however, remain within the CCA facility boundaries allowing the operators to claim CCL discount. This resulted in a situation where the target for the fuel use on site was provided by the EU ETS, while the CCA encouraged more efficient electricity consumption.

3.3 CCL IN THE UK ELECTRICITY GENERATION SECTOR

3.3.1 ELECTRICITY GENERATION SECTOR OVERVIEW. CPS INTRODUCTION

CPS Overview

Recognising that the electricity sector is unique with regards to energy consumption, the government treated the sector differently at the time of the CCL introduction. The electricity generation sector has been completely exempt from the CCL up until April 2013, when a special rate of the CCL was introduced. This special rate, called Carbon Price Support Rate (CPS), applies to electricity generators and certain CHP operators, whereas certain smaller generators don't have to pay CPS rates.

The CPS was designed to top up the EU ETS carbon allowance (EUA) price in order to achieve a predetermined overall target price trajectory following the collapse of EUA prices. This price trajectory is known as the carbon price floor. The primary objective of the policy is to provide a stable, predictable and sufficient carbon price to encourage investment by power generators in low carbon electricity generation capacity, in order to decarbonise the UK power sector. As such, this was an element of fossil fuel policy in the UK which was designed specifically to address a weakness of the EU ETS in the UK, in order to support the UK in meeting climate change and energy efficiency objectives.

The CPS rates are presented in Table 9. The rates are determined based on the average carbon content of the fuels, and designed to provide a target carbon price floor rate relative to the EU ETS.

Table 9 - CPS rate of CCL

CPS rate commodity	Gas	LPG	Coal and other solid fossil fuels
Unit	£ per kWh	£ per kg	£ per GJ on gross calorific value (GCV)
1 April 2015 to 31 March 2016	0.00334	0.05307	1.56860
1 April 2016 to 31 March 2019	0.00331	0.05280	1.54790

Source: HMRC website (UK Government, n.d.-b).

3.3.2 CPS INTERACTION WITH THE EU ETS

In this section, the expected interactions between the CPS and the EU ETS will be described, and subsequently the impact on their effectiveness will be analysed.

Complementary policy instruments

According to the White Paper on Electricity Market Reform (DECC, 2012), the carbon price resulting from the EU ETS cap has not been stable, certain or high enough to encourage sufficient investment in low-carbon electricity generation in order to meet the UK's commitments under the Climate Change Act. One of the main reasons for a low carbon price is the fact that there were too many allowances available on the market. Thus, the UK government decided to introduce this complementary policy in order to provide the robust and reliable incentive that the EU ETS was failing to deliver. The CPS establishes a minimum price that UK electricity generators must pay for carbon allowances. As mentioned, the CPS was designed to top up the EUA price, in order to achieve a predetermined overall target price trajectory. Therefore, CPS can be considered as a complimentary policy to the EU ETS.

Impact on the effectiveness of the EU ETS

The introduction of the CPS was expected to strengthen the effectiveness of the carbon pricing by increasing the cost of carbon allowances and therefore incentivise investments in low-carbon electricity generation technologies. The CPS rate is calculated annually for two years in advance, by taking into account inflation adjusted current and forwards EUA prices. The initial CPS trajectory was reaching £30/tCO_2 in 2009 prices by 2020 (DECC, 2012).

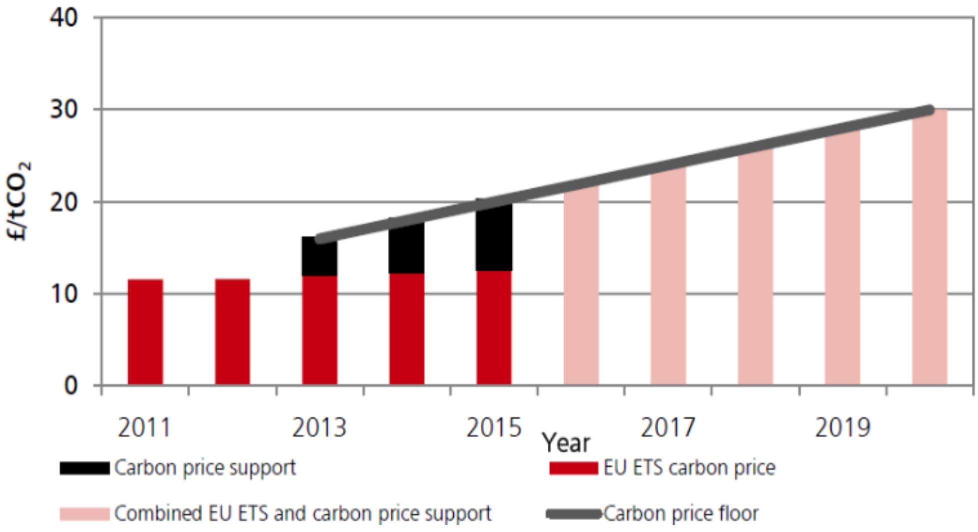


Figure 4 - Carbon Price Floor future estimates. The carbon price floor is shown in its two components: the carbon price support and the EU ETS carbon price

Source: (Sandbag, 2012).

Impact on the effectiveness of the CPS

The interaction of tools can be considered complementary. This is primarily due to the fact that the floor is designed to provide an incentive to invest in low-carbon power generation, and to complement the EU ETS.

3.3.3 Policy harmonisation

Similar to the policy harmonisation process which happened in the industrial sector, the instruments applied to the electricity generation sector went through a series of adjustments to enhance their interaction.

3.3.3.1 EU ETS changes caused by the interaction with the CPS

No changes to the EU ETS. Since the CPS was introduced as a complementary measure to the EU ETS and, therefore, its design was adjusted to the EU ETS mechanism, no changes to the EU ETS took place.

3.3.3.2 CPS changes caused by the interaction with the EU ETS

CPS rate capped due to low EU ETS prices. As for the effect of the EU ETS on the CPS, the UK government decided to cap the CPS because of the significant cost effect of the policy. As time has shown, the EU ETS prices did not rise to the expected level and are now substantially lower than it was forecasted when the carbon price floor was introduced. It argued that if kept in place at the original trajectory, the carbon price floor would cause a large and increasing gap between the carbon price faced by UK energy users and those faced abroad (HM Revenue & Customs, 2014). This would result in UK firms facing significantly higher energy prices than their competitors abroad as well as raising energy bills for households.

As a result, in March 2014, the UK Government announced a reform of the carbon price floor. The carbon price support (CPS) rate per tCO_2 was to be capped at a maximum of £18 from 2016-17 until 2019-20. This effectively freezes the CPS rates for each of the individual taxable commodities across this period at around 2015-16 levels. The government justified this measure as aiming to support UK business competitiveness and help to restrain increases in household energy bills, while still maintaining the incentive to invest in low-carbon generation.

3.4 Policy impacts

As the analysis above has demonstrated, the considered policy instruments have interacted in various ways and have undergone a series of changes. As a result, even though their effects varied, all of them achieved certain level of impact both on the UK GHG emissions and electricity prices. These impacts will be analysed in this section.

3.4.1 Effectiveness of policy instruments

CCL

The CCL was the first major climate change policy affecting the business sector to be announced by the UK government and was expected to make a considerable contribution to the national emission reduction. Alongside the CCAs, it was expected to make a significant contribution to the government's target of cutting annual UK GHG emissions. It was forecasted to achieve an annual savings of 5.4 MtC between 2001 and 2010 contributing towards the 36 MtC needed to meet the national target.

A study published by the UK National Audit Office (National Audit Office, 2007) concluded that the CCL had driven energy efficiencies and emissions reductions relative to business as usual scenarios in both energy intensive and less intensive industries. Analysis suggested the levy had also raised managerial awareness. However, its impact on energy prices was assessed to have been limited. The NAO study went on to conclude that "the extent to which the CCL has impacted on emissions, energy prices and has driven further energy efficiencies in more recent years is harder to discern, especially as it has been joined by other policies and drivers since its introduction." (National Audit Office, 2007).

CCA

Through establishing the energy efficiency targets, the CCA encouraged businesses to reduce their energy consumption resulting in a decrease of GHG emission, achieving significant emission savings.

Based on the data reported by the CCA participants, since it was established, the scheme has achieved the following savings (Department of Energy & Climate Change, n.d.):

- During the first target period (2001-2002) 24 out of 44 sectors have met their targets. The cumulative absolute energy saving as a result of the agreements compared to the baseline years was 228PJ, which is equivalent to 16.4 MtCO_2,
- During the second target period (2003-2004) 21 out of 42 sectors met their targets and 14.4 MtCO_2 emissions were saved per annum,
- During the third period (2005-2006) 32 out of 49 sectors reporting met their targets and 16.4 MtCO_2 per annum were saved in total compared to sector baseline,
- During the fourth period (2007-2008) 36 out of 52 sectors reporting met their targets and 20.3 MtCO_2 per year emissions were saved in total compared to sector baseline,
- During the fifth period (2009-2010) 38 out of 54 sectors reporting met their targets and 28.8 MtCO_2 per year emissions were saved in total compared to sector baseline

In total, over the considered period (2001-2010) the additional GHG emissions savings incentivised by the CCAs added up to almost 100 MtCO_2. The CCA has also contributed to increasing managerial awareness of the energy performance in participating companies.

CPS and carbon price floor

The effect of CPS was limited. The CPS rate is meant to create a carbon price floor for the EU ETS for electricity generators. Although effects have not yet been assessed, the effectiveness was limited by the capping of the CPS rate as described earlier.

EU ETS

Despite certain inefficiencies which the EU ETS has faced as a result of the drop of the EU ETS price in the first to phases of the scheme, a study by the Grantham Institute (Muûls, Colmer, Martin, & Wagner, 2016), claims that the introduction of the scheme did lead to the reduction in industrial carbon emissions without causing detrimental effects on the economic performance. The scheme has also been partly responsible for the increase in low-carbon 'cleantech' innovation since 2005. While there are opportunities for further improving the EU Emissions Trading System (ETS), evidence suggests that it is worthwhile maintaining and developing this landmark policy.

Considering the EU ETS implementation in the UK, the Carbon Trust estimated (Carbon Trust, 2005) that the scheme has delivered a total of 1.6 MtCO_2e GHG emission reductions between 2005-2010, as a result of EUA sales, electricity price effects, and allowance cutbacks.

3.4.2 Distributional impacts on households and industries

While the climate change and energy efficiency related policies in the industrial sector are primarily affecting the businesses, inevitably part of the additional costs borne by the industry is being passed on to the non-residential energy consumers. A recently published study from the Committee on Climate Change has evaluated how the UK's carbon budgets and related policies have affected energy bills for households and businesses (Committee on Climate Change, 2017).

The study explains that electricity prices of the household sector have risen by 61% between 2004 and 2016, with 25% of this increase due to the impact of climate policies. In particular, the study suggests that the impact of EU ETS allowances and the UK CPS on the wholesale electricity price is responsible for the largest share of the price increase caused by the climate policies (about half). Similarly, natural gas prices have also increased over the same period, but this increase occurred mainly due to the rise in wholesale, network and supplier costs. Only 3% of the natural gas price increase is estimated to be related to climate policies.

The above-mentioned study carried out by the Committee on Climate Change (Committee on Climate Change, 2017) also performed an estimate of future energy bills trends. It suggests that the bill impact of shifting to low-carbon electricity will continue to increase slowly, but is likely to be more than offset by continued improvements in energy efficiency. Figure 3 provides a visualisation of the estimated future increase and offset expected due to energy efficiency implementation.

Considering the effects of the climate change policies on businesses, it is recognised that they have increased energy prices, and hence operational costs. Nevertheless, they appear to have had only a limited impact on the total costs of production for the majority of businesses since energy costs do not comprise a significant share of their expenses. Very energy-intensive industries, in turn, are considered for compensation, such as CCA and the compensation for indirect costs of EU ETS (further information provided in the box below), which lower the impacts of the energy price increase. Finally, the above-mentioned study suggests that the costs for businesses associated with low-carbon policies are expected to rise to about 0.5% of operating costs for the commercial sector, 1.0% for manufacturing and 1.6% for energy-intensive sectors by 2030.

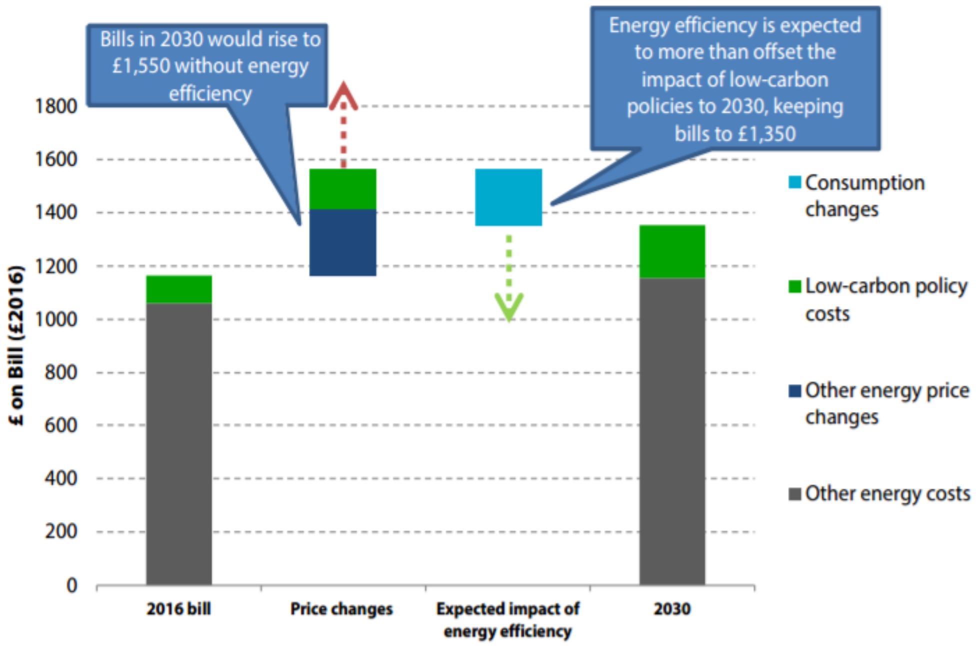


Figure 5 - Central estimated changes in annual household energy bill from (2016 to 2030)

Source: CCC analysis (Committee on Climate Change, 2017).

Cost Compensating Policies

In order to offset extra costs created for the energy consumers as a result of the climate change and energy policies, the government has introduced a number of policy measures aimed at decreasing the cost effects on the energy consumers. In addition to the CCA introduction as a response to the cost of CCL and capping carbon price floor rates, which were already described above, the UK government introduced further measures to compensate the cost of the policy instruments or limit their impact.

Free allocation under the EU ETS. Free allocation under the EU ETS has evolved with time, moving toward an EU-wide and fully harmonised allocation rule from Phase III. The European Commission (EC) describes how this has evolved over time:

- For Phase I and II each Member State (MS) would propose the number of allowances to be allocated to each installation in National Allocation Plans (NAPs) submitted prior to the start of the phase. These NAPs were subject to the EC approval. During these two phases, most allowances were given out to participants for free.
- In Phase III sectors that are deemed to be at risk of carbon leakage continue to receive 100% of the determined quantity by the free allocation, based on ambitious benchmarks. For remaining sectors, a mixture benchmark based free allocation and auctioning is being used. The quantity of allowances allocated for free decreases through the phase, going from 80% in 2013 to 30% in 2020, with the intention of no free allowance by 2027.

- The power generation sector is treated differently. At the start of Phase III it has generally been subject to 100% auctioning and no free allocation is given.

UK government compensation for EU ETS and CPS costs. The UK government has published, in 2015, the document “Compensation for the indirect costs of the EU Emission Trading System and the carbon price support mechanism from 2015” where it is recognised that carbon pricing through the ETS and the Carbon Price Support (CPS) mechanism will have a knock-on effect on the wholesale electricity price, increasing retail electricity prices in the short to medium term and, therefore, posing a key risk to the competitiveness of the most electricity-intensive businesses in the UK.

To address this, the document introduces a compensation scheme to minimise the effect of the competitiveness of the national energy intensive sectors and sets out how businesses can claim compensation for the indirect costs of EU ETS and CPS. These compensation mechanisms are in accordance with the European Commission’s “Guidelines on certain State aid measures in the context of the greenhouse gas emission allowance trading scheme post-2012”. The UK Government has committed to compensate those electricity intensive industries who are considered at risk of carbon leakage in order to help offset the indirect cost of the EU ETS. As of October 2014, 53 companies had been paid over £44 million, mitigating around 65% of these costs.

Exemptions from CCL for selected energy intensive industry sectors. In addition to those measures introduced earlier to support energy intensive sectors, from 1 April 2014, taxable commodities used in mineralogical or metallurgical processes were granted a CCL exemption for eligible energy intensive industrial processes. The exemption ensures the UK tax treatment of highly energy intensive processes is in line with tax treatments elsewhere in the EU, thereby reducing any distortion of competition. Exemption for mineralogical or metallurgical processes does not require committing to any energy efficiency targets and grants CCL exemption purely based on the industrial process type. For this reason, after the introduction of the new exemption scheme, many eligible businesses which were previously parties to CCAs saw no further benefit in maintaining them. As a result, the CCA emissions and sectoral coverage decreased. The mineralogical and metallurgical exemptions do not have interaction with the EU ETS. Therefore, sites covered under the EU ETS continued in participate in the scheme.

3.5 Lessons learnt

3.5.1 Industrial sector

The introduction of the EU ETS on top of the existing UK policy scenario (CCL/CCA) was expected to overlap since both policy instruments impose GHG and energy efficiency targets on the same industrial entities, and the same energy vectors (fuels combusted and electricity consumed). However, despite this overlap, these policies objectives are not identical and may be complementary. As such, there is certain rationale to have overlapping policies, however, this results in increased administrative complexity and regulatory burden for the obligated entities, and consequently, increased costs for the final energy consumers.

Policy makers should seek to design the two instruments to try to minimise the regulatory burden and unnecessary double regulation on industrial operators. If direct incentives for energy efficiency are provided through levies on fuel and electricity consumption at the industrial level, it should be recognised that an ETS would similarly impose a direct incentive to reduce fuel combustion. Following the experience of the UK government, it may be necessary to reduce the created burden on industries, for example through discounts offered through participation in the energy efficiency scheme.

Policy makers should consider whether it is appropriate to have both upstream and downstream regulation in the case of electricity consumption. There may be an advantage in having a downstream incentive (energy levy) in addition to the upstream carbon price (ETS on electricity generation), which is passed through in electricity prices. The UK government has opted for both up and downstream incentives as the view was that price signals are less effective than downstream targets in incentivising electricity efficiency

The level of administrative costs resulting from overlapping policies should be considered. As the UK experience has demonstrated, the question of reducing the administrative burden and costs for the participating entities is crucial for successful policy operation.

3.5.2 Electricity sector

Fossil fuel levies can be used as a mechanism to support the ETS price, through the creation of a carbon price floor, as the UK government did with the introduction of the CPS. The objective was to provide robust and reliable incentive that the EU ETS failed to deliver, and therefore incentivise investments in low-carbon electricity generation technologies. However, there is a risk that if the ETS price does not behave according to expectations, the floor price may need to be adjusted.

If such carbon price floor is adopted, policy makers should acknowledge the risk that the ETS carbon price may not behave according to expectation. Therefore, an in-depth analysis of potential ETS scenarios is required to ensure that the established carbon price floor is set at the appropriate level.

3.5.3 Compensatory measures

Compensatory measures for businesses, households and industries can also be considered in order to minimise the cost of the climate change and energy efficiency policies. This is particularly relevant in case of overlapping policies. A number of compensation mechanisms have been introduced in the UK to support energy intensive industry, beyond the introduction of the CCA (as a response to the cost of CCL) and capping carbon price floor rates. These compensations were implemented to address both the introduction of the UK legislative measures, such as CCA compensating for the effect of CCL, as well as wider EU policies, such as the EU ETS compensation scheme.

Firstly, the free allocation under the EU ETS, which became more stringent for the industrial sectors as the phases ensued. In PI and PII, most allowances were freely allocated, and auctioning was introduced in PIII for those not deemed at risk of leakage (for the latter, free allocation according to benchmarks was introduced). The power sector however was subject only to auctioning as of PIII.

Second, the UK government also developed national compensation mechanism. As a result of national and EU climate policies, wholesale electricity price were expected to increase in short to medium term. Indeed, electricity prices of the household sector rose by 61% between 2004 and 2016, and 25% of this increase was due to these climate policies. The compensation scheme allows businesses to claim compensation for the indirect costs, in line with EU state aid rules. As of October 2014, 53 companies had been paid over £44 million, mitigating around 65% of these costs. Evaluation shows that this scheme has been successful in limiting the impact on the final energy costs.

Finally, exemptions from the CCL were granted to selected energy intensive industry sectors. The mineralogical and metallurgical industries were granted exemptions based on their process types, and did not require committing to any energy efficiency targets.

3.6 Additional notes: Institutional arrangement and lessons learnt from implementing the CCL and CCA

3.6.1 Institutional Arrangements of CCL/CCA in the Industrial Sector

3.6.1.1 Institutional arrangements: Climate Change Levy

Target setting: Department for Energy and Climate Change (DECC), which became part of the Department for Business, Energy & Industrial Strategy in July 2016.

Administrator: HM Revenue and Customs (HMRC).

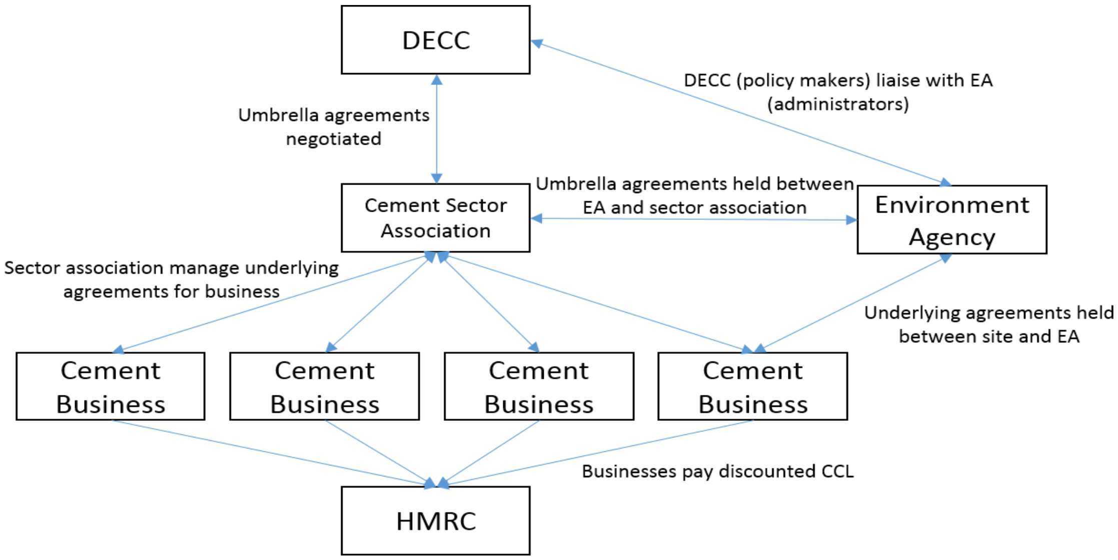
3.6.1.2 Institutional arrangements: Climate Change Agreements

Policy / targets: The Department for Business, Energy & Industrial Strategy are responsible for the policy, legislation and maintaining the Technical Annex and Statutory Guidance.

Administration: The scheme is administered by the EA. Ricardo Energy & Environment is the technical consultant to the CCA scheme.

Implementation support: Sector associations hold umbrella agreements with the EA, manage underlying agreements for businesses within their sector and deal with applications from operators in their sector that wish to join the CCA scheme.

Below is a flow diagram illustrating the scheme structure, using the cement sector as an example:



Dates of implementation and phasing. The CCL/CCA scheme was announced in 1999 and came into force in 2001. The first phase ran from 2001 – 2013. The latest phase started in 2013 and will run until 2023. There are now 4,300 underlying agreements covering 9,900 facilities across 53 sectors. All sectors that were eligible to hold a CCA in the first phase remain eligible.

3.6.1.3 COVERAGE, POINT OF REGULATION, PARTICIPANTS

Sectoral coverage: UK industrial, commercial, agricultural public and other services sectors.

Participants: Business and public sector organisations.

Eligibility for CCA: Energy intensive industrial companies can obtain a reduction on the main rates of CCL if they have entered into a CCA to improve their energy efficiency. CCA covers 53 energy intensive sectors. For an operator to be eligible to hold a CCA it must be carrying out an “eligible process”. The requirements of these are specific to each sector. Facilities apply for CCA through the relevant Sector Association. If an operator has more than one eligible facility in the same sector it could hold individual CCAs for each facility, or choose to group them together under one CCA. The target could then be shared across the grouped facilities.

Point of regulation: The CCL is levied on supplies of four types of taxable commodity consumed by participants, comprising electricity, natural gas, liquefied petroleum gas, coal and other solid fossil fuels[10].

3.6.1.4 COMPLIANCE ARRANGEMENTS

Regulatory measure(s): Primary legislation – Schedule 6 to Finance Act (FA) 2000 (as amended); the main rates are set out in paragraph 42(1) of Schedule 6 to the Act.

Paragraph 42(1) (ba) and (c) of Schedule 6 to FA 2000 provides that, for supplies of electricity only, 10% of the main rate is payable where a supply is a reduced-rated supply. For supplies of other taxable commodities, 35% of the main rate is payable where a supply is reduced-rated supply.

Secondary legislation – The Climate Change Levy (General) Regulations 2001 (SI 2001/838) as amended by the Climate Change Levy (General) (Amendment) Regulations 2013 (SI 2012/713).

Paragraph 2 of Schedule 1 to the Climate Change Levy (General) Regulations 2001 (SI 2001/838) (‘the Regulations’) sets out the formula used by businesses in the CCA scheme to calculate their CCL relief entitlement, including the reduced rate.

Enforcement mechanism(s): Suppliers who make taxable supplies (including taxable self-supplies) must notify HMRC and register for CCL within 30 days of the date of the first taxable supply or self-

[10] These are in full: electricity; natural gas as supplied by a gas utility; petroleum and hydrocarbon gas in a liquid state; coal and lignite; coke, and semi-coke of coal or lignite; and petroleum coke

supply. CCL is subject to HMRC's enforcement and compliance role in administering the UK's tax system.

3.6.1.5 MONITORING, REPORTING AND VERIFICATION (MRV) REQUIREMENTS

Monitoring: The measure is monitored through information collected from tax receipts.

Reporting: Suppliers registered for CCL must keep a Climate Change Levy account. Declarations of suppliers' CCL liability must be made to HMRC every 3 months via a CCL100 return form, or as an annual report for small businesses.

Verification: Suppliers must keep records that prove the amounts of CCL declared are correct for at least 6 years, and have to make all records available to HMRC if it asks to see them. The types of records that must be kept by suppliers include: Credit and debit notes; Climate Change Levy accounting documents (CCLADs); commercial invoices; PP11 CCL Supplier Certificates (supplied by their customers); and any bad debt accounting records.

No other MRV requirements.

3.6.2 CCL/CCA: LESSONS LEARNT AND DESIGN ADJUSTMENTS

CCL/CCA has been in place for approximately 16 years. Over this time, the following adjustments were made, in some cases to address specific challenges identified, .

3.6.2.1 LESSONS LEARNT

- **Improvement in target negotiations.** Target negotiations were initially done on a sector by sector basis. The process of negotiating and reviewing targets was then streamlined by offering voluntary sector amalgamation for target setting and reporting purposes.
- **Administrative costs imposed on participants.** When the scheme started, administrative procedures were undertaken by DECC at no cost to scheme participants. As the scheme developed, this was changed so that the scheme delivery was transferred to the Environment Agency and participants are charged an annual administrative fee.

3.6.2.2 ADJUSTMENTS DUE TO INTERACTING POLICIES

- **Regulatory overlap.** Initially there was an issue of regulatory overlap due to energy being covered by both CCAs and EU ETS. This was remedied by removing the energy covered by EU ETS from the CCAs reporting. It should be noted that although double counting was prevented, the decision created an extra administrative burden for the participants.
- **Changes to flexibility mechanisms.** Initially flexibility mechanisms which allowed risk management of costs to participants were carbon trading. CCA participants were able to bank, trade and retire UK Emissions Trading System allowances to assist with the achievement of

targets. This was then changed and in place of the UK emissions trading registry, a buy-out mechanism was introduced for scheme participants to account for any shortfall against targets. Furthermore participants gained the opportunity to 'bank' any overachievement against targets for a later date.

- **Changes to the main rates.** Although the rates are adjusted annually, the 2019/20 main rates are in the process of being increased in order to make up the shortfall from the scrapping of a complementary carbon pricing system (the CRC energy efficiency scheme), which had run from 2010 but which will cease in 2019.

3.6.2.3 CCL/CCA: Assessment of Political Acceptance

The policy is a key part of the UK's climate change programme and has been in force for 15 years, and is relatively well established and supported by policy makers and private sector participants. Two factors can have highlighted which improved the acceptability of the measure:

- **Revenue recycling**: All revenue raised through the main rates of the CCL is recycled back to business through a 0.3 per cent cut in employers' National Insurance Contributions (introduced at the same time as the levy), and through support to business for energy efficiency and low carbon technologies. This helped the CCL to gain acceptance from its introduction.
- **Discount on the CCL through the CCA**: CCAs were introduced alongside the CCL. Businesses that enter a CCA pay a reduced rate of CCL in return for meeting challenging energy efficiency or emissions reduction targets.

Sources	(Committee, 2008; HM Treasury / HMRC, 2015, 2016, 2016, 2016; House of Commons Library, 2009)

3.6.2.4 Institutional Arrangements of CCL in the Electricity Generation Sector

Target setting: Department for Energy and Climate Change (DECC), which became part of the Department for Business, Energy & Industrial Strategy in July 2016

Administrator: HM Revenue and Customs (HMRC)

Policy is set by DECC, and the scheme is administered by HMRC

Dates of implementation and phasing. 1 April 2013, no preceding instruments.(At time of implementation, the existing CCL only applied to the Industrial / Business sector, not electricity)

3.6.2.5 COVERAGE, POINT OF REGULATION, PARTICIPANTS

Sectoral coverage: the UK power sector. Fossil fuel commodities are liable for the carbon price support if they are a deemed supply for use in electricity generation,

Participants: power generation businesses in Great Britain (the CPS does not apply in Northern Ireland).

Point of regulation: with the tax point being the point the supply enters the generating station.

3.6.2.6 COMPLIANCE ARRANGEMENTS

Regulatory measure(s): Primary legislation – Schedule 6 to Finance Act 2000 (as amended); Secondary legislation – The Climate Change Levy (General) Regulations 2001 (SI 2001/838) as amended by the Climate Change Levy (General) (Amendment) Regulations 2013 (SI 2012/713).

Enforcement mechanism(s): Generators using the carbon price support rate are required to register with HMRC and must monitor the eligible electricity and fuel. This must be declared every 3 months. Records should be retained in line with the normal commercial accounting and taxation record keeping requirements. The levy is subject to HMRC's enforcement and compliance role within the UK's tax system.

3.6.2.7 MONITORING, REPORTING AND VERIFICATION (MRV) REQUIREMENTS

Monitoring: The measure is monitored through information collected from tax receipts.

Reporting: Generators registered for the levy must keep an account and report every 3 months. Support rates of the levy are paid when a taxable self-supply of fossil fuels electricity generation. A tax point (the point at which tax becomes due) is created when a quantity of the commodity arrives at the generating station e.g. the quantity of natural gas metered or quantity of solid fuel delivered.

For solid fuels, the levy amount is calculated based on the gross calorific value of the quantity of fuel delivered. Generators must keep records that prove the amounts of levy declared are correct for at least 6 years, and have to make all records available to HMRC if it requests them.

The types of records that must be kept by Generators include: commercial invoices for taxable commodities supplied for electricity generation.

No other MRV requirements.

3.6.2.8 LESSONS LEARNT AND DESIGN ADJUSTMENTS

As a relatively new measure, the key adjustment to note was as a result of interactions with overlapping policies.

Adjustments due to interacting policies:

- Due to the interaction with the EU ETS, the CPS rate has had to be adjusted in response to a collapse in EUA prices and concerns over escalating electricity costs to industry (as generators pass on the CPS costs through energy bills). When the CPS was legislated for in 2011 the intended target price in 2013 was £16/tCO_2e, rising to £30/tCO_2e by 2020 and £70/tCO_2e by 2030 (prices on real 2009 basis); however, the UK 2014 budget froze the target price at £18/tCO_2e from 2016 to 2020 to limit the competitive disadvantage from higher energy costs relative to other EU countries.

3.6.3 CCL in Electricity Generation: Assessment of Political Acceptance

The policy was announced in 2011, and extensive consultation on the impact on business competitiveness was undertaken. As a result of this consultation, it was introduced at a low level in 2013, and enjoyed relatively high support as a measure to provide certainty for the carbon prices and complement the EU ETS.

However, support for the measure has been deteriorating. As EUA prices have remained persistently low, and perceived costs to consumer energy bills have increased, political enthusiasm for this measure decreased. Amongst the private sector, opposition to the policy has increased; for example, the Engineering Employers Federation, which is an important UK trade body, has called for the CPS to be scrapped. This resulted in freezing the prices for 2016-2020. It remains to be seen whether the policy instrument will endure going forwards. Some analysts have suggested the CPS presents a risk to the EU ETS longer term, as a decreasing demand for EUAs by the UK power sector will depress their prices.

Sources	(HM Revenue & Customs, 2014; HM Treasury / HMRC, 2010, 2016; HM Treasury HMRC, 2016; House of Commons Library, 2014)

4 CARBON PRICING AND BIOFUEL POLICIES

This theme covers how, in the fuel sector, carbon pricing interacts with biofuel policies. As the experience with the interaction of carbon pricing and biofuel policies is restricted to California, British Columbia (Canada) and the EU, the structure of this case study differs slightly. First, it sets out the Brazilian context. Second, it describes the carbon pricing and biofuel policies in California, British Columbia and the EU in detail, including their impacts. Third, it lists the implications for each of the four questions below based on the case study background.

Within the framework, the analysis sets out to answer four questions:

1. What are the interactions of CPIs with mechanisms to support for biofuels such as centralised auctions and biofuel mandates?
2. What is the impact of CPIs, and their combination with biofuel policies, on the competitiveness of fuels (inter-fuel competition)?
3. What are examples of successful biofuel policies in jurisdictions with CPIs?
4. What have been the institutional and policy barriers to the implementation, and how have they been overcome?

4.1 Case study jurisdictions

The international jurisdictions are chosen based on the following criteria:

1. Biofuel mandates: jurisdictions that require a certain share of biofuels in gasoline and/or diesel.
2. Transport fuel carbon pricing: jurisdictions that price the emissions from combustion or (lifecycle) emissions intensity of liquid transport fuels that encourages biofuels.
3. Economy-wide carbon pricing: jurisdictions that price carbon on the economy-level and include stationary emissions from liquid transport fuel refining as well as biofuel production and/or include the transport sector in their economy-wide carbon pricing instrument.

Based on these criteria, California and the EU are the most relevant jurisdictions – and British Columbia is added as a successful case of carbon tax in the transport sector. California and the EU have 1) biofuel mandates, 2) liquid transport fuel carbon pricing that cover the lifecycle emissions (Low Carbon Fuel Standard (LCFS) in California and Fuel Quality Directive (FQD)[11] in the EU), as well as 3) an economy-wide ETS. British Columbia has a carbon tax specifically for transport fuels that provides useful examples throughout. The following briefly sets out the policies in California, the EU and British Columbia.

4.1.1 California

California has ambitious climate targets that it hopes to achieve, in part, by regulating the transport sector. California's Global Warming Solutions Act of 2006 (AB 32) requires that the State lowers its greenhouse gas (GHG) emissions to 1990 levels by the year 2020 (Schatzki & Stavins, 2012). Emissions from transportation fuel combustion are regulated by the emissions trading system (ETS) and the Low Carbon Fuel Standard (LCFS):

- California ETS was established in 2012, covering the industry and the power sectors. It currently covers 85% of the state's emissions, once since 2015 it also covers retail sales of natural gas and transportation fuels, which in 2014 accounted for 37% of the state's emissions (ARB, 2017).

[11] Article 7a of the FQD has not been implemented by EU member states. However, its impact has been assessed.

The California ETS operated in 2016 with a price of US$13/t$CO_2$e. California has a target of reducing 80% of emissions below 1990 levels in 2050, and its overall emissions in 2015 were 394.5 million tCO_2e (IETA, 2015).

- The LCFS mandates reductions in the GHG-intensity of transportation (Schatzki & Stavins, 2012). In 2009, the LCFS regulation was approved to reduce the lifecycle carbon intensity (CI) of transportation fuel used in California by at least 10% by 2020 from a 2010 baseline, based on complete life cycle analysis. In 2011, amendments to the regulation were approved to clarify, streamline, and enhance certain provisions of the regulation. In 2015, the Board re-adopted the LCFS to address procedural issues, which began implementation on January 1, 2016 (ARB, 2017).

The LCFS imposes a carbon price only on fuel emissions exceeding the annual CI standard, and uses the same carbon price to establish a market signal to develop and deploy fuels that result in emissions below the standard. Fuels with a CI higher than the standard generate debits, while fuels with CIs below the standard provide credits, and compliance is achieved when regulated parties use credits to offset debits (ARB, 2017). What drives the LCFS credit prices, and thus the price per gallon impact of the regulation, is therefore the difference between the cost of the last (marginal, or most expensive) unit of fuel used to meet the standard and the cost of the conventional fuel.

The LCFS and ETS have potentially large health impacts and local co-benefits. Modelling conducted by EDF, American Lung Association and Tetra Tech shows that without the LCFS and ETS, the California transportation system is expected to result in cumulative societal economic impacts of $274 billion by 2020 and $387 billion by 2025. According to this modelling, the LCFS and ETS regulations will result in cumulative benefits from avoided health, energy insecurity, and climate change costs of $10.4 billion by 2020 and $23.1 billion by 2025.

Biofuels have zero emissions for the ETS but a positive lifecycle emissions intensity under the LCFS (which also includes indirect land-use change). Due to this accounting difference, emissions reduction effectiveness under the LCFS and the cap-and-trade system will depend greatly on which types of substitutions are made to comply with the LCFS (Schatzki & Stavins, 2012).

4.1.2 EU

The EU White Paper for Transport – 'Towards a competitive and resource efficient transport system' (COM(2011)144) seeks to reduce Europe's dependence on imported oil and sets the goal of cutting carbon emissions in transport by 60% by 2050 (compared to 1990 levels). To help achieve this target, the EU transport sector is affected by three policies that aim at reducing the emissions intensity of fuels: the EU ETS, the Renewable Energy Directive (RED) and the Fuel Quality Directive (FQD):

The EU ETS covers stationary emissions from refining, which covers mineral road transport fuels as well as biofuels production.

The RED established two objectives:

i. a 20% target for renewable energy as a proportion of the total energy consumed in the EU. This overall target means at least a 20% share of energy from renewable sources in the Community's gross final consumption of energy in 2020. The concept of 'gross final consumption of energy' means "the energy commodities delivered for energy purposes to industry, transport, households, services including public services, agriculture, forestry and fisheries, including the consumption of electricity and heat by the energy branch for electricity and heat production and including losses of electricity and heat in distribution and transmission";

ii. a 10% target for renewable energy as a share of energy used in the transport sector. This latter target has been implemented by Member States through various measures, including subsidies or obligations to blend biofuels into conventional petrol and diesel transport fuels. Both, the Renewable Energy Directive and the Fuel Quality Directive contain binding sustainability requirements for biofuels that are accounted towards the above targets (European Commission, 2016a).

The FQD sets the target of reducing the lifecycle emissions intensity of transport fuels by 6% by 2020. The FQD is set up similarly to the LCFS.

The FQD and biofuel mandates overlap, in part, with the EU ETS. The EU ETS covers emissions from oil refineries, but not emissions from the combustion of transport fuels. The coverage of stationary emissions from refineries increases the cost of liquid transport fuels refined in Europe, and creates a cost-disadvantaged compared with imported liquid transport fuels as well as biofuels refined outside of the EU ETS.

Within the 10% renewable energy target posed to the transport sector in 2020, the European Commission (2013) has projected that in 2020 biofuels will represent 7% of final energy demand in the transport sector, reaching a share of 8% in 2030, maintained until 2050. However, to be counted against targets and receive support, biofuels must meet sustainability criteria. There is a risk that the additional biofuels supply will be met by causing indirect land use change emissions. This affects the compliance with sustainability criteria, avoiding them to receive public support and making them commercially non-viable in many cases (Charles et al., 2013).

I**n the EU, FQD and RED have been successful in promoting the use of biofuels.** Ethanol and biodiesel consumption raised steeply from 2007 to 2011, when they started decreasing a little until 2013. Ethanol reached almost 6 billion litters in 2011, while biodiesel reached almost 14 billion litres. After 2013, Ethanol then reached a plateau, whereas biodiesel started growing slightly again, until 2017 (Flach, Lieberz, Rondon, Williams, & Teiken, 2016). According to data from Eurostat (2017), from 2007 until 2015 the share of renewable energy sources in transport across the 28 EU member states went from 3.1% to 6.7%, what shows an important progress towards the 10% target for 2020. However, in 2015, the only three countries presenting a share over 10% were Austria, with a 11.4% participation, and Sweden and Finland, with a share over 20% (Eurostat, 2017). According to Charles et al. (2013), in 2011, the total cost of producing biofuel supply to meet consumption in the EU is estimated to have been between EUR 10.8 and 16.8 billion. This annual production supports the investment in assets, the operational costs and the purchase of raw materials.

Biofuels are restricted to stem from non-food crops. The Directive (EU) 2015/1513, so called the "iLUC Directive", was created to assure that the contribution of biofuels produced from food crops is capped at 7% (EU, 2015). This is in response to several studies that concluded that increased biofuels use has been responsible for up to 70% of raises in corn prices and 100% in sugar prices in 2008 (HLPE, 2013).

4.1.3 British Columbia

British Columbia operates carbon tax covering transport fuels in parallel with a motor fuel tax and biofuel mandates. The carbon tax was established in 2008. It applies to the carbon content of transport fuels and is levied at the point of purchases. The tax was implemented with a five-year schedule to start from CA$10/t$CO_2$e in 2008, rising CA$5/tCO_2e per year until 2012 when it reached the final value of CA$30/t$CO_2$e. This translates into a specific tax rate per fuel based on their carbon content: approximately 6.7 CA¢/litre for gasoline and CA7.7 ¢/litre for diesel (British Columbia, 2017). The taxes apply to ethanol and biodiesel, but certain 100% biomethane and pulping liquor are exempt. Other taxes, such as the motor fuel tax apply to ethanol at the same rate as gasoline and to biodiesel and straight vegetable oil (SVO) at the same rates as diesel.

An important aspect of the tax is that it was designed to be revenue neutral, mitigating distributional impacts. In British Columbia, lowest-income decile spends 7% of income in fuels while highest-income decile spends only 4%. The tax revenue raised directly creates a reduction of taxes levied on households, especially in the low-income group. That includes the Low-Income Climate Action Tax Credit, which (in 2011) returned $115.50 per adult and $34.50 per child to households with incomes of less than $31,700 for singles or $37,000 for couples. In addition, the personal income tax rate was reduced on the first two income tax brackets: a 5% reduction in the tax rate for households with income up to about $75,000, resulting in a larger reduction in the average tax rate for low-income individuals compared with high-income individuals (Murray & Rivers, 2015).

In addition, since 2010, British Columbia has its Renewable & Low Carbon Fuel Requirements Regulation in place. This includes mandates of 5% minimum renewable fuel content for gasoline and 4% for diesel, and a requirement of an average 10% reduction in the lifecycle GHG emissions intensity of transportation fuels in 2020 relative to 2010 (British Columbia, 2017; Wolinetz & Axsen, 2014).

Between its introduction in 2007 and 2013 the carbon tax contributed to a decreased mineral transport fuel consumption. Per capita consumption in British Columbia fell by 16.1%, compared with a decline of 3% in Canada, and total transport emissions fell by 9.1% (Komanoff & Gordon, 2015).

4.2 What are the interactions of CPIs with mechanisms to support biofuels such as centralised auctions and biofuel mandates?

The analysis considers only road transport fuels which comprise mineral fuels and biofuels. Mineral fuels are petroleum products derived from crude oil, for example gasoline and diesel. Biofuels are fuels derived from biomass, for example plant sugars which produce bioethanol, and plant oils which produce biodiesel.

The life-cycle emission from liquid road transport fuels (transport fuels from hereon) fall into three categories: production, transport and combustion of fuels. Lifecycle emissions include emissions from not only fuel combustion, but also production and transport stages, which in the case of biofuels includes agriculture and land use change emissions. The first steps are extraction of resources and production of fuels. The production means, for example, in refineries for mineral transport fuels and emissions from agriculture and land-use change for biofuels. These represent on average 22% for mineral fuels, and 91% for biofuels. Agriculture emissions result from the production of fertilizer and soil amendments, the soil emissions resulting from synthetic and organic additions, and on-farm emissions from energy use in tractors during activities such as planting, cultivation and harvest (ARB, 2017). The second step is the transport of fuels. This means transportation from extraction and production to the final consumption point, which is, however, the minor part and represents between 4 and 6% of the emissions life-cycle intensity of fuels. Combustion of transport fuels is the third part and releases their carbon content and most of mineral fuels lifecycle emissions. These present on average 75% for mineral fuels, and is considered to be zero for biofuels. The typical lifecycle intensities for liquid mineral transport fuels in California are 92 gCO_2/MJ for diesel and between 95 and 100 gCO_2/MJ for gasoline, and between 37gCO_2/MJ and 79 gCO_2/MJ for biofuels, depending on their generation, as shown in Table 10.

Table 10 - Lifecycle intensity by component (gCO_2e/MJ)

Life-cycle Component	Gasoline	Brazilian Ethanol	Corn Ethanol	Cellulosic Ethanol
Production	22	27	19	37
Agriculture and Indirect Land Use Change	0	46	53	0
Transport	4	Accounted for in production	6	Accounted for in production
Combustion	74	0	0	0

Total	**96**	73	79	37

** Source: ARB (2017) and Schatzki & Stavins (2012).*

The interactions among biofuel policies and carbon pricing fall into a few different categories:

- **Biofuel mandates** dictate the share of biofuels in the transport mix, as a proportion of total fuel, and overlap with carbon pricing instruments. Such mandates are used to assure that biofuels, often more expensive than mineral fuels, are included in the transport fuel mix to reduce emissions.
- **Life-cycle emissions intensity** policies cover the total emissions from fuel combustion. They don't account only for the combustion of fuels, but also for the production and transport steps, encompassing in the case of biofuels agriculture and land-use emissions. These regulations require fuel producers to reduce the emissions intensity of their products. Fuel Standards specify a standard below which average carbon intensity (CI), or carbon emissions per unit, of fuel sold must be. If a firm produces fuel with a CI above the standard, it must offset this difference over a compliance period by purchasing credits from firms producing fuels with CI's below the standard (Lade & Lawell, 2015). Thus, the policy generates at the same time incentives to the production of low-carbon fuels and discouragement to the production of high-carbon content fuels as diesel and gasoline.
- **Carbon taxes and ETS** mainly affect the stationary emissions from refining, or in the case of California also the emissions from transport fuel combustion.

Ex-ante analyses show that biofuels supply in California will be enough to comply with 10% CI reduction target. The University of California-Davis' Institute of Transportation Studies estimated the 10 percent CI target displaced roughly 2.14 billion gallons of gasoline and 77 million gallon-equivalents of diesel with low-carbon transportation fuels through 2013. Between 2011 and 2015, use of alternative fuels grew by 31 percent, while the average carbon intensity of these fuels declined by 21 percent. During this period, the program reported 16.8 million tons of reduced carbon emissions overall (Yeh & Witcover, 2016). As the program has matured, increases in lower carbon fuel use have come primarily from biodiesel, renewable diesel, and biomethane; these three sources accounted for the majority of emission reductions from the program in 2015. In addition, the role of electricity has also risen, from less than 1 percent of LCFS-related emissions reductions in 2011 to 6 percent in 2015.

At the same time, strong action on biofuel mandates and fuel emissions intensity standards could reduce the allowance price in the ETS. Modelling for California projects that a doubling of the LCFS emission intensity reduction target would roughly halve the allowances price: a 20% instead of 10% emissions intensity reduction would result in an allowance price of US$15Mt$CO_2$ein 2020 instead of US$33/MtCO_2e (ICF, 2017). Estimations for Ireland, covered by the FQD and RED, show that RED targets of 5% (volume) bioethanol and 10% (volume) are sufficient to meet the FQD target (Malone & Cléirigh, 2017).

The Carbon Tax in British Columbia fulfils a similar role as fuel standards – the crucial difference is that it is levied on the full carbon content of the fuel rather than the emissions intensity compared to a benchmark level. A carbon tax provides a similar incentive to reduce transport fuel emissions as a fuel standard. Under the same tax rate (fuel standard rate), they both provide the same marginal incentive to reduce emissions. However, the total cost of a carbon tax levied on the full carbon content of the fuel is higher than the total cost of a fuel standard levied only on the part exceeding the benchmark.

4.2.1 Implications

Transport fuel emissions can be regulated by three instruments which overlap: fuel intensity standards, biofuels mandates, and CPIs. Lifecycle fuel intensity standards set an emissions intensity target for the lifecycle greenhouse gas emissions per unit of transport fuel supplied. Biofuels mandates stipulate the percentage of biofuels that must be blended to mineral fuels, often expressed as a share of volume. CPI's price emissions resulting from the combustion of transport fuels, and can also cover stationary emissions from refining. CPIs interact with fuel intensity standards and biofuels mandates.

Biofuel mandates make fuel emissions intensity standards less flexible to comply with and are more expensive. As mandates are binding quantities of biofuels that must be used as a proportion of diesel or gasoline, they interact with fuel standards that create an economic incentive for low carbon fuels use through compliance credits. If mandates are ambitious enough, they can themselves create compliance with the standard, in such a way that the standard will be redundant and no longer needed, as may be the case in Ireland. This also means that forcing biofuels into the fuel mix above the level that would be required by a fuel intensity standard may create a higher cost.

Fuel intensity standards (and increased biofuel use to comply with them) create negative interactions with carbon pricing instruments. As illustrated by the LCFS modelling for California, when transport fuels are covered by an ETS, a stricter lifecycle emissions intensity standard and the increased use of biofuels reduces transport emissions sufficiently to affect the ETS allowance price. This reduces the effectiveness of the carbon price signal in other sectors and reduces the emissions reductions unlocked by them, substituting those for the potentially higher-cost emission reductions in transport.

Biofuel mandates erode the tax base and reduce potential tax revenue from carbon pricing instruments. Forcing in amounts of biofuels reduces the overall emissions intensity of the fuel mix and the potential to generate tax revenue from taxing these emissions.

4.3 What is the impact of CPIs, and their combination with biofuel policies, on the competitiveness of fuels (inter-fuel competition)?

Incentives for biofuels use will impact both biofuels and petroleum fuels productive chains. As a result, it will affect particularly the refining sector and land use change. It is also important to notice that once policies create incentives to reduce emissions from the transport sector, they may result in a switch from fossil fuels to electricity, once they lead to a larger adoption of electric vehicle technologies. This would result in an increase in electricity demand. However, considering that electricity sectors emissions are capped by an ETS, the share of fossil fuels in electricity production can only be increased within certain limits.

4.3.1 Implications

Carbon pricing changes the competitiveness of certain fuels and benefits biofuels. It affects the cost of refined fuels (liquid transport fuels) by taxing the emissions from refining, or, as in the case of British Columbia and Mexico, tax the carbon content of the fuel itself. The impacts depend on what proportion of emissions are taxed.

For an ETS and carbon tax, the impact depends on whether the transport sector is covered:

- If only stationary emissions from refining are affected, domestically produced mineral transport fuels will be costlier than imported mineral transport fuels, and there is less inter-fuel cost difference between gasoline and diesel as are produced concurrently in refineries.[12] However, as emissions from refining biofuels are lower than for mineral transport fuels, biofuels will gain an advantage.
- If combustion is included, the impacts are between domestic and imported mineral fuels are less pronounced as only the stationary refinery emissions create a difference. However, depending on how biofuels are treated – whether they are considered to have combustion emissions or such emissions occur during the production stage – the impacts may be a benefit for biofuels in comparison to mineral transport fuels.

For emissions intensity policies (LCFS and FQD), the distance to the set benchmark determines the cost of compliance. This means that some fuels, often biofuels, will receive a benefit in the forms of generating credits for having a lower lifecycle emissions intensity than the target, in contrast for mineral transport fuels, which often are above the target. This transfer between fuel producers provides an additional discrepancy between the prices of these fuels and increases the inter-fuel competitiveness

[12] Further, refineries have a comparatively low potential to reduce the carbon intensity of gasoline and diesel. Estimates show that, by 2020the emissions intensity could fall by 1.5 per cent due to energy efficiency improvements, integration of renewable energy inputs such as biomethane, and use of innovative technologies including solar thermal (Promotum, 2015).

impacts in comparison to an ETS that may vary significantly. Whereas the carbon tax in British Columbia has risen following a pre-announced path, the LCFS price has been very volatile and resulted in comparatively high cost per tCO_2e abated (in comparison to the ETS). LCFS credit prices have varied between less than US$10, when the instrument was established in 2013, and over US$120 recently, in 2017.

For biofuel mandates, they dictate outcomes of inter-fuel competition. The share of biofuels will not be based on cost competitiveness. This creates uncertain prices in complying with the policy.

4.4 What are examples of successful biofuel policies in jurisdictions with CPIs?

Successful biofuel policies are centred around the following objectives:

1. Reduce emissions in a cost-efficient manner
2. Provide industrial policy to increase the consumption of biofuels
3. Minimise distributional impacts, i.e. price increases, for consumers
4. Minimise competitiveness impacts on different fuel producers
5. Allocate revenues from its scheme to tax payers

Policies specifically targeting biofuels only need to be considered when the encouragement of biofuel consumption is the target.

Within these policies, the incentives should be set clearly.

- This means to account for lifecycle emissions
- Excluding biofuel quantity mandates as they reduce the cost-effectiveness of the policy by restricting the solution space.
- Do not provide or show a preference for specific fuels

Allowing for trading increase the cost effectiveness of all measures. Regardless of whether a carbon tax or quantity instrument is set, trading of compliance units is beneficial.

A carbon tax or fixed compliance cost may reduce the impact on consumers. This carbon tax may even have specific rates for transport fuels, avoiding spillover effects or correlation with the development of carbon emissions in other sectors. At the same time, a carbon tax provides a clearer signal regarding the relative competitiveness of fuels, which helps biofuels understand and compete in the market place. Implementing a carbon tax in the fuel sector does not necessitate that the carbon pricing instrument in other sectors also be a tax, as the international experience of hybrid instruments illustrates. France, Ireland, Portugal, and Sweden all apply carbon taxes to selected non-EU ETS sectors (Wang-Helmreich et al., 2017).

Potentially strict standards result in a large price increase and price volatility of emission reductions. In California, the comparatively challenging 10% lifecycle emissions intensity reduction by 2020 led to fuel suppliers accumulating a bank of credits in the early years of the policy for future compliance use. This increased credit prices from an average US$22 in May 2015 to US$122 in February 2016, which has fallen again to currently around US$96 (PIRA, 2017). This presents a deep trade-off between a price and quantity instrument – certainty of costs versus certainty of achieving a specific emissions intensity level.

Successful biofuel policies also allow prices and costs to be passed through. Cost pass-through mechanism is essential for the CPI to be most effective in mitigating emissions by unlocking fuel efficiency and energy efficiency improvements. The carbon cost pass-through rates have normally been between 51-100% and its key drivers include how easily could costumers switch from domestic to imported fuels, market concentration and pricing power. In more competitive markets, prices may reflect carbon costs, although the highest-cost producers will face difficulties in passing the full cost increase to costumers (World Bank, 2016).

When interactions between biofuels and carbon pricing policies are strong, careful analysis of the overlap can prevent negative outcomes. Particularly for quantity mechanisms, the increased use of biofuels could have repercussions on the (allowance) price and, through it, on other sectors. This is especially true for an ETS, where the additional abatement in transport from biofuel and other policies could negatively interact with incentivising mitigation in other sectors.

4.5 WHAT ARE THE INSTITUTIONAL AND POLICY BARRIERS FOR IMPLEMENTING BIOFUEL AND FUEL STANDARDS?

The implementation of biofuel policies and low carbon fuel standards requires overcoming technical, institutional and policy barriers. Technical barriers prevent greater use of biofuels and constrain the ambition of policy in countries without a significant share of flex fuel engines that can use mineral road transport fuels or biofuels. However, this is not the case of Brazil, where 88% of vehicles licensed in 2016 were flex fuel (MME, 2016). This section therefore focuses on the institutional and policy barriers.

To understand the barriers and the solutions that have worked in other jurisdictions, it is important to consider who the stakeholders are, what their main concerns are and what the process has been to overcome these concerns.

4.5.1 THE STAKEHOLDERS

The introduction of a fuel standard involves the following stakeholders:

- lawmakers;
- a government agency (the regulator);
- industry groups of major fuel suppliers - both domestic and international; and

- consumers.

The lawmakers direct a government agency to take on a regulatory role and implement the policy. The Californian Executive Order S-1-07 designated the California Air Resources Board (CARB) to be responsible for applying the LCFS through designing implementation plans, rulemaking and timelines. The CARB approved the LCFS in 2009 and implemented it in 2010, as an early action measure under Assembly Bill 32. The CARB subsequently approved amendments to the LCFS in December 2011, which took force on January 1, 2013 (CARB, 2017). In the EU, the FQD is regulated by the European Commission Directorate General for Climate Action (DG CLIMA). The European Commission is responsible for the implementation of each article of the Directive: setting measures, conducting consultation processes, and submitting amendment proposals to European Parliament.

Road transport fuel producers and suppliers (within and outside the biofuel and CPI jurisdiction) and their industry groups are the primary stakeholders. The Canadian Association of Petroleum Producers (CAPP) and the Brazilian Sugarcane Industry Association (UNICA) have been active stakeholders in the LCFS implementation process in California, participating in workshops and providing feedback throughout all stages of the LCFS. For the EU FQD, stakeholders included fossil fuel and the biofuel producers and their industry association such as the European Petroleum Industry Association, but also the vehicle manufacturers.

Fuel regulation also has the potential to affect stakeholders outside the regulated jurisdictions. For the LCFS, major suppliers of road transport fuels (fossil-based and biofuels) include producers from other American states and other jurisdictions. The impact of the LCFS on cross-border suppliers has been the subject of the legal challenges discussed later. Similarly, the EU FQD affects non-EU fuel suppliers including petroleum-based fuel providers from the US and Canada; and biodiesel and bioethanol exporters from Argentina, Indonesia and Brazil (Global CCS Institute, 2012).

Consumers represent another significant stakeholder group. In California, the consumer alliance, *Fueling California,* has developed studies and discussions about the LCFS, including the 2012 study ‘A Comprehensive Analysis of Current Research and Outlook for the Future’ which summarises LCFS impacts on fuel costs, the broader economy, and technical feasibility. The organization also conducted a symposium in 2012 to gather experts and discuss the impacts of the LCFS on California's economy and emissions (Fueling California, 2017).

4.5.2 Main concerns

The main concerns are the costs and legality of fuel standards and biofuel mandates.

Limiting the carbon-intensity of road transport fuels increases compliance cost for suppliers and producers. Compliance costs have been volatile. For example, LCFS credit prices have shown high volatility in the past (as shown in Section 1.4.1) and experienced a steep increase since 2014 (CARB, 2017). In the early stages of implementation, the strictness of the LCFS led to concerns about excessive compliance costs (Fueling California, 2012). Stakeholders also scrutinized the initial plan to achieve LCFS compliance, stating that it relied on the use of alternative fuels and vehicle technologies that would not be commercially available by 2020. The plan developed to achieve LCFS compliance assumed substantial market penetration of battery electric vehicles (BEVs); fuel cell vehicles (FCVs); plug-in hybrid electric vehicles (PHEVs); and significant quantities of consumption of low-CI ethanol, which was considered unfeasible within the timeline (Gross, 2010).

The overall desirability of fuel standards and biofuels policies, however, depends on the comparison of costs and benefits. EU FQD stakeholders are divided on whether the benefits of the FQD carbon-intensity (CI) restrictions outweigh the costs of complying with it. When consulted by the regulator, the majority of EU member states did not have an opinion on the costs and benefits of the FQD. Austria, Germany and Sweden were positive about the cost/benefit impact of the FQD; while France, the Czech Republic and the Netherlands stated that the costs outweigh the benefits. The majority of car manufacturers were positive about the cost/benefit implications, although most fossil fuel manufacturers indicated that FQD restrictions on petrol and diesel led to an increase in fuel production costs (European Commission, 2017).

Both in California and the EU, fuel suppliers from other jurisdictions challenged the legality of the policies, arguing that they attempted to regulate entities outside of their jurisdictions. Industry groups challenged the legality of California LCFS based on the laws of federalism. Ethanol producers from other US states argued that LCFS discriminated against interstate commerce. When the LCFS attributed a higher CI to ethanol produced outside of California, other states claimed that it intended to regulate them without jurisdiction, which led to revisions to the LCFS resulting from legal proceedings. In Europe, fuel suppliers from Canada and US contested that the FQD imposed technical barriers to world trade that violated World Trade Organization principles.

4.5.3 Process to overcome concerns

Stakeholder engagement has been crucial for fuel and biofuel policies to overcome concerns. This process started in advance of the introduction and design of the biofuel and fuel policies, the revisions of the policy and, to a lesser extent, is part of a continuous process.

Prior to the introduction and design of the policy, regulators collected stakeholders' contributions to anticipate pressure points. In 2007, two years before the implementation of the LCFS, the CARB formed workgroups to discuss elements of the policy such as the regulatory framework, compliance and enforcement mechanisms, and the lifecycle emissions of fuels. These groups connected ARB staff with representatives from companies in the energy sector and related associations. Through 2008 and 2009, the CARB staff conducted public meetings and workshops to discuss economic, environmental, and fuel pathways lifecycle analyses of the LCFS. The European Commission arranged pre-consultations prior to the introduction of the FQD to cover the implementation of Article 7a (fuel carbon intensity standards) and the accounting of indirect land-use change from biofuels production.

Stakeholder concerns, challenges and feedback were part of the revisions to biofuel and fuel policies. CARB revised the LCFS two times in response to legal challenges and stakeholder concerns.

Among other modifications, models to calculate fuel carbon intensity were updated, required emissions-intensity reduction was reduced and the pathway towards it stretched out further. Stakeholder input was key for the development of some of the modifications of the LCFS, including the incorporation of a mechanism to cap LCFS credit prices, streamlining the application process for alternative fuel producers seeking a carbon intensity score, and improving the process for LCFS credit generation by charging electric vehicles (CARB, 2017). FQD Article 7a was revised in 2014 due to stakeholder feedback to loosen the reporting restrictions on the sources of crude oil used for fuel production.

Continuous stakeholder consultation is part of maintaining the biofuel and fuel quality policies. CARB holds workshops approximately every two months to assess compliance, trends in fuel carbon-intensity and cost. For the FQD, the European Commission conducted an evaluation roadmap aimed at examining the actual results and impacts of the FQD up to 2016, compared to what was expected. The evaluation focuses on the relevance, the effectiveness, the efficiency, and the value added by the FQD to the EU.

4.5.4 Implications

Challenges to the implementation of biofuel and fuel standard policies are mostly related to the compliance required of companies based in other jurisdictions. Exporter companies, their industry associations, and their governments claim that low-carbon fuel standards discriminate against commerce. The establishment of standard values based on feedstock and their origin raises discontent from suppliers of higher emissions-intensity fuels.

The introduction of biofuels policy that covers the entire jurisdiction (e.g. on a national rather than state level) may create less friction and legal concerns. Implementing a nationwide fuel and biofuel policy eliminates concerns about compliance between states. Nevertheless, such a policy still may raise concerns with stakeholders that are outside the jurisdiction but regulated by the biofuel and fuel policy.

4.6 Lessons learnt

Lifecycle fuel intensity standards and biofuels blending mandates overlap with each other and the carbon price. Biofuels mandates overlap with the carbon pricing signal in the same way that renewable energy targets do, in that they stipulate minimum shares of biofuels in transport fuels. A fuel emissions intensity standard can interact negatively with the carbon price signal by lowering the allowance price (if an ETS), as seen in California, which can reduce the effectiveness of the carbon pricing signal in other sectors in exchange for potentially higher cost transport sector abatement.

Fuel intensity standards and biofuels blending mandates can interact to increase the costs of compliance. Fuel intensity standards effectively redistribute emissions credits from emission intense fuel producers to less emissions intense fuel producers based on a pre-determined threshold. These credit prices can be volatile and lead to highly varied costs of abatement. Similarly, mandates pick winning fuels, which can reduce the cost-effectiveness of the instrument by reducing the options available for compliance with fuel intensity standards. This entails that the compliance with the mandate is either redundant or excessively costly. Increasing the regulatory costs for the transport sector can have significant knock-on effects on other sectors, due to the interlinkages between transport and other sectors in an economy. Furthermore, biofuels mandates can erode the carbon tax base (if a tax).

A CPI may benefit the inter-fuel competitiveness of biofuels, depending on the transport sector coverage and point of obligation. A CPI affects the cost of refined fuels (liquid transport fuels) by taxing the emissions from refining or by taxing the carbon content of the refined fuel itself (as in Mexico and British Colombia). for an ETS and carbon tax, the impact depends on the transport sectoral coverage and the point of obligation. If the CPI covers only stationary emissions from refining then domestic mineral transport fuels become costlier than both imported mineral transport and biofuels are advantaged. If the CPI covers combustion emissions, then biofuels may benefit depending on whether the design incorporates point of obligation on combustion emissions or only production emissions.

Fuel intensity standards can interact with a CPI to accelerate fuel switching, but at potentially high(er) cost. California's fuel standard (LCFS) imposes a carbon price only on fuel emissions exceeding the annual emissions intensity benchmark. Biofuels benefit by generating credits for having a lower lifecycle emissions intensity than the benchmark. The LCFS and ETS have potentially large health impacts and local co-benefits: cumulative societal economic benefits in California estimated at $274 billion by 2020. However, the benchmark fuel intensity determines the cost of compliance and mineral transport fuels are often above the benchmark. Producers above the benchmark level need to purchase credits from more efficient producers to comply with the fuel standard and these transfers create a discrepancy between fuel prices and increase the inter-fuel competitiveness impacts. Compliance costs can be volatile as credit prices can be unstable and result in comparatively high cost per tCO_2e abated, for example LCFS credit prices varied between less than US$ 10 in 2013, to over US$ 120 in 2017.

A well-designed CPI may fulfil the objectives of a biofuels policy without some of the downsides of biofuel-specific policies. Levying a carbon price against the full carbon content of fuels avoids the distortionary impacts that fuel emissions intensity standards entail due to the use of emissions intensity thresholds. Imposing a carbon price on the full carbon content of a fuel ensures incentives are aligned to reduce this content by as much as possible. CPIs also do not exhibit any preference for particular fuels as they are market-based measures. Table 11 summarizes five common key objectives of biofuels policies and the design elements of CPIs that can be used to achieve them.

Table 11 - CPI design can ensure that the objectives of biofuels policies are achieved

Key objectives of biofuels policies	CPI design element
1. cost-efficient abatement	full carbon content priced, flexible compliance
2. promote biofuels consumption	transport sector coverage and point of obligation

3. minimise distributional impacts on consumers	carbon revenue recycling, tax reform
4. minimise competitiveness impacts on other fuel producers	allow cost pass-through in liberalised fuel sector, carbon revenue recycling, tax reform, allow trading
5. allocate revenues to tax payers	carbon revenue recycling, tax reform

A carbon price can also be designed to encourage biofuels. If the carbon price covers only stationary emissions, lower refining emissions from biofuels gives them a cost advantage; but if combustion emissions are also covered then the benefit to biofuels will depend on whether they are considered to have combustion emissions or if these emissions are attributed to the production stage

A carbon tax provides greater cost certainty than an ETS and/or biofuels mandates and it can be separate from CPIs in other sectors. As discussed above, a carbon price can achieve greater cost-efficiency in abatement than mandates and emissions-intensity standards while also supporting biofuels production. A carbon tax provides greater cost certainty to producers and consumers than an ETS and/or biofuels mandates due to fixed prices on emissions. The further promotion of biofuels in the fuel sector would not influence the tax (but may incentivise further emissions reductions at potentially higher cost). This is in contrast to an ETS in the fuel sector, where promoting biofuels can lower allowance prices, which would reduce emission reduction incentives across the entire coverage of the ETS. Implementing a carbon tax in the fuel sector does not necessitate that the carbon pricing instrument in other sectors also be a tax, as the international experience of hybrid instruments illustrates. France, Ireland, Portugal, and Sweden all apply carbon taxes to selected non-EU ETS sectors (Wang-Helmreich et al., 2017).

Policy barriers to implementing fuel standards are the compliance costs and extra-jurisdictional obligations. The fuel standards of both California and the EU ETS were challenged by fuel producers outside the jurisdictions on the grounds of WTO contraventions. Domestic regulations reduce the margins of producers of higher emissions-intensity fuels by lowering the competitiveness of their product. Extra-jurisdictional producers claim these regulations attempt to regulate entities beyond their remit. To overcome these barriers, affected stakeholders should be engaged from the beginning of the implementation of the policy and feedback should be considered for revisions. Furthermore, jurisdiction-wide scale regulations are preferable to regional policies and may create less friction and legal concerns between states. California's LCFS is subnational and, as a result, has experienced legal challenges from ethanol producers in the different US states, who perceived the policy as regulating them beyond its jurisdiction.

5 INTERNATIONAL EXPERIENCE OF CARBON PRICING IN THE TRANSPORT SECTOR

5.1 INTRODUCTION

This chapter provides an overview of the role for carbon pricing in the road transport sector in theory, before reviewing the international experience in this field.

Carbon Pricing may play a role as part of a portfolio of measures to mitigate GHG emissions in the road transport sector. This section begins by providing an overview of how carbon pricing can be used to meet these policy goals, and the conditions under which it is effective. Carbon pricing (ETS and CT) may be used most effectively to incentivise low to mid cost abatement measures, however studies show that its effectiveness depends on the elasticity of demand of vehicles and fuels in the economic context. Typically, carbon prices are too low however to incentivise abatement measures with high up-front costs.

Subsequently, the international experience of carbon pricing in road transport is presented.

To begin with, the feasibility challenges associated with introducing emissions trading or carbon taxes are presented, as well as how some jurisdictions have overcome these challenges. The diffuse nature of emissions sources in the road transport sector poses a challenge for choosing the point of regulation, which involves a trade-off between the strength of the carbon efficiency incentive and the administrative costs. This contributed to the EU's decision not to implement an ETS in this sector, whereas California adopted a mixed regulatory approach, and Ireland adopted carbon taxes to complement ETS.

Next, the section presents some of the key considerations for introducing CPIs into the existing policy landscape, given potential policy interactions. The experience of the EU shows that, while command and control (CAC) instruments can be complementary, if the landscape is already congested with them, it can limit the effectiveness of the CPI. In addition, harmonising potentially contradictory energy pricing policies is essential for preserving the carbon pricing signal.

Finally, for the cases in which ETS or CT are not feasible or would not be effective, we present some innovative alternatives which jurisdictions worldwide have been implementing. This includes Colombia's carbon levy and offsetting mechanism, and Guangdong's up-scaled crediting mechanism. Both of these alternatives limit the costs to final consumers, and channel funds into high cost abatement measures. In addition, some examples of how market based mechanisms are being introduced with CAC regulations for fuel and vehicle manufacturers in Colombia and EU are provided.

5.2 THE ROLE OF CARBON PRICING IN GHG MITIGATION FOR ROAD TRANSPORT EMISSIONS

This section provides an overview of the role for carbon pricing in the road transport sector, and the conditions under which it is effective.

Carbon pricing has a role to play as part of a portfolio of measures to reduce GHG in the road transport sector. The table below provides an overview of the policy instruments which can be used to mitigate road transport emissions by supporting the overarching objectives of transport demand management or low carbon vehicles. In addition, it indicates where carbon pricing instruments can be used to achieve the same policy objective.

	Policy objective	Instruments	Potential role for carbon pricing
Transport demand management	Reducing private vehicle ownership	Vehicle pricing - vehicle license/registration fees, taxes	Carbon taxes based on vehicle carbon efficiency
		Fuel pricing – taxes	Pricing the carbon content of fuels
	Improve transport diversity, and support modal shift: • Private to public passenger transport • Road to rail freight transport • Increase non-motorised transport	Investment in mass transit programmes (BRT, metro) and rail projects.	Carbon pricing usually too low to incentivise this. However, CPIs can recycle revenues toward these and/or crediting mechanisms provide financing
		Preferential pricing for public transport.	Carbon pricing of fuel/vehicle use indirectly support this
	Congestion & vehicle circulation management	Command and control (Rodízio, speed limits)	n/a
		Integrated land use and transport planning	n/a

Promoting low carbon vehicles		Circulation tolls / charges	Carbon pricing of fuel/vehicle use indirectly support this
	Biofuel support policies	Fuel pricing / subsidies	Carbon pricing of fuel consumption support this substitute
		Command and control - Blending mandates / quotas	As a price signal, carbon pricing is complementary but does not replace these policies, which create a regulatory requirement to use biofuels.
		Green certificate trading	
	Improve carbon efficiency of vehicles	Fuel economy regulations, CO_2 equivalent standards and labelling	As above, carbon pricing (such as taxes based on vehicle efficiency) is complementary but does not replace these standards.
	Support alternative (biofuel, hydrogen, electric) vehicles	Investment in R&D for hydrogen fuel cell, advanced biofuel conversion and improved batteries for electric and hybrid vehicles	Carbon prices usually too low to incentivise this. However, CPIs can recycle revenues toward these and/or crediting mechanisms provide financing
		Supporting roll out programmes	

Source: Ricardo Energy & Environment analysis, adapted from (Ribeiro et al., 2007).

The analysis shows that a range of instruments are required to achieve the stated objectives, and while carbon pricing can play a role, it should be introduced as a portfolio of measures.

Carbon pricing (ETS and CT) may be used most effectively to incentivise low to mid cost abatement measures. For example where carbon pricing is used to affect vehicle or fuel pricing, and cost of circulation, in order to reduce private vehicle ownership, support congestion management and a switch to biofuels.

However, studies show that the effectiveness of carbon pricing depends on the elasticity of demand of vehicles and fuels to changes in price signals. The chapter on transport mitigation in the 4th IPCC assessment report (Ribeiro et al., 2007) states that globally, demand for vehicles, vehicle travel and fuel use are more elastic in developing countries, where a more modest price increase has greater impacts on GHG emissions. Nonetheless, Colombia found that a carbon tax on transport fuels would not necessarily lead to measureable GHG emission reductions, due to the low price elasticity of fuels (Colombia Ministry of Environment and Sustainable Development, 2014). Based on the elasticity of -0.2, a carbon tax of 10 USD per tCO_2 in Colombia would have an impact of reducing transport emissions by only 0.4% or less than 100,000 tCO_2 per annum. This means that to achieve approx. 10% reduction of CO_2 emissions through a carbon tax, the fuel prices would have to double. In Colombia this is partly explained by the fact that both in short and intermediate run, consumers are expected to respond less to changes in gasoline price if the price volatility over the past year has been high.

Typically carbon prices are too low to incentivise abatement measures with high up-front costs. CP can only provide supplementary incentives for modal shift and alternative vehicles. Indeed, the results of a global IEA study emphasised that a carbon price alone would not lead to significant change in the transport sector, unless much higher prices were achieved - US$50-300 t/$CO_2$e (Kopp, 2013). Nonetheless, the CPI can be designed so that revenues can be recycled, or a crediting mechanisms developed, to provide financing for these options.

Finally, the table indicates that there are a number of policies which carbon pricing can support but not replace. These are command and control policies which create regulatory requirements for the use of biofuels or carbon efficiency standards, where command and control (CAC) regulation is preferable.

5.3 International experience of carbon pricing in road transport

Having provided an overview of the possible role for carbon pricing, this section begins by exploring in greater detail the international experience with regards to introducing carbon pricing in this sector.

The first section presents some of the feasibility challenges associated with introducing emissions trading or carbon taxes in road transport, and how some jurisdictions have overcome these challenges.

Non-withstanding, the second section looks at how jurisdictions have successfully introduced these instruments into this sector, and some of the key considerations for doing so, for example, the interactions with the existing policy landscape which may already be congested with complimentary instruments, or whether contradictory instruments exist.

Finally, where ETS or CT are not feasible or would not be effective, this section presents alternatives to carbon pricing for this sector.

5.3.1 Overcoming feasibility challenges associated with carbon pricing in road transport

This section begins by explaining the feasibility challenges associated with introducing CPIs into the road transport sector, due largely to the large number of diffuse emissions present, which was a key barrier for introducing it in the EU. Nonetheless, the experience of Ireland and California is subsequently presented to illustrate how other jurisdictions have overcome this barrier.

The diffuse nature of emissions sources in the road transport sector poses a challenge for choosing the point of regulation (POR) for ETS and CT systems. The POR could be downstream, on the entities that directly emit the GHGs themselves (such as the vehicle owner), midstream (for example vehicle manufacturers) or upstream (fuel suppliers).

The choice of which point of regulation involves a trade-off between the strength of the carbon efficiency incentive and the administrative costs. Regarding the incentive, this is determined by whether the regulation is placed directly on the entity responsible for the emissions, and their place in the fuel/ car manufacturing supply chain. Regarding the administrative costs, these vary with the number of emission sources included.

Comparing administrative costs for ETS and Carbon Tax. Note that the costs of administering ETS are higher than for carbon taxes, due to the trading mechanism which must be implemented. In addition, particularly for the transport sector, most jurisdictions are familiar with energy or fuel taxation, and the regulatory infrastructure is usually already in place.

Point of regulation	Strength of the carbon efficiency incentives	Administrative Costs
Downstream: vehicle owner	**Direct carbon cost**. The carbon cost incentive is placed directly on the entity responsible for the GHG emissions, as opposed to being passed through e.g. fuel prices. **Drives efficiencies all along the fuel and car manufacturing supply chain**. Placing the incentive downstream encourages efficiencies along fuel and manufacture supply– e.g. demand for fuel efficient vehicles or low carbon content of fuel. **Greater impact.** Expected to spur greater technological innovation and the use of more varied abatement measures (e.g. energy efficiency, fuel switching, and employment of end-use emissions treatment technologies), than upstream approaches (Helme, 2005).	Due to number of emission sources, costs are potentially prohibitive in terms of monitoring and capacity building all vehicle users, and establishing new data sets per individual (km driven, fuel consumed, cars owned etc).
Midstream: vehicle manufacturer	**Indirect carbon cost passed through.** The carbon cost incentive must be passed through vehicle prices. The extent to which this will affect consumer behaviour depends on elasticity of demand.	Less costly due to lower number of vehicle manufacturers compared to downstream approach.

	Drives the development of more efficient cars, but misses opportunity to change driver behaviour. A key problem with this approach is that the lifetime CO_2 emissions of a car would have to be estimated at point of sale, which would require average emission factors for heterogeneous cars and fuels. This misses the key point of rewarding / incentivising better behaviour (such as reduction in fuel content or efficient driving) as all drivers are treated equally.	
Upstream: entry of fuel into the supply chain (e.g. fuel supplier, as refineries, blenders / importers, or distributors)	**May drive incentives along the fuel supply chain, but incentive is indirect.** The carbon cost incentive must be passed through fuel prices, which may not be possible in some markets. The extent to which this will affect consumer behaviour depends on elasticity of demand. Moreover, provides only indirect incentive for improvement in car manufacturing.	Less costly due to lower number of entities to regulate. This requires less data collection (usually pre-existing data sets on fuel consumed or vehicles manufactured) and monitoring, capacity building and administrative costs.

The experience of the EU highlights some of the tensions above. While an ETS was considered for road transport in the EU, it was not implemented due to feasibility challenges. The EU ETS covers 45% of EU's GHG, namely power, combustion and industrial sectors (European Commission, 2017). The sectors covered gradually expanded as the ETS was implemented, using a phased approach which enabled learning by doing. In Phase I (2005-2007), only large combustion plants and industries were included. In Phase II (2008-2012), domestic aviation within the EU was included, and in Phase III (2013-2020) coverage was extended to include additional industrial plants and CCS installations.

At the time of implementation policy makers considered whether road transport should be included. However, since the EU was committed to the principle of direct emissions and a downstream point of regulation, it was much more feasible to introduce the EU ETS in sectors with a small number of large emission sources (EU Comission of European Communities, 2000). In addition, existing regulation which covered these large sources (Large Combustion Plant and Integrated Pollution Prevention and Control Directives) provided a starting point for determining the trading system population.

Nonetheless, the exclusion of sectors with diffuse emission sources, particularly ones as significant as the road transport sector, was recognised as a significant weakness at the time. The European Commission (EC) was determined to ensure that equivalent policies and measures were in place. Thus, for the remaining sectors not covered by the ETS, there are binding targets for GHG reductions under introduced under the 2009 the Effort Sharing Decision (ESD) mechanism.

Nonetheless, a number of EU states have chosen to implement carbon taxes under the ESD, in order to complement the ETS and introducing carbon pricing in un-traded sectors. In 2016, 14 European member states had carbon taxes implemented, covering a variety of sectors which in some cases include the road transport sector (World Bank, 2016). In eight of these, the carbon tax predates the EU ETS, while in the remainder of the states, these were introduced at the same time as the ETS, or following it, implying that it has been designed to complement the ETS in some way.

For example, Ireland, introduced carbon taxes from 2009 to cover emissions in non-traded sectors (mainly transport, heat in buildings and heat and process emissions by small enterprises). Taxes for liquid transport fuels were introduced in the first phase, covering petrol and auto diesel, and non-transport and solid fuels were covered in subsequent phases. When it was first introduced, the tax was €15/tCO_2e (2009-2012), and has increased to €20/tCO_2e from 2012 (Ireland Department of Finance, 2004). The tax was designed to avoid overlap with the European level policy (ETS and the energy taxation directive - ETD) by exempting companies covered by the latter from compliance under the Carbon Tax. Nonetheless, it has been noted that the discrepancy between the carbon cost of the EU ETS and the carbon tax may lead consumers to favour electricity as a form of fuel.

The box below describes the impact of the Irish Carbon Tax on the road transport sector.

Impacts of the Irish Carbon Tax on the Road Transport Sector

Ireland has adopted a carbon tax on all energy products not covered by the EU ETS (mainly transport and heat in buildings).

According to an IEEP study (Institute for European Environmental Policy, 2013) it is hard to measure the impact of the tax, because although consumption of petrol and diesel fell (by 21% and 13% from 2008-2011), this was at the same time as the economic downturn and the impact of existing regulation is difficult to determine. One cited author concluded that the carbon tax rates are probably not high enough to induce substantial changes in emissions in the medium term from transport, mentioning also that there are no practical alternatives or existing infrastructure precludes a change in behaviour.

Although intended to be revenue neutral, revenues from the tax have to date gone to the general exchequer rather than reduce labour costs or increase welfare rates. The tax was found to be ‘mildly regressive’, as it weighs somewhat more on rural than urban households. In addition, regressive effects have most impact for heating and transport fuels where substitutes are not available and where domestic heat efficiency is low.

Although further research is needed to determine distributional impacts, Social Justice Ireland (2012) claimed that despite attempts to mitigate impacts on households, the combination of the carbon tax and changes to the fuel allowance programme have led to an increase in fuel poverty.

Some of the funds were recycled to be used in sustainable energy management programmes for homes, and support given to fuel poor for heating their homes.

California however provides an example of a jurisdiction which was able to include road transport in the ETS by adopting a mixed regulatory approach (up and downstream POR). The California ETS had a narrow sectoral scope in the 1st Phase (2012-2014), covering large sources such as generators and industrial facilities, and in the 2nd phase (2015-2020) this was expanded to include transportation fuels, small industrials, residential and commercial fuel use.

Unlike the EU ETS, this implied a mixed regulatory approach.

Even with an upstream approach in the fuel sector however, there were a number of candidates for the regulated parties (e.g. refiners, blend-stock importers, and distribution terminal racks, varying also by fuel type). In choosing the party, the California Air Resources Board (California Air Resources Board, 2009) sought to maximise the emission coverage while minimising the number of entities regulated. In addition, to ensure that only the large consumers incurred a carbon cost, the regulated party had to be able to monitor and net out the fuel supplied to smaller customers. Finally, they chose to regulate "*the entity who has title to the fuel immediately upstream of the terminal or refinery rack*". For example, if Importer A sells ethanol in bulk to Company B, and company B delivers finished fuel across the terminal rack to Company C for distribution, Company B is the regulated entity that must report and comply with the ETS (California Air Resources Board, 2014).

However, Californian policy makers were aware that they were trading off feasibility with the strength of the carbon efficiency incentive. The Center for Clean Air Policy (Helme, 2005) had advised that while an upstream POR achieves broad coverage and minimises the administrative burden, this may limit the effectiveness of the instrument. The carbon price signal would not be sufficient to encourage technological innovation since the obligation is placed on fuel suppliers rather than for car manufacturers. In addition, if passengers have no other transport options, this may not reduce the number of vehicle miles travelled.

5.3.2 Policy interactions: considerations for introducing CPIs into the existing policy landscape

Bearing in mind the role for carbon pricing in road transport, this section draws on international experience to present some of the key considerations for introducing this CPIs into the existing policy landscape. Whether carbon pricing should be introduced depends on the pre-existing policy landscape, in particular whether the interaction with complementary policies already exist (the landscape is congested), or whether contradictory policies exist.

There are a number of examples of successful combination of carbon pricing and command and control policies for the road transport sector. A number of EU states have successfully combined CAC (such as fuel economy standards) with fiscal measures such as carbon taxes. While such standards are low cost and effective means of increasing vehicle efficiency, combining these with taxes reduces the rebound effect. (Ribeiro et al., 2007). The experience of California in combining similar regulation and the cap and trade programme will be shown below.

However, the combination of CPIs and CAC is effective only under certain conditions. A landscape already congested with CAC regulations may limit the effectiveness of the CPIs, as well as increase the regulatory and administrative burdens. When considering the introduction of an ETS, pre-existing complementary policies ultimately reduce level of effort required to meet emission targets, but obligated entities have less choice over what abatement options to adopt. This reduces the demand for emission allowances, and lowers the carbon price signal. This was the finding of the EU when considering the introduction of an ETS in the sectors already covered by similar regulation. While the carbon tax price signal will not be affected in such a situation there are other trade-offs to consider when introducing a tax, instead of an ETS**.** It is important to question whether additional regulation in the form of a CPI is necessary, if other regulation already exists.

In addition, the carbon price signal can be affected by existing energy pricing policies. Harmonising energy and carbon taxation is necessary to ensure that contradictory incentives are not being created. When considering the interaction with fuel pricing policies, the experience of the EU in trying to adopt carbon taxes on fuels demonstrates that the energy taxation policy has to be analysed as whole, to ensure the different components are not contradictory. A carbon tax cannot be imposed without considering the overall effect of other taxes and subsidies on the final prices which consumers face, and the relative attractiveness of competing fuels. [*Please see Chapter 2 - Interaction of Fuel Price Policy and Carbon Taxes – for fuller analysis of the interactions of energy pricing policies and carbon prices*].

5.3.2.1 EXPERIENCES OF COMBINING CPIS WITH EXISTING COMMAND AND CONTROL REGULATION

The experience of the EU illustrates that the existence of a number of command and control regulations will limit the effectiveness of introducing an ETS. Meanwhile, California designed a policy package which took into consideration such interactions.

In the EU, a number of instruments have been introduced at EU level with the objective of increasing vehicle efficiency in the road transport sector. As explained, the Effort Sharing Decision (ESD) was established in 2009 establishing binding GHG emission reduction targets for the sectors not covered by the ETS. In response to these requirements, a number of EU level and member state level regulations have been introduced in these sectors(European Commission DG Clima, 2016). To exemplify, the box below shows that a combination of command and control (standards, regulations), market based and fiscal instruments, eco-labelling and voluntary initiatives have been adopted at EU level.

Key climate policy instruments in the EU road transport sector

The notable policy at EU level includes these policies aimed at different regulated entities:

- **Vehicle manufacturers**: CO_2 standards for new passenger cars and light commercial vehicles, which set targets of average fleet performance requirements by 2020. Non-GHG standards and obligations to reduce emission from mobile air conditioners also exist.
- **Vehicle retailers**: CO_2 emission and fuel economy labels.
- **Fuel producers and suppliers**: fuel quality directive, requiring reduction of GHG intensity of road transport fuels (gasoline, diesel, and biofuels) by up to 10% by 2020, accounting for lifecycle emissions.
- **Final consumers:** energy taxation directive, set a minimum rate for energy products used as motor fuel, for energy products used as heating fuels, and for electricity.

While further interventions will be necessary to meet binding targets, Ricardo's analysis suggests that the congested policy landscape will limit the effectiveness of an ETS.

Ricardo's impact assessment of the ESD in the transport sector (Ricardo AEA et. al, 2012) indicates that although EU vehicles have become more efficient, improvements have been outweighed by an increase in demand for passenger and freight transport. Without further policy interventions, the transport activities covered under the ESD will not achieve their emission reduction commensurate with the 2030 and 2050 targets in the EU.

While this might suggest the need to expand the ETS, the study explains that the existing regulatory landscape, in particular regulations on emissions from cars and vans, are expected to drive the take up for the most cost-effective abatement measures in the sector. These policies would actually serve to weaken the carbon price in the ETS. Much of the remaining abatement potential in 2020 appears to be comparatively expensive in transport requiring higher carbon price band of over €25/tCO_{2e}, such as development of full hybrid passenger road cars, the development of electric cars, and more efficient car engineering. Rather than introducing carbon pricing, the study recommends focusing on policies to encourage the uptake of electric vehicles and behavioural change to improve efficiency of both the vehicles and transport system from the demand side.

The box below presents the measures being taken in the EU to encourage the development and uptake of electric vehicles.

Preparing for Electric Vehicles in the EU

The electrification of road transportation is a key element of the EU's roadmap to reduce transport emissions. However, studies suggest that techniques such as life cycle assessments should be used to compare the environmental impact of electric vehicles, because both their production and operation represent an environmental burden.(Hawkins, Singh, Majeau-Bettez, & Strømman, 2013)

According to Ricardo's study (Ricardo AEA et. al, 2012) if electric vehicles are to be taken up, there is the need to provide clear long-term policy signals to stimulate technology and market development. A shift to an alternative energy system (e.g. electricity, hydrogen, or biofuels) will also require a supporting infrastructure for energy distribution and supply to vehicles.

A 2015 study by the Centre for European Economic Research (ZEW GmbH) identified four barriers to increasing demand for electric vehicles. (Achtnicht et al., 2015)

- **Barrier 1: High purchase cost.**
- **Barrier 2: Slow spreading of infrastructure for recharging.** The ability to expand the availability of alternative fuel stations is crucial to increase the demand for non-conventional vehicles. Related to this, ensuring sufficient, de-carbonised grid capacity is essential, as the increasing number of EVs will create considerable pressure on power supply. Further, since the fuel which is used to power EV will have a significant impact on its mitigation capacity, decarbonisation of the grid is essential. It is possible that if thermal electricity is supplied to charge the EV it could have a higher emission impact than conventional vehicles.
- **Barrier 3: consumer acceptance.** Including overcoming “range anxiety”, the perception that EVs will have a low distance range.
- **Barrier 4: Relative evolution compared with other alternative technologies.**

Given the variety of barriers, a multi-instrument approach addressing both demand and supply side issues is recommended.

- Solutions for the **Barrier 1** include financing support, such as tax credits, capital cost rebates, grants and subsidies, or concessional financing. For example, a number of European countries have sought to increase the demand for alternatives vehicles by providing grants subsidies for their purchase. In the UK for example, grants are provided toward the cost of a new electric (plug-in) car, van or motorcycle, provided it falls within one of 6 categories of low emission vehicles (UK Government, 2017).
- To tackle **Barriers 2** and **3**, short run strategies include focusing on plug-in hybrid electric vehicles around urban areas, where charging infrastructure can be developed in concentrated spaces, and less range is required. (Kihm & Trommer, 2014)
- Regarding **Barrier 4**, the government can play a role in encouraging advances in technology by subsidising research to the point at which the technologies become mature enough to enter the market. In fact, such research can be funded through revenues raised by carbon pricing instruments. The EU ETS directive states that at least half of auction revenues should fund complementary GHG reduction measures in EU and developing countries. In 2013, the EU ETS’s total auctioning revenue amounted to €3.6 billion. From this, around €3 billion was used for climate and energy related purposes such as energy efficiency, renewables, research and sustainable transport (Environmental Defense et. al, 2015).

California designed a policy package to be introduced with the ETS, aiming to mitigate some of these concerns. Indeed, the cap and trade scheme is only one of a comprehensive policy mix for reducing road transport emissions in California. Current regulations target car manufacturers, fuel suppliers and local government and seek to complement the carbon price signal. The Low carbon fuel standard imposes obligations on fuel suppliers to meet reduction targets, but allows trading of allowances. Car manufacturers have both GHG standards, and obligations to produce increasing amounts of low carbon vehicles. Finally, to encourage an Integrated approach to regional transportation and land-use planning, regional governments have targets for GHG reduction from transport. Full details are provided in the box below.

However, the effectiveness’ of combining an upstream ETS and CAC standards in California has not yet been assessed.

Key measures in California to address road transport emissions

Other than the cap and trade programme, California ARB highlighted the following (California Air Resources Board, 2013):

- **Low carbon fuel standards**: established in 2007, requires producers of petroleum-based fuels to reduce the carbon intensity (based on life-cycle assessment) of their products, beginning with a quarter of a percent in 2011 culminating in a 10 percent total reduction in 2020 (California Energy Commission, 2017). It uses a market based cap and trade approach to lower GHG from transport fuels. Producers can either develop their own low carbon fuel products, or purchase credits from companies that develop and sell low carbon alternatives.
- **Advanced Clean Car Programme**: Light-duty vehicles sold in 2025 will emit 75% less smog-forming pollution and 34% less GHG emissions. Two components Low-Emission Vehicle (LEV) requiring reduction in pollutants and GHGs of light and medium vehicles, and the Zero-Emission Vehicle (ZEV) regulation, which requires manufacturers to produce an increasing number of pure ZEVs (meaning battery electric and fuel cell electric vehicles), with provisions to also produce plug-in hybrid electric vehicles (PHEV) in the 2018 through 2025 model years (California Air Resources Board, 2017a).
- **Sustainable communities and climate protection act** (California Air Resources Board, 2017b): Focuses on coordinated transportation and land use planning with the goal of more sustainable communities, and sets regional targets for GHG emissions reductions from passenger vehicle use.

5.3.2.2 EXPERIENCE OF HARMONISING CONTRADICTORY ENERGY PRICING POLICIES

Before considering the introduction of a CPI in the transport fuels sector, existing policy interventions must be analysed to ensure that contradictory signals are not being sent. Transport fuels are usually already subject to significant pricing policy interventions, in the form of taxes and subsidies. These will exist for a variety of reasons, including revenue raising and pollution control, inflation control[13] and in some cases environmental reasons.

Experience in the EU reveals that contradictory energy and carbon taxation existed, and a proposal to harmonise this was put forwards. The Energy Taxation Directive (ETD) set minimum tax rates for all energy products used for heating and transport in the EU. Apart from trying to minimise market distortions between member states, the main goals of this taxation policy are to raise revenue and provide incentives to purchase cleaner technologies, in addition to supporting the achievement of climate change objectives (European Commission DG ENER, 2011b).

In 2011, a proposal was put forwards to revise the ETD as it was creating incentives contradictory to the energy and climate goals. Since the minimum rates apply to the volume of the energy product consumed, they do not reflect the energy content or the CO_2 emissions of the energy products. This

[13] In Brazil, inflation control objectives is paramount. The price of gasoline has a very significant weight on the inflation index, and that is why the government and Petrobras have kept the price of gasoline below world market prices, at a major cost to the economy.

leads to inefficient energy use and promotion of carbon intensive activities, for instance, by promoting the use of diesel over petrol motor fuels, and discriminating against renewables.

A revision to the ETD is proposed, with 2 mains components:

- CO_2-related taxation, based on the CO_2 emissions of the energy product, fixed at a level of 20 euro per tonne CO_2. Such taxation will provide for a technology-neutral advantage for all low carbon energy sources. This is designed to complement the EU ETS, by applying only to the emitters not included in the ETS.
- General energy consumption taxation, based on energy content measured in GJ, regardless of the energy product, thus providing an incentive to save energy. The tax will reflect the actual energy that a product generates and energy efficient consumption would automatically be rewarded.

The impact assessment modelled the impact on the fuel mix of aligning the petrol and diesel rates on an energy content and CO_2 basis (European Commission DG ENER, 2011a). They were found to improve the functioning of the internal market, as they remove distortions between the tax treatment of energy sources. Regarding environmental effectiveness, these options would lead to a reduction in CO_2, and a readjustment of demand between petrol and diesel. Finally, the options were expected to result in positive budgetary impacts.

Nonetheless, the proposal was rejected following a vote in April 2012, and has now been withdrawn by the commission. Reasons stated for the lack of political acceptance include the perception of the tax unfairly penalising diesel fuel costs and car manufacturers.

5.3.3 Alternative carbon pricing instruments for the road transport sector

As has been demonstrated, CPIs in the form of ETS or CT may not be appropriate for a particular jurisdiction. This may be due to the feasibility challenges, the limited effectiveness that carbon pricing will have (due to demand elasticities or policy landscape congestion), the costs associated, or simply because a jurisdiction is seeking to incentivise higher cost abatement options.

In light of this, this section presents examples of how Carbon Pricing has been used in innovative ways in the road transport sector. Colombia proposes to combines a carbon levy with an offsetting system, to incentivise high cost abatement measures and limit fuel price rises. In Colombia's case, a carbon tax would be too expensive and would not achieve the emission reductions desired. Instead, a carbon levy combined with an offsetting mechanism, which could also be funded internationally through NAMAs, was proposed.

Also aiming to fund high-cost abatement, and provide project developers climate financing, Guangdong has implemented an up-scaled crediting mechanisms alongside its ETS. The CDM programme of activities is aimed at funding the replacement of buses. Since such mitigation options have high up-front costs, they usually cannot be incentivised by a carbon price signal alone**.**

Colombia and the EU have also adopted market based approaches to imposing GHG performance standards on vehicle manufacturers and fuel suppliers. The obligations have been innovatively combined with trading and offsetting elements, to reduce burden on entities.

Finally, also noteworthy is the experience of a number of European introducing carbon taxation on vehicle registration or ownership, in order to influence the purchasing decision. Particularly in France, this approach has had positive results.

5.3.3.1 COLOMBIAN CARBON LEVY, NAMAS AND PERMIT TRADING

When elaborating their MRP in 2014, Colombia already had in place a number of low carbon measures in the road transport sector (Colombia Ministry of Environment and Sustainable Development, 2014). These included congestion charging, fuel and technology standards, urban planning, promotion of non-motorised and hybrid vehicles, and demand side management, all within the Colombian Low Emissions Development Strategy (Pardo, 2013). Against this policy backdrop, Colombia considered the introduction of an ETS or Carbon Tax.

While Colombia did consider the introduction of a carbon tax, the low elasticity of demand of transport fuels meant that a very high tax would be required to achieve targeted GHG reductions. Achieving a 10% reduction in road transport emissions through a carbon tax would require doubling the fuel price.

Instead, the introduction of an offsetting scheme funded by a carbon levy would achieve desired reductions much more cheaply. A 10% reduction in GHG emissions could be achieved by increasing the fuel prices by 4%. The revenues raised would be earmarked (not entering the general budget) and recycled into sustainable transport projects. In order to minimise impacts on consumers, this 4% increase would substitute a portion of the existing fuel surcharge, keeping fuel prices constant.

While a portion of the funding for these projects would therefore come nationally from the general budget, this was considered more politically acceptable than a carbon tax which would be more costly for consumers and funds could be earmarked to directly support sustainable transport projects. Nonetheless, a drawback of approach is that it misses the opportunity to provide a carbon price signal for rational fuel use or fuel switching.

To complement this, the MRP proposed the development of NAMAs (up-scaled crediting projects) in the transport sector which could also to attract international financing. One of the NAMA projects being considered is the implementation of CO_2 performance standards for car manufacturers and importers, with a market based allowance trading mechanism (see box below).

Performance standard with permit trading in Colombia

As an additional measure, Colombia has put forward innovative proposals to credit GHG mitigation policies, such as the implementation of performance standards.

The Colombian MRP proposes the implementation of a GHG performance standards for vehicles, an obligation to be placed on either the vehicle manufacturer or importer. Following the EU example, binding emission targets for vehicle fleets would be implemented, based on the average performance of vehicle fleet. Where a regulated party exceeds its target, an excess emissions premium would have to be paid. In addition, parties would be assigned allowances and trading permitted between parties. As such, an incentive is created to price low carbon vehicles more competitively, to meet targets and avoid penalties of non-compliance.

The EU's Fuel Quality Directive similarly combines an obligation with a trading mechanism. Imposed on fuel suppliers, it requires a 10% reduction in the GHG intensity of road transport fuels when lifecycle emissions are considered, fuel suppliers are allowed the flexibility achieving 2% of the target through the use of credits from the Clean Development Mechanism.

5.3.3.2 CDM PROGRAMME OF ACTIVITIES IN GUANGDONG TO COMPLEMENT THE ETS

In Guangdong, scaled-up crediting approaches were combined with the ETS to capture the opportunity for emission reductions in road transport. In 2012, a Programme of Activities (PoA) in the Chinese Guangdong Province that promotes the replacement of diesel buses by LNG buses was developed. There are no overlaps with the ETS launched in Guangdong in 2013 as the ETS does not cover the transport sector.

CDM Programmes of Activities (PoAs) apply the concept of crediting to an aggregated number of emission sources. Once a PoA is registered, an unlimited number of component project activities (CPAs) can be added without undergoing the complete CDM project cycle, aiming to overcome certain implementation barriers . A typical barrier is for example high number of very small emissions sources for which the MRV requirements are too cumbersome if applied individually. Eligible methodologies in the transport sector include Bus Rapid Transport, mode shift from road to rail, more efficient transport systems, scrapping of old vehicles, biodiesel for transport and cable car projects.

National or international sources of funding can be used. Credits generated under the PoA could be used in the Chinese ETS pilots, including Guangdong, or in the national scheme once developed creating a source of demand. In addition, credits can be sold internationally. The acceptance of the scheme is high because it can attract foreign funding.

However, a number of financing, institutional and methodological barriers remain. Although international funding can be sought through carbon markets, no credits have been issued so far, and this may be due to the fact that CER prices are currently very low and hence may not make the investment viable. PoAs currently face challenges such as low demand and prices for CERs which dis-incentivise the development of new projects and issuance of credits from already registered projects. Moreover, it can be a barrier that in-country institutions to manage the programmes have to be established. Besides, the complexity of developing baselines and benchmarks across sectors in different jurisdictions has proven to be challenging.

5.3.3.3 CARBON TAXES FOR VEHICLE REGISTRATION AND OWNERSHIP IN THE EU

In Europe, CO_2 taxation is also often used for vehicle registration and/or ownership, in order to influence the decision to purchase new vehicles. In Austria this tax is levied upon the first registration of the vehicle, electric vehicles are exempted and there is a penalty of €20 for each g/km emitted in excess of 250 g/km (Achtnicht et al., 2015). Alongside the carbon tax in Ireland, the Vehicle Registration Tax (VRT) and an annual motor tax were re-calibrated from July 2008 to be based on open market selling price and CO_2 rating, and have had a significant impact on the composition of the new car fleet (Institute for European Environmental Policy, 2013). Although some attempt was made to harmonise this in the EU, to avoid distortions and double taxation, there is still huge variation in how it is applied.

In France, a hybrid approach which combines carbon taxing and carbon standards for vehicles has been implemented in since 2008. It is designed to encourage the purchase of vehicles that emit the least amount of CO_2. A rebate (bonus) is paid to buyers of vehicles that emit less than 130g of CO_2 /km. Inversely, a tax is imposed on the purchase (malus) of all cars that emit more than 160g CO_2 /km. The measure has had a significant effect on new vehicle sales in France: average new vehicle emissions were lowered to 140g CO_2 /km in 2008, a 9g reduction from the previous year (compared with an average reduction of 1g per year in previous years).

5.4 LESSONS LEARNT

5.4.1 ROLE OF CARBON PRICING IN THE ROAD TRANSPORT SECTOR

Carbon pricing has a role to play as part of a portfolio of measures to reduce GHG in the road transport sector. ETS and CT are most effective to incentivise low to mid cost abatement measures, for example affecting vehicle or fuel pricing, and cost of circulation, in order to reduce private vehicle ownership, support congestion management and a switch to biofuels. However, the effectiveness of carbon pricing depends on the elasticity of demand of vehicles and fuels to changes in price signals.

There are limitations on the role of carbon pricing. Typically carbon prices are too low to incentivise abatement measures with high up-front costs. CP can only provide supplementary incentives for modal shift and alternative vehicles. In addition, there are a number of policies which carbon pricing can support but not replace. These are command and control policies which create regulatory requirements for the use of biofuels or carbon efficiency standards, where command and control (CAC) regulation is preferable.

5.4.2 FEASIBILITY CHALLENGES

The diffuse nature of emissions sources in the road transport sector poses a challenge for choosing the point of regulation (POR) for ETS and CT systems. The choice of which point of regulation involves a trade-off between the strength of the carbon efficiency incentive and the administrative costs.

The experience of the EU highlights some of these tensions. While an ETS was considered for road transport in the EU, their commitment to the principle of direct emissions and a downstream point of regulation meant it was not implemented due to feasibility challenges. At the time (2000), this was recognised as a key weakness.

Subsequently, a number of EU states have chosen to implement carbon taxes in order to complement the ETS as a means of introducing carbon pricing in un-traded sectors. For example, Ireland introduced carbon taxes from 2009 to cover emissions in non-traded sectors (mainly transport, heat in buildings and heat and process emissions by small enterprises).

California however was able to include road transport in the ETS by adopting an upstream approach for transport fuels. In order to cover the transport sector, the 2nd phase of the ETS was expanded to cover fuel distributors, although policy makers were aware of the trade-offs implied, since placing the obligation on fuel suppliers missed the opportunity to incentivise technological improvements in car manufacturing.

5.4.3 Policy interactions: considerations for introducing CPIs into the existing policy landscape

There are a number of examples of successful combination of carbon pricing and command and control (CAC) policies for the road transport sector. A number of EU states have successfully combined CAC (such as fuel economy standards) with fiscal measures such as carbon taxes. While such standards are low cost and effective means of increasing vehicle efficiency, combining these with taxes reduces the rebound effect.

However, the combination of CPIs and CAC is effective only under certain conditions. A landscape already congested with CAC regulations may limit the effectiveness of the CPIs, as well as increase the regulatory and administrative burdens. When considering the introduction of an ETS, pre-existing policies may reduce the level of effort required to meet emission targets, and leave participating entities with less choice over what abatement options to adopt. This reduces the demand for emission allowances, and lowers the carbon price signal. This was the finding of the EU when considering the introduction of an ETS in the sectors already covered by similar regulation.

In addition, the carbon price signal can be affected by existing energy pricing policies. Harmonising energy and carbon taxation is necessary to ensure that contradictory incentives are not being created. When considering the interaction with fuel pricing policies, the experience of the EU in trying to adopt carbon taxes on fuels demonstrates that the energy taxation policy has to be analysed as whole, to ensure the different components are not contradictory. A carbon tax cannot be imposed without considering the overall effect of other taxes and subsidies on the final prices which consumers face, and the relative attractiveness of competing fuels.

5.4.4 Alternative carbon pricing instruments for the road transport sector

As seen, carbon pricing in the form of ETS or CT may not be appropriate for a particular jurisdiction. In light of this, jurisdictions worldwide have been using carbon pricing in transport in innovative ways.

Colombia proposes to combine a carbon levy with an offsetting system, to incentivise high cost abatement measures and limit fuel price rises. In Colombia's case, a carbon tax would be too expensive and would not achieve the emission reductions desired. Instead, a carbon levy combined with an offsetting mechanism, which could also be funded internationally through NAMAs, was proposed.

Guangdong has implemented an up-scaled crediting mechanisms alongside its ETS aiming to fund high-cost abatement, and provide climate financing to project developers. The CDM programme of activities is aimed at funding the replacement of buses. Since such mitigation options have high up-front costs, they usually cannot be incentivised by a carbon price signal alone**.**

Finally, jurisdictions have been using market based approaches for imposing standards and incorporating carbon taxation in vehicle ownership. Colombia and the EU have adopted market approaches to imposing GHG performance standards on vehicle manufacturers and fuel suppliers. The obligations have been innovatively combined with trading and offsetting elements, to reduce burden on entities. Also noteworthy is the experience of a number of European introducing carbon taxation on vehicle registration or ownership, in order to influence the purchasing decision. In France this approach has shown positive results.

6 IMPLICATIONS FOR BRAZIL: INTERNATIONAL EXPERIENCE OF CARBON PRICING IN FUEL SECTOR

6.1 INTERACTIONS OF FUEL POLICY AND CARBON PRICING INSTRUMENTS

[Covering both the themes on interactions with ETS and Carbon Tax]

Current Brazilian policy priorities of inflation containment through intervention in fuel pricing may not be in line with the introduction of a CPI in the fuel sector. Mexico introduced the carbon tax on fuels as a small part of a much wider energy sector reform, which focused on liberalising the energy market, increasing competition and introducing cost reflective pricing. The introduction of a carbon tax in Mexico was complementary to the policy goal of cost reflective fuel pricing. It is not clear that the same is true of the policy context in Brazil, which is still prioritising inflation containment over cost reflective pricing.

In this interventionist policy context, it is unclear whether the carbon price signal would be effective. Although recent years have seen the Brazilian government allowing Petrobras more autonomy in setting cost reflective fuel prices, the CIDE excise duty is still being used as a lever to contain inflationary pressure of fuel prices. In this policy context, one should question whether the carbon price signal will be allowed to reach consumers at all, or whether it will be ineffective. In Mexico, the removal of fuel price stabilisation policies were a necessary precondition for an effective carbon price signal. In fact, the carbon tax was included as small part of a much wider energy sector reform.

Nonetheless, Mexico's case demonstrates that the carbon tax can be designed in a manner which is sensitive to inflationary pressure concerns, and uses a reference fuel approach. In Mexico, concerns about the fuel price increase after the tax introduction, potential impact on general inflation levels and competitiveness of Mexican firms resulted in the carbon tax rate set at a limit of 3% of the price of the fuel. In addition, in Mexico natural gas was determined as the reference fuel (the baseline) against which the carbon content of all other fuels was to be determined. In a similar way, biofuels could be set as the reference fuel in the Brazilian road transport sector.

In two cases studied, protection of low income households was a key part of fuel policy which was extended as a result of introducing the carbon tax. Protection of low income households was a key policy priority in Ireland and B.C., and in both cases the regressivity of the carbon tax was an issue which had to be addressed. Ireland conducted various studies prior to the introduction of the carbon tax to determine expected impacts on low income groups, and provided further assistance to these through a fuel allowance. Similarly, B.C. introduced a tax credit scheme aimed at low income households alongside the carbon tax. Further, the B.C. carbon tax was set up as a revenue neutral policy tool, meaning that every dollar collected as part of the tax is returned to the society through reductions elsewhere in the tax system. Earmarking carbon tax revenues to offset the carbon tax can support low income populations and make the tax politically acceptable.

Finally, a number of design elements and compensatory measures can be adopted to protect industrial competitiveness, a key policy priority in the Brazil. The UK provides a good example of such measures, to address both the introduction of EU policies, such as the EU ETS compensation scheme, and UK legislative measures, such as CCA compensating for the effect of CCL.

Regarding EU policies, free allocation under the EU ETS became more stringent for the industrial sectors as the phases ensued. In PI and PII, most were freely allocated, and auctioning was introduced in PIII for those not deemed at risk of leakage (for the latter, free allocation according to benchmarks was introduced). The power sector however was subject only to auctioning as of PIII.

Second, the UK government also developed national compensation mechanism. As a result of national and EU climate policies, wholesale electricity price were expected to increase in short to medium term. Indeed, electricity prices of the household sector rose by 61% between 2004 and 2016, and 25% of this increase was due to these climate policies. The compensation scheme allows businesses to claim compensation for the indirect costs, in line with EU state aid rules. As of October 2014, 53 companies had been paid over £44 million, mitigating around 65% of these costs. Evaluation shows that this scheme has been successful in limiting the impact on the final energy costs.

Finally, exemptions from the CCL were granted to selected energy intensive industry sectors. The mineralogical and metallurgical industries were granted exemptions based on their process types, and did not require committing to any energy efficiency targets.

6.2 Carbon Pricing and Biofuel policy

RenovaBio is effectively a carbon pricing instrument in road transport. It incentivizes biofuels in the same way a carbon pricing instrument would. The tradeable compliance units (CBios) provide an incentive across covered fuels (gasoline), and mandates for biodiesel cover the remainder. As such, additional carbon pricing instruments covering transport may create unintended interactions and/or replicate the effort and direction given by the RenovaBio policy.

The design of RenovaBio will determine the impact of additional carbon pricing instruments in transport. Particularly, what emission reduction target will be chosen will influence the price of CBios and the impact of the RenovaBio policy. Future amendments or current design details of RenovaBio could be guided by the lessons learnt from successful biofuels policies and carbon price policies.

6.3 Carbon Pricing in the Transport Sector

6.3.1 Priority mitigation options in Brazil

As stated in Section 1, Brazil's priority mitigation options in the Road transport sector are:

- Urban transportation. Shift to bus rapid transit and metro, implanting traffic management measures.

- Regional transportation. Modal shift for passenger and freight transport, such as expansion of high-speed passenger trains between Sao Paulo and Rio de Janeiro to replace the use of planes, cars, and buses, or increased use of water and rail transit for freight
- Fuel switching. Increasing the switch from gasoline to bio-ethanol fuels. The key challenge is to ensure that market price signals are aligned with this objective. In addition, a financial mechanism to absorb oil price shocks is also recommended.

Of the options outlined above, modal shift in urban and regional transportation are characteristically large capital intensive infrastructure projects, with high up-front costs. Fuel switching however is focused on ensuring the correct price signal is sent so that biofuels are more attractive than fossil alternatives. Transport demand management may be achieved by a combination of pricing signals and regulation.

6.3.2 Potential effectiveness of carbon pricing.

Carbon pricing may play a role in supporting these mitigation options, but as shown is most effective at incentivising low to mid cost abatement measures. For example it can be used to influence vehicle or fuel pricing, and cost of circulation, in order to reduce private vehicle ownership, support traffic management and a switch to biofuels.

Fuel switching. In a context such as Brazil's, where there is already the widespread use of biofuels, the carbon price signal could play an important role in supporting switching to biofuels. Nonetheless, an analysis of the elasticity of demand of these fuels would be necessary, in order to determine how costly such a fuel switch would be for consumers and the economy as a whole. In addition, further support may be required, for example in the form of complementary regulation to support biofuel production, and importantly, harmonising energy price signals. This is dealt with in the interaction analysis section below.

Modal shift. With respect to modal shift through transport infrastructure projects, very high carbon price signals would be required to justify the project on the basis of carbon pricing alone. The World Bank study (Gouvello, 2010) estimates a marginal abatement cost of approximately U$40 / tCO_2e for BRTs, and a break even carbon price of between U$200-300/ tCO_2e for the project to become attractive to the private sector. However, such projects usually have enormous co-benefits, and indeed are being implemented in most major cities in Brazil (and in Latin America more generally), so the carbon price would not be the critical investment factor.

Some jurisdictions however have developed alternative carbon mechanisms in order to support large transport projects. This is the case of Colombia, which proposed to implement a carbon levy and offsetting scheme which recycle revenues into transport projects. In addition, Guangdong provides an example of up-scaled crediting mechanisms which could be designed to raise funds for these projects. Offsets generated could be sold into other capped sectors of an ETS.

6.3.3 Feasibility challenges

In addition to considering the effectiveness of carbon pricing for the desired abatement options, the question of which point of regulation to choose depends on feasibility, and will impact the effectiveness of the instrument. The diffuse nature of emissions sources in the road transport sector poses a challenge for choosing the point of regulation (POR) for ETS and CT systems, which involves a trade-off between the strength of the carbon efficiency incentive and the administrative costs. The cost of administering a downstream scheme in the road transport sector is potentially prohibitive given the number of car users in Brazil. There were 36 million vehicles in Brazil in 2014, and according to the National Energy Plan for 2050, this is expected to rise to 130 million by this date (Diário do Transporte, 2014). In this sense, regulating upstream may be more feasible, as Brazil has a concentrated fuel supply market. 60% of the market share for distribution of automotive gasoline is controlled by 3 distributors in 2016 (Agência Nacional de Petróleo Gas Natural e Bicombustíveis, 2013). However, the trade off is that the end-user is not being regulated, and the effectiveness of the measure depends on the strength of the passed through carbon price signal.

Brazil may learn from some jurisdictions such as California, whose cap and trade programme covers the fuel supply, by having adopted a mixed regulatory approach (up and downstream), or the case of many EU states such as Ireland, which adopt an carbon tax alongside the EU ETS.

6.3.4 Policy Interactions.

Interactions with complementary policies. While this review shows that there are a number of examples of successful combination of carbon pricing and command and control policies for the road transport sector, the combination is effective only under certain conditions. A landscape already congested with CAC regulations (fuel and vehicle standards, transport demand measures) may limit the effectiveness of the CPIs, as well as increase the regulatory and administrative burdens. In particular, the price signal of an ETS may be weakened by the existence of such overlapping policies.

Although not the remit of this chapter, one area of further study will be the interaction of a possible CPI and planned mechanisms to support biofuels. Brazil was one of the first countries to implement policies to stimulate biofuel consumption. Currently, flexible fuel vehicles are eligible for federal value-added tax reductions ranging from 15–28%. In addition, all gasoline should meet a legal alcohol content requirement of 27%. Moreover, the planned RenovaBio mechanism aims to introduce a biofuel supply obligation and permit trading mechanism, which will stimulate the supply market. The question will be whether additional support for biofuels will be necessary in light of this existing regulation. This is dealt with in depth in *Chapter 4- Carbon pricing and biofuel* .

Regarding interactions with **contradictory policies**, the carbon price signal be affected by existing energy pricing policies. Although Brazilian fuel pricing policy has been formally liberalised to be reflective of costs conditions, there has been a history of intervention in prices to control distributional impacts and inflationary pressures. Harmonising energy and carbon taxation is necessary to ensure that contradictory incentives are not being created, as the example of the EU demonstrated. These policy interactions are covered in greater detail in *Chapter 2- Interaction of Fuel Price Policy and Carbon Taxes*.

The same is true if carbon taxation for vehicle circulation or ownership is considered in Brazil. The price signals sent through existing regulation for vehicle circulation and ownership must be reviewed prior to introducing a carbon price.

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