Effective Carbon Prices

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BETTER POLICIES FOR BETTER LIVES

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Foreword

Comparisons of the effective price put on carbon by policies in different sectors and countries provide valuable insights into the cost-effectiveness of alternative policies to reduce greenhouse emissions (GHGs), and their potential impacts on competiveness. The value of this type of analysis was demonstrated by a report, published in May 2011 by the Australian Productivity Commission, entitled Carbon Emission Policies in Key Economies. *The analysis presented in that report had a major impact on that country's decision to introduce an explicit carbon pricing system on 1 July 2012.*

OECD decided to further develop this study by expanding the sector and country coverage, using the same methodology. The study by the Productivity Commission provided estimates of the costs per tonne of CO_2 *abated as a result of policies applied to electricity generation and road transport in Australia, China, Germany, Japan, Korea, New Zealand, the United Kingdom and the United States. This report expands the coverage of countries to include Brazil, Chile, Denmark, Estonia, France, South Africa and Spain. In addition, effective carbon prices regarding the pulp and paper and cement sectors, as well as households' domestic energy use, are also estimated.*

The book demonstrates large differences in effective carbon prices:

1. *within a given sector, across the countries covered;*
2. *across the different sectors, within each of the countries;*
3. *across the different instrument types, across all the countries covered.*

The challenge facing the world community in relation to climate change is so enormous that it can only be achieved by applying policies that are as cost-effective as possible. This report demonstrates that there is a large scope for improvement in this respect.

Acknowledgments

This book builds on a 2011 report by the Australian Productivity Commission, *Carbon Emission Policies in Key Economies*, and on a number of additional case studies prepared by a team of national consultants, using a similar methodology to the one used by the Productivity Commission. The study extends the range of sectors examined by the Productivity Commission from electricity generation and road transport to include the pulp and paper and cement sectors, as well as households' domestic energy use. The additional countries covered, and the consultants who performed the analysis, are as follows:

Brazil: Adilson de Oliveira and Diana Roa Rubiano of Universidade Federal do Rio de Janeiro, Brazil.

Chile: Trevor Morgan and Paul Absalon of Menecon Consulting, Winchester, United Kingdom.

Denmark: Helge Sigurd Naess-Schmidt, Jens Sand Kirk and Tina Lykke Pedersen of Copenhagen Economics, Copenhagen, Denmark.

Estonia: Silja Kralik and Eva Kraav, Tallinn, Estonia.

France: Pierre-André Jouvet, Jérémy Elbeze, Stephen Lecourt and Suzanne Shaw of the Climate Economics Chair of Paris-Dauphine University, Paris, France.

Spain: César J. Galarza and Nuria Badenes Plá, CO_2 Evolution, Valencia, Spain.

South Africa: Britta Rennkamp, Tara Caetano and Andrew Marquard at the Energy Research Centre at the University of Cape Town, Cape Town, South Africa.

Simon Baptist, John Ward and Raluca Soare of Vivid Economics prepared a case study that estimated effective carbon prices in the pulp and paper and cement sectors in the countries that were covered in the Productivity Commission's report. The same authors also carried out a detailed comparison of the methodologies that had been applied in the other case studies, and prepared a report presenting the methodology applied in the project more broadly.

Anna Drutschinin prepared a case study of effective carbon prices in the household sector in Australia, New Zealand, the United Kingdom and the United. She also extracted detailed data from all the case studies for the preparation of the tables in Chapter 3 of this book – and added supplementary information, where possible.

Nils Axel Braathen of the OECD Secretariat pulled the different inputs together and drafted the synthesis report.

Australia, Korea and Norway provided financial support for the preparation of this report.

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Executive summary

Comparisons of the effective price put on carbon by policies in different sectors and countries provide valuable insights into the cost-effectiveness of alternative policies to reduce greenhouse emissions (GHGs), and their potential impacts on competiveness. The value of this type of analysis was demonstrated by a report by the Australian Productivity Commission, *Carbon Emission Policies in Key Economies*,* which had a major impact on that country's decision to introduce an explicit carbon pricing system on 1 July 2012.

OECD decided to further develop this study by expanding the sector and country coverage, using the same methodology. The main metric used in both the Australian and present study is the *net cost to society* paid for each unit of abatement induced. This approach gives an estimate of the costs to society of achieving current levels of abatement. Any revenue raised by policies is assumed to be put to other good uses, and are not counted as costs to society.

Many of the policies covered by the case studies were not primarily introduced with the aim of limiting GHG emissions – in several cases this was not at all among the objectives of the policy. The policies were nevertheless deemed to have an impact on such emissions. When assessing their cost-effectiveness it is, however, important to also take the objectives of the other policies into account.

The report provides a snapshot of the post-policy situation compared to a counterfactual snapshot of no policy. It gives an indication of the relative incentives to abate carbon in 2010 within and across the countries examined. In spite of methodological and data limitations, the differences in magnitude of the abatement incentives are sufficiently large to provide a good level of confidence about the lessons drawn about the cost-effectiveness of different policy instruments in abating GHG emissions.

Electricity generation: The estimates available range from less than zero to EUR 800 per tonne of CO_2eq abated. However, carbon prices of at least EUR 25 were found in most of the countries, indicating relatively significant incentives, explicit or implicit, to abate *some* carbon emissions in this sector in each of the countries.

* See *www.pc.gov.au/projects/study/carbon-prices/report*.

The total abatement costs were between 0.01% and 0.05% of GDP in Australia, Chile, China, France, Japan, Korea and the United States. Abatement costs were (much) higher in other countries, such as Denmark, Estonia, Germany and the United Kingdom. In Germany they were up to a third of a percentage point of GDP.

The highest costs by far per tonne of CO_2 abated are associated with various capital subsidies and feed-in tariff systems, both in terms of the averages calculated and the maximum values observed. The lowest costs per tonne abated were for trading systems, in line with classical economic theory – a fact which confirms "textbook suggestions" that trading systems (and broad-based carbon taxes) are the most economically efficient policy tools to mitigate climate change. This is especially so when the trading systems address the environmental externality as directly as possible – like with a trading system for GHG emission allowances.

The estimated carbon prices in the *road transport* sector also show considerable variation. The costs per tonne of CO_2eq abated are *very* high in certain cases; exceeding EUR 1 000 per tonne for some policies related to the promotion of biofuels. Significant subsidies are provided for biofuels in all regions of the world. However, the costs of the US and Danish biofuels policies were each estimated to represent of the order of 0.1% of GDP. In contrast, motor fuel taxes resulted in the lowest cost per tonne of CO_2 abated by far.

Almost all the estimated carbon prices related to the *pulp and paper* and the *cement* sectors are very modest, compared to those found for electricity generation, road transport and household energy use. The project has not focused on the motivations behind the policy approaches applied in the different countries, but one factor that may contribute to the modest carbon prices facing these sectors is a fear of loss of international competitiveness.

In many of the countries covered, the *household sector* is facing quite significant GHG abatement incentives, well above EUR 100 per tonne of CO_2eq in a number of cases. The costs are particularly high in relation to some feed-in tariff systems and other subsidy schemes.

To sum up, large differences have been found in effective carbon prices:

1. *within* a given sector, *across* the countries covered;

2. *across* the different sectors, *within* each of the countries;

3. *across* the different instrument types, *across* all the countries covered.

In many respects, the last two findings are perhaps the most interesting and robust. There are a number of caveats that should be kept in mind when analysing the estimates. However, while there may be some uncertainty regarding the "ranking" of carbon prices within a given sector across countries, it is very unlikely that any caveat could "explain away" the latter two main findings – and they do not seem very sensitive to the exact year of study.

It also seems very likely that the *lower effective carbon prices* found for taxes and emission trading systems compared with other instrument categories in several sectors is related to their greater *cost-effectiveness*. Some of the other instrument types are simply not effective in reducing CO_2 emissions, so costs measured per tonne of CO_2 abated tend to be very high. In some cases (e.g. subsidies for house insulation), abating CO_2 emissions was not the main policy objective, so only "judging" their "performance" in terms of costs per tonne of CO_2 abated can be "unfair". However, for a number of the other instruments with very high effective carbon prices (e.g. measures promoting biofuels and other renewable energy sources), carbon abatement has indeed been one of the main arguments applied in public debates in favour of their introduction.

The challenge facing the world community in relation to climate change is so enormous that it is unlikely that it can be met unless countries apply policy instruments that are as cost-effective as possible. This report has emphasised that there is a large scope for improvement in this respect.

Chapter 1

Methodologies for estimating effective carbon prices

Comparisons of the effective price put on carbon by policies in different sectors and countries provide valuable insights into the cost-effectiveness of alternative policies to reduce greenhouse emissions (GHGs), and their potential impacts on competiveness. The carbon prices can be explicit, *such as carbon taxes or prices of emission allowances in GHG emission trading systems, or they can be* implicit, *reflecting the cost to society per tonne of* CO_2*eq abated as a result of any type of policy measure that have an impact on GHG emissions. This chapter discusses various methodologies for estimating such carbon prices.*

1. Introduction and background

Comparisons of the effective carbon prices, or the carbon abatement incentives, that different economic sectors face within and across countries are of great economic and political interest. Effective carbon prices arise either via *explicit* carbon prices provided by carbon taxes or emission trading systems, or *implicitly*, via the abatement incentives embedded in other policies that influence greenhouse gas (GHG) emissions.

Such comparisons can, for example, be used to assess whether the abatement incentives vary widely across emission sources *within* a country – information that is essential to determining the efficiency of the overall policy framework. They can also give indications to countries considering introducing new policy instruments as to whether competitors in other countries face more or less similar abatement incentives.

Increasing policy attention has been paid to the issue of effective carbon prices. For example, in October 2010, Vivid Economics released an assessment of the implicit carbon prices in the electricity sector in six economies, conducted for *The Climate Institute* in Australia (Vivid Economics, 2010). In that report it was noted that there were a number of conceptual challenges in undertaking such assessments and that more work was required. A later report, published in May 2011 by the Australian Productivity Commission, *Carbon Emission Policies in Key Economies,*[1] had a major impact on that country's decision to introduce an explicit carbon pricing system on 1 July 2012.

Given the high interest in this earlier work, and the policy relevance of the findings, OECD decided to take the analysis undertaken by the Productivity Commission further, by expanding the sector and country coverage, but using a similar methodology. This report synthesises the work done so far.

The study by the Productivity Commission provided estimates of the short-term carbon abatement incentives facing *electricity generation* and *road transport* in Australia, China, Germany, Japan, Korea, New Zealand, the United Kingdom and the United States. OECD's project expands the coverage of countries to also include Brazil, Chile, Denmark, Estonia, France, South Africa and Spain. In addition, the short-term carbon abatement incentives facing the *pulp and paper* and *cement* sectors, as well as *households' domestic energy use*, are also estimated.

The Productivity Commission did its stock-taking through a combination of own research, utilisation of pre-existing overviews of emissions-reduction policies,[2] consultation with government agencies in each of the study countries, and assistance from specialist consultants. In OECD's work, a number of consultants (or groups of consultants) have been used; one for each of the additional countries covered, one to cover the pulp and paper and cement sectors in the countries that the Productivity Commission had covered, and one to cover household energy use in a selection of those countries.

2. Different approaches to estimate effective carbon prices

There are a number of methodologies that can be applied to calculate an effective carbon price, and these are compared and contrasted below, to identify the different insights that can be obtained from the alternative approaches. Comparison of carbon prices across countries is complex. It is important for policy makers to be aware of what each measure does and does not imply about relative action across countries. The key point to note is that no single number can be used to encapsulate *all* dimensions of emission reduction policies.

Productivity Commission (2011) used the example of a renewable energy subsidy to make the point that there are several different ways to conceptualise a "carbon price equivalent" of a particular policy, and that each measure can yield useful insights. It is also true that there are different ways to aggregate these policy-specific measures into an estimate of an overall measure and that these, too, yield useful insights.

The main metric chosen in this study is the *net cost to society* paid for each unit of abatement induced. This is also the principal approach adopted in Productivity Commission (2011). However, although transfers between different groups in society (via e.g. taxes or subsidies) do not count as a *net* cost to society, both Productivity Commission (2011) and the present report include transfers given to low-carbon electricity producers in the cost estimates. Some alternative approaches in this regard are briefly described in Box 1.1.

The *net cost to society* approach gives an estimate of the current costs that society is bearing to achieve current levels of abatement. In this approach, policies are aggregated using weights of the share of total abatement accounted for by each policy. Any revenue raised by policies is assumed to be put to other good uses. For instance, the revenue raised through a carbon tax is not counted as a net cost to society.

Methodologies for assessing effective carbon prices can also differ in the manner in which they combine estimates of effective carbon prices across different products or sectors, cf. Box 2 It is important in this regard to consider carefully which methodology is appropriate to the situation of interest. The challenge of combining estimates across sectors increases as the relevant output becomes more heterogeneous; however, the primary constraint is a measurement issue, rather than a conceptual issue.

Box 1.1. **Alternative estimates of effective carbon prices**

Other metrics than the one developed by the Productivity Commission and applied in this report can also be used to compare climate policies, each of them answering a different question.

One alternative could be to assess which *comprehensive carbon price would induce equivalent costs to be imposed* upon electricity generators, households, etc. This approach could be used to estimate the costs borne to reduce emissions and would capture the average cost impact of policies across all activity, expressed in tonnes of CO_2-equivalent to illustrate what carbon price would result in the same cost-wedge between high- and low-carbon activities. Combined with estimates of cost pass-through, this approach can be used to identify the carbon price that would be required to deliver the same average increase in prices. This was the approach adopted in Vivid Economics (2010), and relates to the measures of electricity price up-lift in Productivity Commission (2011) and in the present report. In this case, aggregation of policies is done using the share of activity for each policy as weights (e.g. of generation for electricity, or of use for households).

A second alternative metric is *the comprehensive carbon price which would achieve the same level of abatement as achieved by current policies*. McKibbin et al. (2010) used this approach to compare the stringency of commitments made by national governments following the Copenhagen Accord. The estimate for each country depends upon the amount of abatement being currently achieved, and the cost of abatement in that economy as compared to others (i.e. the shape of the marginal abatement cost curve), and the mix of types of policy in use. This measure assumes that policy is implemented in a perfectly efficient manner, such as through an economy-wide comprehensive carbon price with perfect measurement and no uncertainty.

A third alternative approach could be to assess which countries have the most efficient policy mix. Policy-efficiency comprises doing the right amount of abatement and also doing it in the most cost-effective manner. Policy action across countries would be compared in terms of how much abatement is being induced relative to a particular allocation of targets across countries, and in terms of how much that abatement costs, relative to the least-cost abatement options available for each country. This issue was analysed by Vivid Economics and Norton Rose Australia (2011) in a report for GE. There is no aggregate implicit carbon price associated with this measure.

Box 1.2. **Different approaches to weighing together different carbon price estimates**

Consider a multiproduct firm, or a desire to combine estimates across different sectors. The Productivity Commission (2011) method (also applied in the present report) uses abatement as the comparable unit across sectors, and abatement also becomes the weights by which the estimates are combined. The Vivid Economics (2010) method, alternatively, used the weight of output that the policy applies to. So, for example, if a policy only applied to one product in a two-product sector, then the appropriate weight for the policy would be the share of the first product in total output. The challenge in this case becomes to compare output in the correct units, which is equivalent to getting nominal values and then having accurate deflators to change nominal values into real quantities. For some sectors or products, such as computers, it is very challenging. For others, such as electricity or cement, it is less challenging, because the outputs are more homogeneous. In any case, it is important to consider the quality of the data when applying any of these methods. The third metric discussed above, calculating the comprehensive carbon price that would result in the same level of abatement, is unaffected by the number of sectors in which policies are implemented. The fourth metric becomes increasingly complex as the number of sectors expands, due to the requirement to consider interactions and multiple policy objectives.

Note that the method used in the present report does not quantitatively analyse some important elements of policy, such as policy efficiency. The report demonstrates that some policies are reducing emissions at a higher cost than others, and this allows *some* inference of policy efficiency. However, a complete analysis of efficiency requires a comparison of implemented emissions reductions with those which are theoretically least cost. Nonetheless, it is clear that emissions can be reduced in ways that are more or less costly, and a high implicit carbon price could be the result of ambitious emissions reduction goals *or* poorly designed policy. Garnaut (2011) also emphasised this point:

> *"the mainly regulatory measures being taken by those countries impose greater costs on business and on their communities' standards of living than carbon pricing… While the higher costs of emissions reduction in other countries should not be counted as a contribution to the mitigation effort, neither should it count against them so long as they are meeting their commitments to constrain emissions."*

All emissions-reduction policies have in common that they impose costs that someone must pay in order to reduce emissions. Hence the term "effective carbon price" can be interpreted as the cost of reducing greenhouse gas emissions.

Despite a large variety of policy instruments applied, all policies designed to promote lower greenhouse gas emissions essentially must either provide incentives to abate or disincentives to emit greenhouse gases, or both. The project also addresses policies that in effect have such impacts, without being 'designed' with an explicit purpose of affecting greenhouse gas emissions.

Broadly speaking, policies can be classified as those that:

- Encourage substitution of low-emissions technologies and products (for example, renewable electricity and biofuels) for higher-emissions technologies and products (such as coal-generated electricity and fossil fuels) – these policies essentially focus on the production or supply side of the economy.
- Discourage consumption of products that generate emissions, either through price increases of those products and/or non-price induced decreases in demand for emissions-intensive products (e.g. due to labels showing embedded CO_2 emissions of various products) – these policies work through the demand side.

But whichever side of the market particular policies target, they will have implications for the other. Policies that effectively tax one commodity implicitly subsidise others. For example, to achieve their objective, policies that seek to reduce greenhouse gas emissions must alter relative prices to favour products that involve low emissions and to discourage products with the opposite characteristics.

For example, a carbon tax or a carbon emission trading system raises the relative price of products generating carbon emissions (thus reducing demand for those products) while, at the same time, effectively subsidising production of low-emissions substitutes, by increasing the price that can be charged for them in the market. A carbon pricing mechanism will therefore give rise to a wide range of responses generating abatement, based on consumer and producer assessments of the relative costs and benefits to them. For instance, consumers might reduce their driving, or drive in a more fuel-efficient manner if taxes on petrol or diesel were increased – and over the longer term, they can buy more fuel-efficient vehicles. Producers of alternative fuels (by assumption here, being taxed less) would be able to charge more for their products, and can thus be expected to increase their production.

Many other emissions-reduction policies instead directly support use of low or zero-emissions technologies or production of 'cleaner' products. Sometimes this is done through explicit budgetary subsidies. More common mechanisms are mandated targets and regulations. In these cases, the transfers to producers of certain products or technologies are less transparent. Whether the subsidies are explicit or implicit, the effect in terms of increasing payments to induce additional production from targeted producers is the same.

The schemes do, however, differ in terms of who ends up paying for them – taxpayers, who pay for explicit budget subsidies, or households and firms, who pay the increased product costs due to regulations and mandates. Where users pay, the policies will also generate some 'demand-side' abatement and impose a consumption cost. The present report also includes estimates of such demand-side abatement.

3. Key elements of a methodological approach

There are four key questions that one could ask regarding the methodological approach:

- what should be the measure of cost imposed by a policy; in particular, to what extent should transfers be included;
- should either, or both of, demand- and supply-side abatement be considered;
- what counterfactual should be used to assess the impact of the policy; and
- should the weights used to aggregate the values associated with each policy be based upon the scope of abatement or activity?

Each of these points is addressed briefly in the following sub-sections.

What should be the measure of costs of a policy?

There are three elements of cost potentially associated with an emissions-reduction policy:

- the additional costs of low-carbon activities over high-carbon activities (i.e. the resource cost of changing the activity mix);
- the additional profits (or rents) which accrue to low-carbon activities (e.g. payments they receive over and above the cost of production) which, although not strictly costs to society as a whole, are transferred from consumers or taxpayers as part of the measures to incentivise low-carbon activities; and
- any revenue raised from measures being imposed on high-carbon activities.

The first two of these elements apply to all policies which encourage low-carbon activities and are counted in the approach used here, whereas the final element is not included.

Whether the revenue raised from measures being imposed on high-carbon activities is included as a cost is only important for policies which act on emissions, rather than those which act on abatement.[3] Policies which act on emissions, such as fuel taxes and emissions trading systems, may generate economic transfers which are real economic costs to the persons who are paying them, but not real economic costs to society at large (as this revenue, for example, can be returned to the economy through tax cuts). This revenue can be used to provide transfer of resources from one party to another. Revenue raised by a carbon tax or emissions trading system hence does not count as a cost to society.

Being concerned with the net cost to society, rather than the costs to the entity carrying out the relevant activity – as proxied by the "total subsidy equivalent" approach – the approach used here assumes that the revenues are returned to society. Note that the use of total subsidy equivalent (which includes some, but not all, transfers) is an *approximation* of net social cost – see Annex 2.A1 for further illustration.

Should either, or both of, demand- and supply-side abatement be included?

There are two different ways in which policies might lead to abatement:

- *Supply-side abatement* results from policies that encourage the increasing use of lower-emission technologies. In these cases, in this report it is estimated how much implicit or explicit subsidy policies provided per tonne of abatement achieved by these lower-emission technologies (termed an *abatement subsidy*), the total abatement that the policies had generated and, as the product of these two former variables, the total subsidy equivalents triggered by each policy.
- *Demand-side abatement* is the abatement delivered by policies that increase the price paid for emission-intensive outputs, leading to a reduction in demand for that output and hence in emissions from that activity. In these cases, the analysis provides estimates of the emissions savings, the *consumption cost* of the reduction in demand and the consumption cost per tonne of CO_2.

Note that demand-side abatement will be of particular importance in industrial sectors, such as pulp and paper and cement, through *indirect emissions* from purchased electricity. In such downstream sectors, it may be that there is no supply-side abatement, if the only policies in operation are those affecting purchased inputs. Where there are policies affecting *direct emissions*, such as clinker use in cement or combined heat and power use in pulp and paper plants, then supply-side abatement will also apply to the industrial sectors.

What should be the counterfactual applied to assess the impact of the policy?

In order to calculate the costs and abatement induced by a policy, a decision needs to be taken as to what would have occurred in the absence of the given policy. This is an inherently difficult decision and there is no clear and universally applicable approach that can be applied across all countries and all sectors. There are some specific elements of the decisions surrounding the counterfactual that are important to consider when evaluating a particular carbon price estimate:

- What are the assumptions regarding the rate of pass-through of costs into prices, and the subsequent assumptions of the responses of demand to the changes in prices?
- How are producers of emissions-intensive goods assumed to react to the incentives provided by policies?
- What is the emission-intensity assumed for the activity that would have taken place in the absence of the policy; for example, in the electricity sector, is the *marginal* or *average* emissions intensity of the system of generation used or, in the transport sector, is the lifecycle emission-intensity for the fuel used and how is it calculated?
- To what extent is a policy, such as one supporting renewable energy generation, assumed to have triggered all of the increase in low-emission production?

The approach taken as regards the counterfactual by the different case studies for each policy needs to be evaluated in order to understand whether it is appropriate for that situation. The assumptions made in these regards have in each case study been based on a judgement of what would be most relevant in that country's context, and the fact that they differ somewhat across case studies does not necessarily mean that the calculations are incomparable; although it may be that they are, in fact, not *fully* comparable.

There are some elements in relation to the counterfactual that have not been included in the present analysis, but it may be possible to do so in a larger study. One example is whether the imposition of energy and carbon taxes would allow income or consumption taxes to be reduced and whether this would provide any additional benefits, such as a potential "double dividend", in the form of increased economic growth and/or employment. Another example would be to consider second-round impacts in related markets, such as the impacts of fuel taxes on demand for vehicles. Such second-round effects were not considered in these case studies, due to time and resource constraints.

Which weights should be used to combine policy-level measures into a sectoral aggregate?

The decision on which weights to apply is a consequence of the choice on the appropriate measure of cost. If interest lies in the average subsidy being paid by society for each unit of abatement, then the appropriate weights are the *shares of overall abatement* that can be attributed to the policy (and transfers should, as far as possible, not be included).

An alternative measure, outlined in Box 1 above, could have been to focus on what is the carbon price that would generate the same cost-wedge between low- and high-carbon activities. In that case, the *share of activity* to which the policy applies must be used as the weight. This is because the cost burden imposed on entities is a direct function of the breadth of the policy: policies which only apply to a small amount of output will impose only a relatively small average cost burden; policies that apply to a larger proportion of output impose greater average costs.

The difference between these two approaches to weighting can be seen by considering an example where a country is promoting low-carbon electricity supplies by providing comparatively large subsidies to a small proportion of electricity generation. In this case, the subsidy equivalents here will capture the fact that *the amount that society is paying for each tonne of abatement is high*, and will correspondingly give a high carbon price estimate, while the alternative methodology would capture the fact that the *policies are not imposing significant costs on generators in general* (as subsidies are only being provided to a small proportion of generation) and provide a low estimate. In the transport sector, an analogous example would be large tax exemptions for electric vehicles when the share of electric vehicles in the overall fleet was very low. In an industrial sector, a similar example would be a policy that strongly incentivised efficient lighting when lighting only accounted for a small proportion of the sector's emissions.

Notes

1. See *www.pc.gov.au/projects/study/carbon-prices/report*.
2. Datasets included those published by the International Energy Agency, the United Nations Framework Convention on Climate Change and the Australian Department of Climate Change and Energy Efficiency.
3. For example, a carbon tax in the electricity sector acts upon emissions, whereas a feed-in tariff acts upon abatement.

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Chapter 2

OECD's approach to estimate effective carbon prices

Comparisons of the effective price put on carbon by policies in difference sectors and countries provide valuable insights into the cost-effectiveness of alternative policies to reduce greenhouse emissions (GHGs), and their potential impacts on competiveness. The carbon prices can be explicit, *such as carbon taxes or prices of emission allowances in GHG emission trading systems, or they can be* implicit, *reflecting the cost to society per tonne of* CO_2*eq abated as a result of any type of policy measure that have an impact on GHG emissions. This chapter provides further information about the specific methodology used to estimate effective carbon prices in this project, explains the selection of policies for inclusion in the study, and discusses strengths and weaknesses of the approach used.*

1. Selection of policies for assessment

Three main criteria have been used in determining whether to include policies in the stock-taking of potential candidates for further analysis. Generally, policies were included if they:

- are in place or committed – where "committed" means that the policy not only has a high probability of being implemented, but specific details have also been released (for example, the policy is in the process of enactment);
- have the explicit intent, or the effect, of reducing emissions (for example, fuel excise taxes are often considered to be road-user charges or general taxation, but they also have the *effect* of reducing emissions); and
- operate at the national or state/provincial level (policies at the local government level have generally not been included because they are not likely to be material to cross-country comparisons).

Two further criteria were used to identify a smaller number of policies that have been subject to detailed analyses. Generally, policies were analysed if they:

- penalise emissions or give an incentive for abatement (which covers explicit or implicit taxes and subsidies, and regulations, but not voluntary codes);
- have a material impact on a country's emissions in a sector and/or impose significant total costs.

2. Strengths and weaknesses of the approach used

While providing policy-relevant and useful information, calculating effective carbon prices does raise a number of important practical and methodological issues. These range from concerns about the availability of reliable data to issues surrounding how to measure the implicit carbon prices embedded in direct regulations governing the use of certain technologies, in renewable energy targets, or in subsidies for low-carbon technologies.

Short-term vs. long-term estimates

The approach used here is a *partial* equilibrium, comparative *static* approach that compares, in the latest year for which data are available, a *snapshot* of the post-policy situation to a counterfactual snapshot of no policy. Ideally the impacts would be measured in terms of changes in economic welfare, taking into account influences on both the supply and demand sides, divided by the abatement achieved.

The estimates presented here give an indication of relative shadow prices of carbon in 2010 within and across OECD countries. They do not necessarily properly reflect the long-term abatement incentives embedded in existing or planned policies in the countries concerned.

An alternative approach could, in principle, have been to try to incorporate emission forecasts and cost estimates for future years. An advantage of such a methodology would be that it could allow the use of *average* emissions and costs *over a number of years*, which could smooth out short-term variations in the relevant figures.

However, any estimate of future abatement impacts would be prone to a number of important uncertainties. For example, the *marginal impacts* of a given policy instrument will crucially depend on the economic developments and technological changes that take place in future years, as well as on interactions with other policy instruments that will be applied over the period in question. In addition, addressing the long-term impacts of current or planned policies would also require that countries agreed on which approach to discounting would be appropriate to use.

The issue of short-term versus long-term abatement impacts is *to some extent* addressed in the case studies via the use of different assumptions regarding the relevant price elasticities. The larger the price elasticity (in absolute value), the more responsive is demand to a given price change. It is generally found that price elasticities are larger in the long term than in the short term, as the users of a product have more possibilities to look for cheaper alternatives in the long term.

The particular elasticities used were chosen by the authors of the various case studies, as the appropriate elasticity may vary across countries and sectors. As guidance, authors were asked to use the elasticities suggested by Productivity Commission (2011) where possible; in turn, those elasticity estimates were the result of a comprehensive review of the relevant economic literature.

The Productivity Commission suggested that a range of elasticities be used in the calculations, in order to reflect the uncertainty surrounding the precise magnitude of some of these numbers. Hence, for example in relation to electricity, price elasticities of -0.2 and -0.7 have been used in the case studies. For many of the activities covered by policies considered in the case studies, the changes induced by the policy may take a number of years to occur;

for example, new investment in capital stock in the industrial or electricity generation sector will take some time. Therefore, the end of the range of the elasticity estimates with the higher magnitude could be considered to be more relevant in the longer term.

Some of the policies covered by this report will provide benefits long into the future, and the present analysis does not capture this. The case studies provide snap-shots, and they do not consider all the future benefits and costs of the relevant policies. For example, investment in renewable energy today may provide a benefit in the future if increased deployment results in increased learning and lower production costs in the future.

The marginal source of electricity generation

In assessing the impact of a policy to encourage additional low-carbon electricity generation, it is important to know the emission-intensity of the generation which is replaced (or that which would have occurred in the absence of the policy). A feed-in tariff, for example, acts on abatement because the tariff is only received for units of renewable electricity produced. Generation of more renewable energy causes abatement as higher-emissions generation is displaced, and so a feed-in tariff is equivalent to a policy acting directly on abatement. The amount of abatement will be dependent upon the nature of the displaced generation.

Productivity Commission (2011) attempted to specify the marginal source of generation in each electricity market, sometimes differentiating between season and time of day. This approach is more accurate in determining the short-term impact on emissions of additional renewable generation. Some, but not all, of the case studies carried out for OECD also adopted this approach.

There are alternative approaches, such as presuming that additional low-carbon generation displaces high-carbon generation or the average unit of generation. Assuming displacement of high-carbon generation can be a good approach when taking a long-term view, while the short-term impact may be variable, depending upon the transitory prevailing conditions in the electricity market. The nature of the displaced generation may also change over the course of time; in the long term, the policy goal of additional low-carbon generation is to displace high-carbon generation. Over a number of decades – a time horizon relevant to long-lived capital, such as electricity generation assets, smart grids, and battery technology, etc. – the electricity market dynamics observed today will likely alter, making calculations based upon short-term market dynamics less relevant.

Other benefits of the policies assessed

Many of the policies covered by the case studies were *not* primarily introduced with an aim to limit GHG emissions – in several cases, GHG abatement was not at all among the objectives of the policy. The policies examined were nevertheless deemed to have an impact on such emissions. When assessing their cost-effectiveness, and the estimated effective carbon prices, it is, however, important to take their other (intended) impacts into account.

This is a difficult issue to incorporate appropriately in the cross-country comparisons, and it is discussed in some detail in Productivity Commission (2011). In the present analyses, no account was generally made for associated "co-benefits". If such benefits were to be included, then the cost of the policy which might be ascribed to GHG emissions reduction would be lower.

One pertinent example of this is whether to consider taxation of transport fuels as a GHG emissions reduction policy or not. Clearly, taxes on transport fuels are implemented for a number of reasons; indeed, it is likely that in most countries, GHG emissions reduction is a minor motivating factor behind such taxes. However, on the other hand, taxation of transport fuels is economically equivalent to a carbon tax on transport fuels – and such taxes have been included in the present analysis.

Voluntary policy approaches

The case studies only consider policies which give a systematic, binding incentive to reduce emissions in a sector. Voluntary codes are not considered to provide an enforceable and comprehensive incentive and, in any case, it would be very difficult to ascertain the appropriate counterfactual where action was voluntary. Hence, such codes are not covered by this study. For a similar reason, one-off subsidies or other idiosyncratic support (such as Clean Development Mechanism [CDM] projects) are also not included.

The scope of the policies assessed

One should keep in mind that the approach used in this report does not *a priori* consider the scope of the policy, i.e. whether a policy applies to a large or small share of the sector in question. However, the discussion of the estimates seeks to address such considerations as well.

There are alternative measures which could be used which better incorporate the scope of the policy, but these have other disadvantages, cf. Box 1 above.

When interpreting the estimated abatement incentives, it is important to take into account that it is not necessarily so that high average consumption costs reflect desirable climate change policy-making. First, a policy can induce a high average consumption cost because the policy is not cost-effective, or because the policy reflects a desire to implement high abatement incentives. Second, there are factors other than consumption cost that should be included in an overall policy assessment. The consumption cost induced is affected by the policy design; a clear example being the nature of free allowance allocation in emissions trading schemes. There are a range of factors determining, for example, the appropriate nature of inclusion of free allowance allocation in the estimates, and it is not necessarily true that the method which results in the highest average consumption cost will also result in the preferred public policy outcomes.

Comparability of the present carbon price estimates

Several steps have been taken to make the numbers developed across countries as comparable as possible. As already referred to, all the case studies have been carried out using a common approach – and to underpin this, each consultant received a 3-page terms-of-reference to guide their work. In spite of this, the numbers originally estimated were *not* fully comparable. In practice, each consultant had to make a number of "decisions" regarding what to include or not include, how to proceed, etc., and these decisions can have a small or significant impact on the estimates calculated. The OECD Secretariat was in close contact with the consultants during the work, and did in several cases request modifications to be made, but i.a. for time reasons; it was not possible to secure full comparability between all the estimates.

Once a full set of case studies was on the table, Vivid Economics made for OECD a detailed comparison of the specific methodologies applied in each of them. This comparison indicated that there was scope for further harmonisation of the approaches used, and the respective authors were informed about the findings of the comparison. Several modifications have been made to the estimations in response to this, but it is underlined that the available numbers are still not *fully* comparable across sectors and countries.

Keeping all the caveats above in mind, it is nevertheless believed that the estimates presented in this report represent *useful and policy-relevant indications* of the magnitude of the carbon abatement incentives currently facing the selected sectors in the countries covered.

3. Coverage of the project

Table 2.1 gives an overview over the countries and the sectors covered, and the institutions that have contributed the different estimates. Estimates of the abatement incentives facing household energy use have, for practical reasons, not been prepared for four of the countries that originally were covered by the Productivity Commission, namely China, Germany, Japan and Korea.

Table 2.1. **Country and sector coverage of effective carbon price data and sources**

	Sector				
	Electricity generation	Road transport	Pulp and paper	Cement	Households
Australia	PC	PC	OECD	OECD	OECD
Brazil	OECD	OECD	OECD	OECD	OECD
Chile	OECD	OECD	OECD	OECD	OECD
China	PC	PC	OECD	OECD	--
Denmark	OECD	OECD	OECD	OECD	OECD
Estonia	OECD	OECD	OECD	OECD	OECD
France	OECD	OECD	OECD	OECD	OECD
Germany	PC	PC	OECD	OECD	--
Japan	PC	PC	OECD	OECD	--
Korea	PC	PC	OECD	OECD	--
New Zealand	PC	PC	OECD	OECD	OECD
South Africa	OECD	OECD	OECD	OECD	OECD
Spain	OECD	OECD	OECD	OECD	OECD
UK	PC	PC	OECD	OECD	OECD
US	PC	PC	OECD	OECD	OECD

Reference

Productivity Commission (2011), *Carbon Emission Policies in Key Economies*, Research Report Australian Government Productivity Commission, Canberra. Available at *www.pc.gov.au/projects/study/carbon-prices/report*.

Annex 2.A1

Further description of the methodology used

This appendix gives a mathematical and a diagrammatical representation of different methodological approaches for estimating "effective carbon prices", in order to pinpoint differences between them.

Formal representation of the methodology

As noted in Chapter 2, there are a number of metrics which could be considered when making international comparisons of low-carbon policies. In this section, the measure adopted in this report is presented formally. In order to present the method in a clear manner, a number of variables are defined. For policy i, let :

- r_i be the resource cost to society in monetary units (e.g. dollars, euro, etc.);
- z_i be the revenue raised by the instrument in monetary units;
- y_i be the additional profits from low-carbon activity induced by the policy in monetary units;
- se_i be the subsidy equivalent cost (i.e. $r_i + y_i$);
- c_i be the total cost to liable entities affected by the policy, including transfers (i.e. $r_i + y_i + z_i$);
- a_i be the total abatement induced by the policy in tonnes of CO_2-equivalents;
- g_i be the total activity liable to pay the cost or receive the benefit of the policy (including zero-emitting power for ETSs) in the units of the activity (e.g. GWh for electricity or tonnes for cement)
- α_i be the average emissions intensity of the activity covered by the policy, in tonnes of CO_2-equivalents per activity unit;

- ρ_i be the cost pass-through from producer costs to consumer prices for policy i;
- p_i be the price associated with direct pricing policies, such as taxes or emissions trading schemes, in monetary units;
- I_i be an indicator function which takes the value "1" if the policy acts upon abatement, and "0" if the policy acts upon emissions
- G be a measure of the total amount of the activity in the economy, in activity units;
- A be total abatement in the sector in tonnes of CO_2-equivalents.

The method applied here uses subsidy equivalent as a measure of the net resource cost of each policy, but this is only an approximation. Considering the case of no policy interaction for simplicity of exposition, the approach can be summarised as:

$$\textit{Total subsidy equivalent per tonne of abatement} = \sum_i \frac{a_i}{A}\left(\frac{se_i}{a_i} I_i + p_i(1 - I_i)\right)$$

Note that z_i will be zero for most renewable energy support policies, such as feed-in tariffs or renewable energy targets. The main policies for which z_i will be non-zero are taxes (either on carbon or on particular fuels) and for emissions trading schemes (although not for some baseline-and-credit schemes).

Graphical presentation of the methodology, using a stylised electricity market

A diagrammatical representation of the approach and how it applies to some policy examples are presented in Figures 1 and 2. These figures adopt the stylised electricity market described in Box 2 of Productivity Commission (2011). In this market, carbon-intensive base-load electricity sources (say, coal-based electricity generation) are assumed to be able to supply any amount of electricity at a constant marginal cost of p_{BL}. The supply curve for renewable energy is assumed to be given by S_R, reflecting increasing generation costs. There is a single demand curve, D, as consumers, by assumption, do not differentiate between electricity generated by the two types of sources.

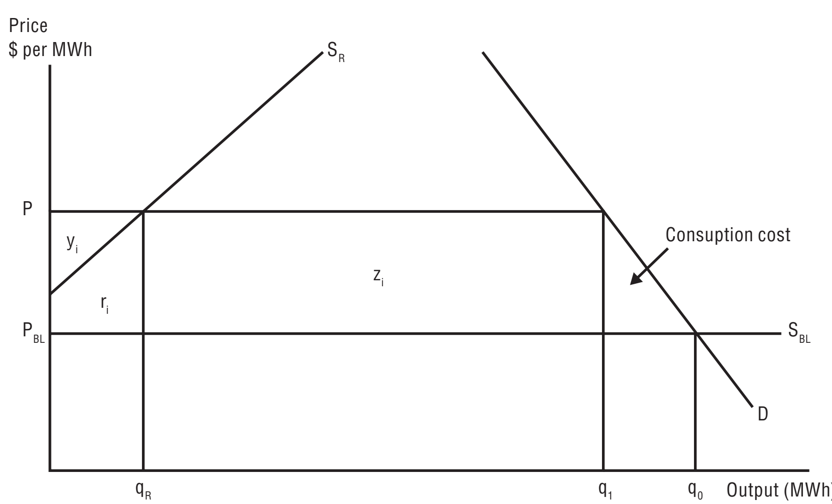
Prior to the introduction of any regulation, there is no renewable production, as even the lowest-cost renewables have a cost of supply greater than the constant cost of base-load generation. Base-load generators supply q_0 MWh of electricity at a price (and cost) of $\$p_{BL}$.

Example 1: A carbon tax

Following the example given in Box 2 of Productivity Commission (2011), Figure 1 shows the case of an explicit carbon price, such as a carbon tax. The tax is levied at a rate equivalent to $(P - P_{BL}) per MWh. This raises the price of electricity to P and total demand falls to q_1. As a result of the tax, some renewable generation is now profitable and renewable generators supply q_R MWh to the market. Base-load generators supply the remaining (q_1 - q_R) MWh. The areas market y_i, r_i and z_i show the additional profits made by renewable generators, the resource cost of the policy, and the revenue raised, respectively.

The subsidy equivalent of a carbon tax is given by $y_i + r_i$, and this is the approach to assessing cost adopted by the Productivity Commission as well as in this report. The cost per tonne of abatement is then calculated by assessing the amount of abatement induced by the generation of q_R units of electricity based on renewable sources. This is greater than the true economic resource cost of the scheme, which is given by area r_i alone, but is less than the revenue raised by the scheme, which is given by area z_i.

Figure 2.A1.1. **A stylised electricity market with an explicit carbon price**



Source: Vivid Economics.

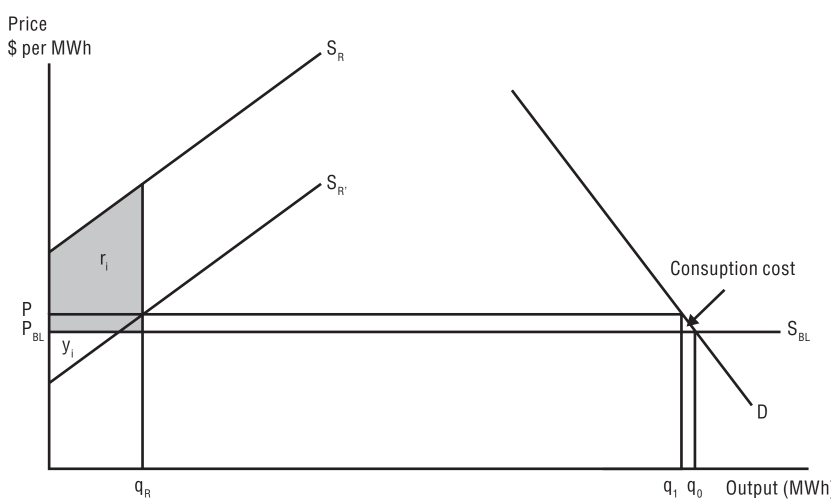
The total subsidy equivalent per tonne of abatement uses the abatement induced by the policy, the emissions saved from reducing base-load electricity supply from q_0 to $(q_1 - q_R)$, to aggregate policies. This is a consequence of the choice of the measure of cost: both area y_i and area r_i only apply to displaced generation.

Example 2: A production subsidy for renewable energy

Figure 2 shows the example of a production subsidy for renewable electricity generation, which lowers the cost of production of renewable electricity from S_R to $S_{R'}$. This increases renewable electricity generation from zero to q_R at a cost equal to the sum of the areas r_i (shaded) and y_i. If one assumes that the subsidy is raised from base-load electricity generators and they are obliged to spread the cost of the subsidy across all electricity sales, this causes the price to rise from P_{BL} to P, where the amount of the price rise is such that the area $r_i + y_i$ is equal to $q_1{}^*(P - P_{BL})$. Base-load supply falls from q_0 to $(q_1 - q_R)$ and total electricity demand falls from q_0 to q_1.

As there is no revenue raised by this policy, $z_i = 0$, the cost of this policy is calculated as $r_i + y_i$. The methodology used applies a weight of 1 to this policy (as in this example, the subsidy is the only policy and so accounts for all abatement).

Figure 2.A1.2. **A stylised electricity market with a production subsidy for renewable generation**



Source: Vivid Economics.

Chapter 3

Estimated effective carbon prices

Comparisons of the effective price put on carbon by policies in difference sectors and countries provide valuable insights into the cost-effectiveness of alternative policies to reduce greenhouse emissions (GHGs), and their potential impacts on competiveness. The carbon prices can be explicit, *such as carbon taxes or prices of emission allowances in GHG emission trading systems, or they can be* implicit, *reflecting the cost to society per tonne of* CO_2*eq abated as a result of any type of policy measure that have an impact on GHG emissions. This chapter presents the estimates that have been elaborated in the project, covering electricity generation, road transport, pulp and paper and cement production and households' domestic energy use. The chapter compares the estimates across countries, across sectors of the economy and across different types of policy instruments, finding large variations in each case.*

Keeping all the caveats mentioned in the two prior chapters in mind, this chapter discusses the estimated effective carbon prices across different countries, sector by sector, as well as *across* different instrument categories. Section 3.6 below discusses the estimates more generally, i.a. pointing out major differences in the estimates *within* the different countries.[1]

The tables later in this section present a *range* of estimates for CO_2eq emissions abated, abatement as a percentage of counterfactual emissions, total abatement cost, cost per tonne of CO_2eq abated, and total cost of a given policy as a percentage of GDP. Estimates are presented as a range, instead of as "high" and "low" estimates, because the variables that are modified to generate a range of estimates differ across sectors and policies. These variables include the own-price elasticities of demand, the discount rate, the marginal emissions intensity of electricity, certificate prices in certificate trading schemes, and the degree of coal-to-gas substitution possibilities for electricity generation. The method used to calculate the range of estimates for each sector in each country can be found in the individual case studies. It is important to note, however, that the upper-bound estimate of the cost per tonne of CO_2eq abated is not always the upper-bound estimate of the total cost divided by the lower-bound tonnes of CO_2eq abatement, and *vice versa*, precisely because of the different variables that are modified when performing calculations on each policy instrument.

The policy instruments presented in the synthesis tables are shaded by type of instrument. The legend is below.

Instrument type	Shade
Taxes	
Trading schemes	
Feed-in tariffs	
Tax preferences	
Other regulatory instruments	
Other subsidies	

In some instances, case studies have estimated the CO_2eq abatement, the total cost, and the cost per tonne of CO_2eq abated of a number of different policies combined. In these circumstances, the policy combination has been shaded with the colour of the policy instrument with the greatest impact, unless otherwise stated in a footnote.

A final point to bear in mind when reading the synthesis tables is that for capital subsidies, which are particularly present in the electricity generation sector and the household sector, the estimates presented in the "total cost" column are *annualised subsidy equivalents*, and not total expenditure on subsidies in 2010. This follows the methodology of Productivity Commission (2011), which was based on the logic that whilst a capital subsidy is paid upfront as a lump sum, the benefits in terms of CO_2eq abatement span over a number of years. To adjust for this temporal dissonance, the subsidy is annualised over the lifetime of the product or technology that it is providing an incentive for.

1. Electricity generation

Comparisons across countries

Table 3.1 presents estimated effective carbon prices from the different case studies regarding electricity generation in the respective countries. Information given on the rows where the country names are provided are averages for the sector as a whole in the respective countries; while in most cases, further information regarding specific policy instruments is given in additional rows below the country names.

The table presents information on total GHG emissions in electricity generation at present, the magnitude of the abatement achieved, the costs of achieving this abatement, and the cost per tonne CO_2eq abated.[2] The table also gives indications of how large the abatements are in per cent of counterfactual emission levels, and relates total abatement costs to the GDP of the country in question.

The table highlights that there are important differences in the effective carbon prices facing the electricity generation sector across the countries being studied in this project. Where estimates are available, they range from less than zero to EUR 800 per tonne of CO_2eq abated – with carbon prices of at least EUR 25 being found in almost all of the countries. In other words, in one way or another, most of the countries studied do explicitly or implicitly provide relatively significant incentives to abate *some* carbon emissions in the electricity generation sector. As a comparison, the price of an allowance in the EU ETS system in early September 2013 was about EUR 5, and the carbon price introduced in Australia in 2012 is about EUR 16 per tonne CO_2.

The highest carbon price across individual policy instruments applied in the electricity sector has been estimated for Korea. However, the policy in this country that is linked with the highest carbon price has a limited scope, affecting only a small share of the emissions from the sector as a whole, so the average abatement costs in the electricity sector, measured in per cent of GDP, are relatively low in Korea, compared for example to what has been estimated for electricity generation in some of the European countries.

Table 3.1. **Abatement and abatement costs related to the electricity sector**

	Total emissions in the sector, million tonnes CO_2e	Total abatement, million tonnes CO_2e	Abatement in % of counterfactual emissions	Total abatement cost, million	Cost per tonne CO_2eq abated	Total cost in % of GDP
Australia	196	7-11	3.6-5.2	328-481	30-68	0.04-0.05
Renewable energy certificates (RECs)		4-8	2.0-3.9	232-385	29-89	0.02-0.04
Greenhouse Gas Reduction Scheme		0.6	0.3	1.9	3.16	0.0002
Queensland Gas Scheme (certificate trading)		2.1	1.0	26.5	12.5	0.003
Feed-in tariffs		None *additional* to RECs		66.4		0.007
Brazil[1]	64.2	6.72	9.5	85.7	12.7	0.006
Feed-in tariff: Biomass		*0.87*	*1.2*	*14.5*	*16.7*	*0.001*
Feed-in tariff: Wind		*1.74*	*2.5*	*28.4*	*16.3*	*0.002*
Feed-in tariff: Small hydro		*4.11*	*5.8*	*42.7*	*10.4*	*0.003*
Chile	22[2]	1.3-3.7	5.6-14.4	83	13-65	0.05
Renewable portfolio standard				*69*		
Transmission subsidy for renewable energy				*14*		
Direct financial support for renewable energy				*0.5-0.8*		
China	3 370	41-52	1.2-1.5	1 271-1 599	24-39	0.03-0.05
China (including abatement from LSS)		159.2-225.6	4.5-6.3	1 271-1 599	5.5-10.4	0.03-0.05
Wind feed-in tariffs		*35-45*	*1.0-1.3*	*935-1 198*	*26-33*	*0.02-0.03*
Value-added tax exemption for wind power						
Jiangsu PV feed-in tariffs		*0.19-0.23*	*0.005-0.007*	*57.5*	*247-301*	*0.001*
Biomass feed-in tariffs		*4.9-6.1*	*0.14-0.18*	*244*	*40-50*	*0.005*
Large Substitute for Small (LSS) Program[3]		*119-173*	*3.4-4.8*	*–1 500 to 900*	*–12.4 to 7.6*	*–0.03-0.02*
Subsidy for solar PV in buildings		*0.11-0.13*	*0.003-0.004*	*6.6-12.4*	*50-93*	*0.0001-0.0003*
Golden Sun demonstration scheme		*0.28-0.35*	*0.008-0.01*	*30-56*	*86-160*	*0.0007-0.001*

Table 3.1. **Abatement and abatement costs related to the electricity sector** *(cont.)*

	Total emissions in the sector, million tonnes CO_2e	Total abatement, million tonnes CO_2e	Abatement in % of counterfactual emissions	Total abatement cost, million	Cost per tonne CO_2eq abated	Total cost in % of GDP
Denmark	18	8.7	32.7	324.2	37.2	0.14
EU ETS – coal-to-gas switching		*0.13*	*0.5*	*1.7*	*13.6*	*0.0007*
EU ETS – indirect subsidy to renewable energy generation		*8.6*	*32.2*	*116.8*	*37.5*	*0.05*
Subsidies for renewable energy generation				*205.6*		*0.09*
Estonia	7[2]	0.4-0.5	5.4-6.7	28.5-38.3		0.20-0.27
Renewable Energy and Cogeneration Support (choice of feed-in tariff or capital subsidy)		*0.39-0.48*	*5.3-6.4*	*19.6*	*44-77*	*0.14*
EU ETS		*No additional abatement*		*5.4-6.7*		*0.04-0.05*
Increased electricity prices from policies above				*3.5-12*	*6-7.4*	*0.02-0.08*
France	47	5-14	10-23	479-623		0.02-0.03
EU ETS – Supply-side effect		*0.6-2.1*	*1.2-3.4*	*8.7-30.5*	*14.5*	*0.0004-0.002*
EU ETS – Demand-side effect				*67-169*		*0.003-0.009*
Feed-in tariffs		*4.7-11.8*	*9.0-19.3*	*403-423*	*34.3-90*	*0.02*
Germany	299[2]	67-73	18.3-19.6	6 993-8 214	95-124	0.28-0.33
EU ETS, fuel switching		*0.7-3.9*	*0.2-1.0*	*10-56*	*14.2*	*0.0004-0.0022*
EU ETS, subsidy to renewable		*No additional abatement*		*953*		*0.04*
EU ETS, subsidy to CHP		*No additional abatement*		*95*		*0.004*
Renewable Energy Sources Act (feed-in tariffs)		*59.1*	*16*	*5 611-6 778*	*95-115*[4]	*0.22-0.27*
Feed-in tariff for combined heat and power		*7.3-10.1*	*2.0-2.7*	*276*	*28-38*	*0.01*
Japan	396[5]	3-4	0.8-1.1	463-651	108-199	0.01-0.02
Petroleum and coal tax		*No additional abatement*		*13-39*		*0.0003-0.0009*

Table 3.1. **Abatement and abatement costs related to the electricity sector** *(cont.)*

	Total emissions in the sector, million tonnes CO_2e	Total abatement, million tonnes CO_2e	Abatement in % of counterfactual emissions	Total abatement cost, million	Cost per tonne CO_2eq abated	Total cost in % of GDP
Renewable Portfolio Standards		*2-3*	*0.5-0.8*	*208*	*100-165*	*0.005*
Project for promoting the local introduction of new energy (subsidy)				*13-24*		*0.0003-0.0006*
Project for supporting new energy operators (subsidy/debt guarantee)				*76-143*		*0.002-0.003*
National PV capital subsidies		*1*	*0.3*	*102-190*	*118-242*	*0.002-0.005*
Tokyo PV capital subsidies				*1.5-2.8*		*0.00004-0.00007*
Solar PV feed-in tariffs				*53*		*0.001*
Korea	191[5]	0.9-1.4	0.5-0.7	217-262	156-278	0.03
Korea Certified Emission Reduction Scheme		*0.3*	*0.16*	*0.9*	*3.29*	*0.0001*
Feed-in tariffs		*0.6-1.0*	*0.3-0.5*	*177*	*181-301*	*0.02*
Preferential loans for renewable energy		*No additional abatement*		*10-31*		*0.001-0.004*
Regional Deployment Subsidy programme		*0.05-0.09*	*0.03-0.05*	*14-26*	*208-391*	*0.002-0.003*
General Deployment Subsidy programme		*0.01-0.02*	*0.005-0.01*	*3.5-7*	*190-359*	*0.0005-0.0009*
One Million Green Homes programme		*0.02-0.03*	*0.01-0.02*	*11-20*	*427-800*	*0.001-0.003*
New Zealand	5.4				6	
NZ ETS					*6*	
South Africa	540					
Spain	58					
Premiums for renewable energy generation		*0.0064*	*0.01*	*1.2-1.4*	*193-225*	*0.0001*
United Kingdom	151[2]	12-27	7.5-15.4	1 414-1 685	62-118	0.08-0.10
UK, EU ETS, coal-to-gas substitution		*4-14*	*2.5-7.9*	*72-252*	*18*	*0.004-0.015*
UK, EU ETS, interaction with other policies		*No additional abatement*		*175*		*0.01*
Renewable energy certificate scheme		*6-11*	*3.7-6.2*	*944-985*	*92-161*	*0.06*
Feed-in tariff, hydroelectricity					*16-335*	

Table 3.1. **Abatement and abatement costs related to the electricity sector** *(cont.)*

	Total emissions in the sector, million tonnes CO_2e	Total abatement, million tonnes CO_2e	Abatement in % of counterfactual emissions	Total abatement cost, million	Cost per tonne CO_2eq abated	Total cost in % of GDP
Feed-in tariff, wind					*16-635*	
Feed-in tariff, PV					*528-775*	
Feed-in tariff, micro CHP					*131*	
Feed-in tariff, anaerobic digestion					*110-161*	
Feed-in tariff, existing micro-generators					*110*	
Climate Change Levy exemption, renewables		*0.96*[6]	*0.5-0.6*	*81.6*	*85*	*0.005*
Climate Change Levy exemption, CHP		*1.5*	*0.8-0.9*	*24.5*	*16*	*0.001*
Offshore Wind Capital Grants Scheme				*3.6-6.8*		*0.0002-0.0004*
United States	2 270	67	3.0	1 998-2 312	30-34	0.02
Renewable Portfolio Standards		*66*	*2.8*	*383*		*0.004*
Renewable Electricity Production Tax Credit				*1 186*		*0.01*
Treasury Grants				*291-543*		*0.003-0.005*
Californian Solar Initiative	*104.6*[7]	*0.5-0.7*	*0.5-0.7*[8]	*87-103*		*0.006-0.007*[9]
California – New Solar Homes Partnership				*1.5-3.0*		*0.0001-0.0002*[9]
California – Self-Generation Incentive Program				*29-54*		*0.002-0.004*[9]
California – Emerging Renewables Program				*23-43*		*0.002-0.003*[9]

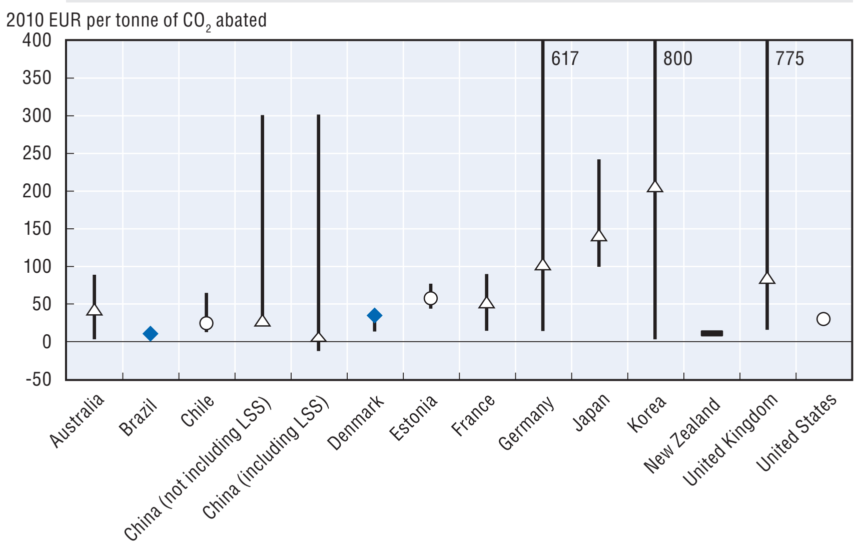
Notes: 1. Average of the period 2006 to 2010. 2. 2009 data. 3. The "Large Substitute for Small" (LSS) programme, which involved the decommissioning of old, inefficient thermal power plants, was only tentatively included in Productivity Commission (2011) due to the fact that it is a "no regrets" policy that would have been implemented irrespective of concerns about climate change. Productivity Commission (2011) presents estimates of total cost, abatement, and abatement subsidies both with and without the LSS programme; therefore the current report has taken the same approach. 4. This is the range of the average effective carbon price across all feed-in tariffs for different renewable energy technologies. Effective carbon prices range considerably between technologies, from EUR 24 per tonne of CO_2 for landfill, sewage and mines gases to EUR 617 per tonne of CO_2 for solar PV. 5. 2008 data. 6. Abatement that is additional to that under the Renewables Obligation. 7. Emissions from electricity generation in the State of California, 2009. 8. Abatement as a percentage of *California's* counterfactual emissions from electricity generation. 9. As a percentage of *California's* GDP in 2010.
Where no numbers are included in this and subsequent tables, the case studies have not provided the information that would have been required to present such information.

Sources: Productivity Commission (2011), estimates in case studies prepared for the OECD and UNFCCC Greenhouse Gas Inventory Data.

In order to help in the interpretation of the information given in Table 3.1, a number of graphs highlighting particular issues are also presented. Figure 3.1 gives a condensed, graphical illustration of the estimated average effective carbon prices in the electricity generating sector across the selected countries. The full length of the bars illustrates the range of effective carbon prices found for individual instruments within each of the countries, and in addition, an "average" value is also presented. While it is emphasised that these averages are not fully comparable (see the legend), the graph clearly highlights the very large ranges that has been found in the estimated effective carbon prices linked to electricity generation, both across countries, as well as within some of them.

Figure 3.1. **Estimated average effective carbon prices in the electricity sector, by country**

Symbol	Minimum value	Maximum value	Average value
Triangle △	Individual policy	Individual policy	Average of weighted averages
Diamond ◆	Individual policy	Individual policy	Single weighted average
Circle ○	Weighted average	Weighted average	Average of weighted averages
Dash ▬	NZ ETS permit price	NZ ETS permit price	NZ ETS permit price



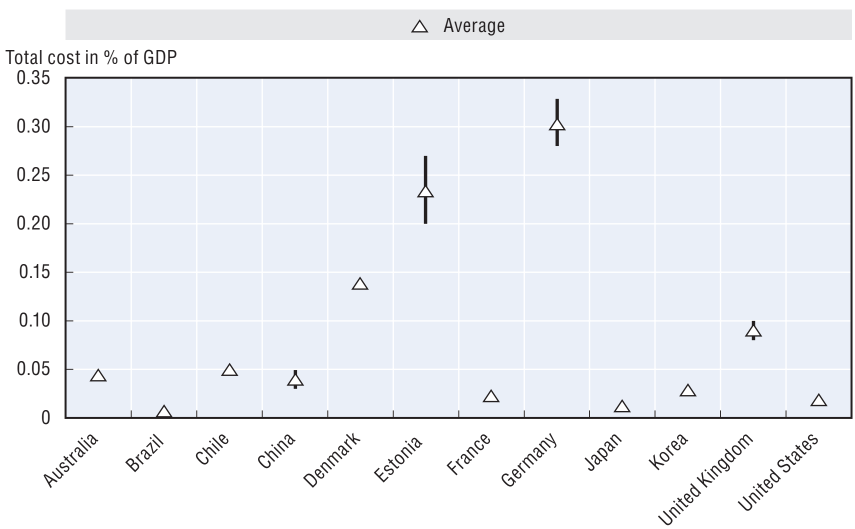
Note: The estimate for Estonia includes only supply-side abatement. For China, "LSS" refers to the "Large Substitute for Small" programme.

Figure 3.2 illustrates total abatement costs of the carbon-related policies applied in the electricity sector and covered by this project, in per cent of GDP, across the countries for which it has been possible to calculate this. The total abatement costs are *relatively* similar in a number of the countries – being somewhere between 0.01 and 0.05% of GDP in Australia, Chile, China, France, Japan, Korea and the United States.[3]

Denmark, Estonia, Germany and the United Kingdom have, however, implemented policies that entail quite significantly higher total abatement costs, relative to GDP – with the abatement costs of the German policies being found to represent up to a third of a percentage point of GPD, or around EUR 7-8 billion per year.

Figure 3.2. **Total costs of carbon-related policies applied in the electricity sector**

In per cent of GDP



Note: See Table 3.1 for caveats regarding the different policy instruments. Ranges shown for some countries reflect different choices about assumptions used in the estimates.

As can be seen in Figure 3.3, it is in particular the feed-in tariffs under the *Renewable Energy Sources Act* that entail quite significant economic costs in Germany – even if the upper range of the estimated *costs per tonne* abated is not higher than what is found in a number of other countries. It is because a relatively high cost per tonne concerns a huge volume of abatement that the total economic cost of this instrument is particularly large.[4]

In terms of the amount of carbon abatement that has been achieved for the costs accrued, Denmark stands out, with almost a third of the counterfactual emissions[5] estimated to be abated, cf. Figure 3.4. However, also Brazil, Chile, Germany and the United Kingdom are estimated to have abated more than 10% of the counterfactual emissions in the electricity sector via the policies covered in the present analysis.

Figure 3.3. **Total costs of individual policy instruments applied in the electricity sector**

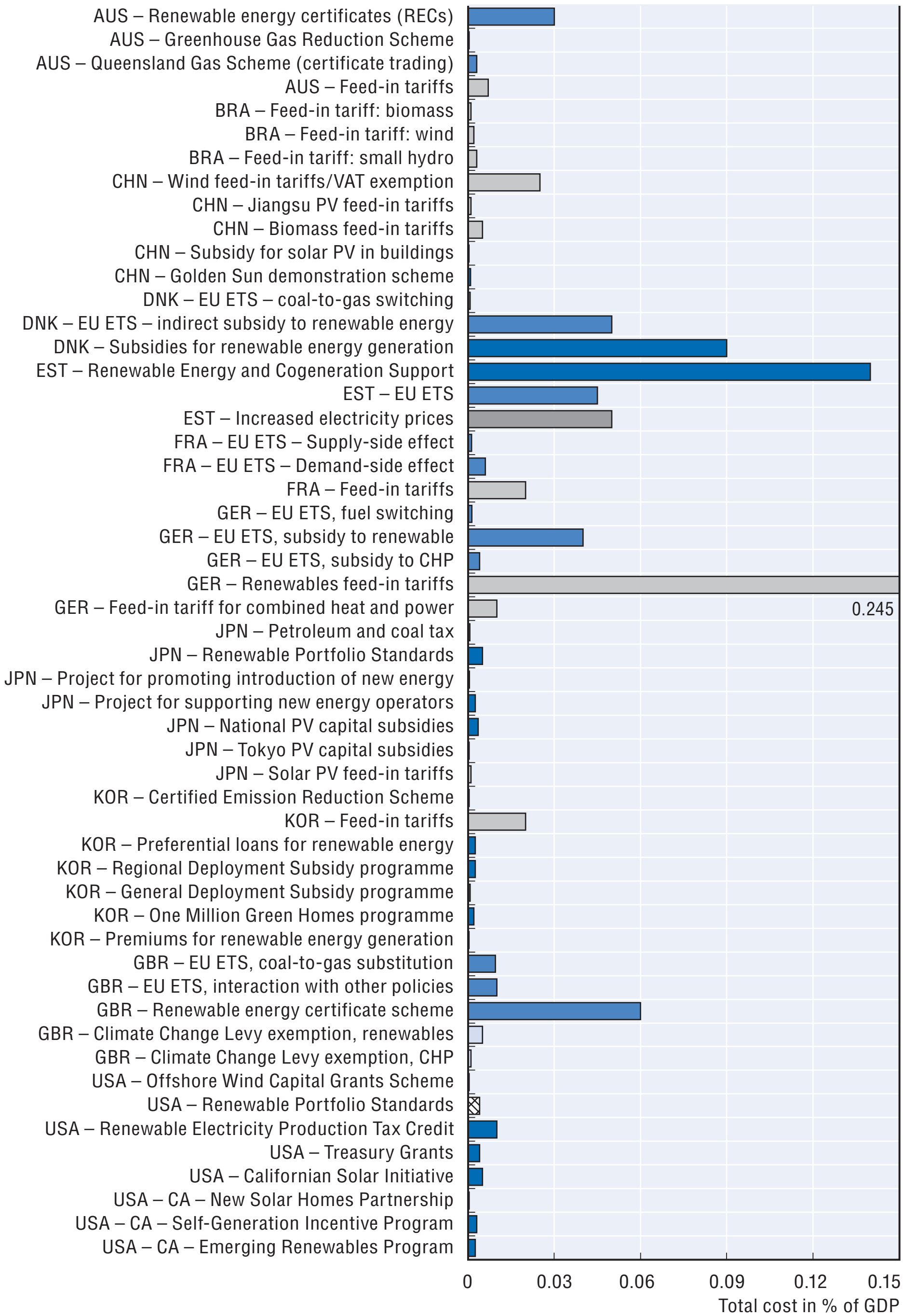
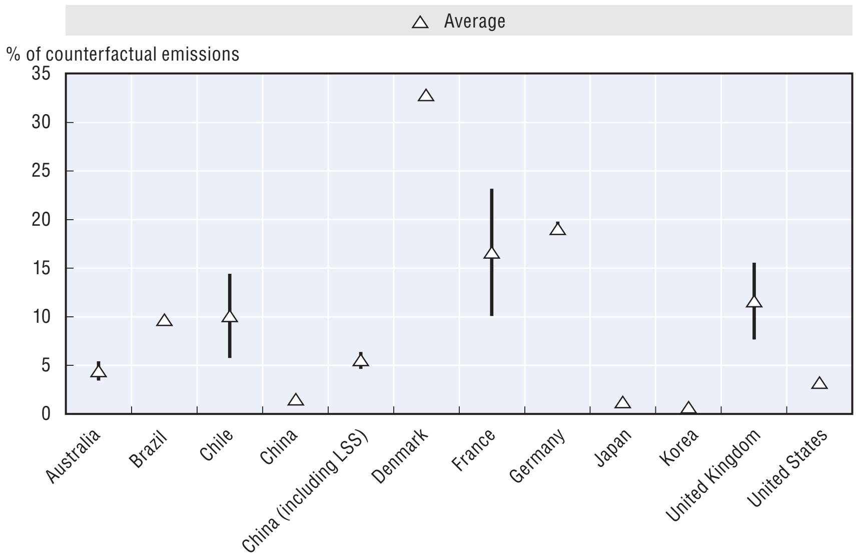


Figure 3.4. **Abatement achieved with instruments addressing electricity generation, national averages**



Note: Ranges shown for some countries reflect different choices about assumptions used in the estimates.

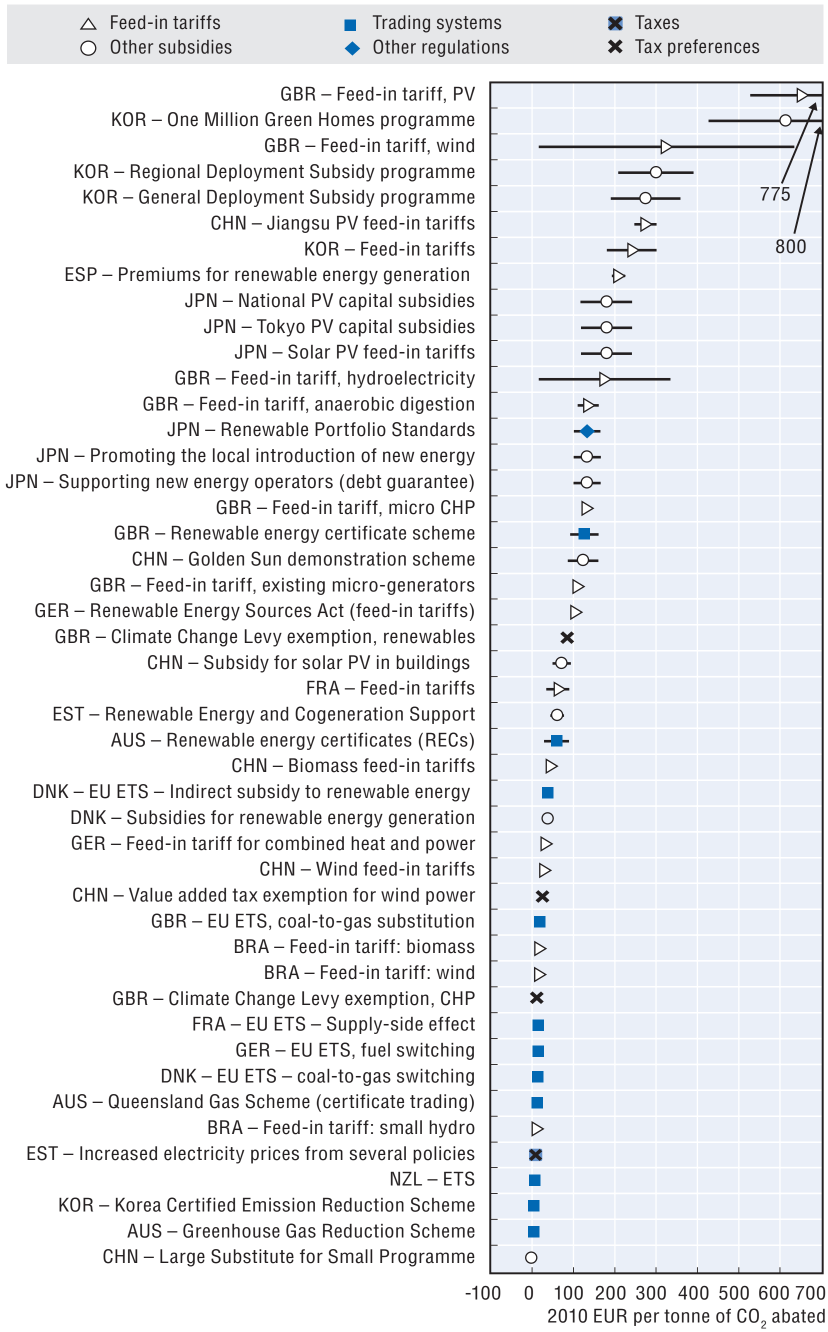
Comparisons across instrument categories

Figure 3.5 presents the estimated effective carbon prices of individual instruments applied in the electricity generation sector, sorted in decreasing order, and with a "coding" according to instrument type. The figure demonstrates very clearly that feed-in tariffs and various (other) subsidy schemes entail the highest costs to society per tonne of CO_2eq abated, while trading systems dominate the low-cost part of the graph. The costs per tonne of some of the feed-in tariff systems and other subsidy schemes are indeed *very* high.

One can also notice that the two trading systems that entail the highest costs are not *emission* trading systems (that generally would address the environmental externality directly), but instead *renewable certificate* schemes, which represent a more indirect way of addressing GHG emissions.

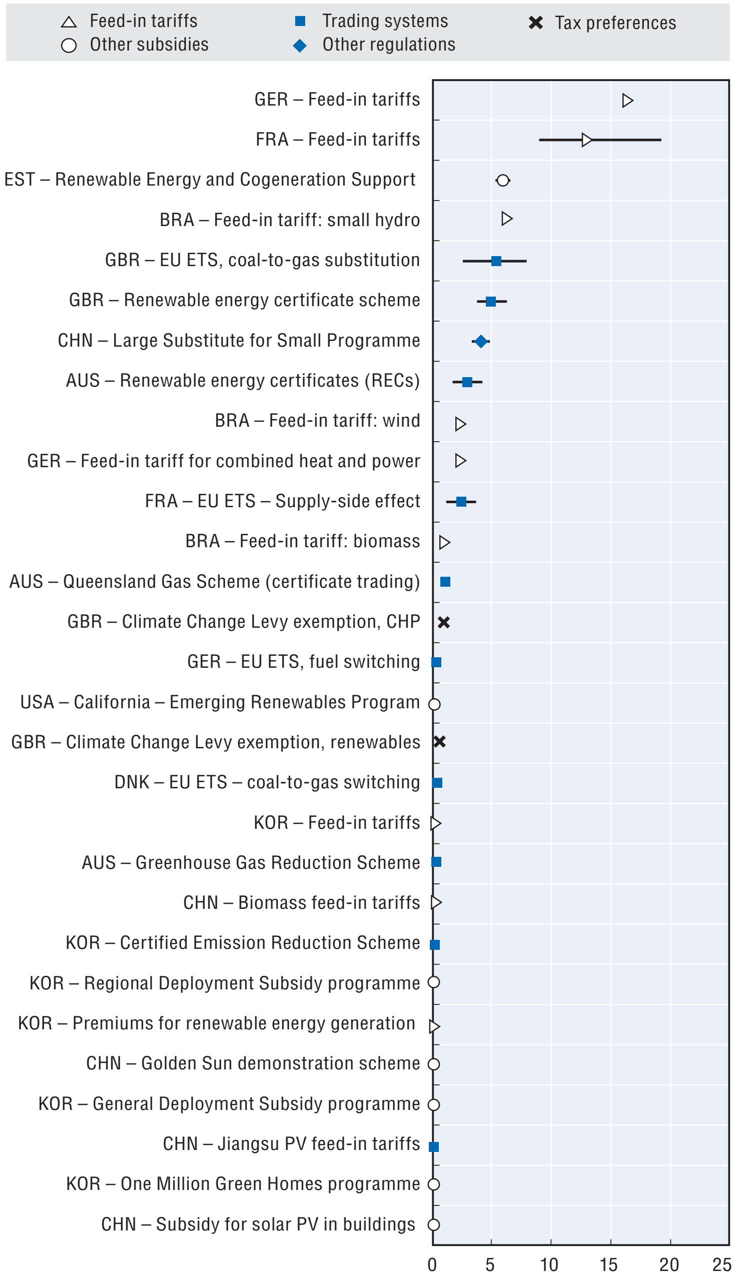
While Figure 3.4 presented national averages as regards the amount of abatement achieved by the policy instruments that countries apply in the electricity generation sector, Figure 3.6 provides such information for individual instruments, for which abatement estimates are available. Different types of instruments are colour-coded according to the legend that can be seen above the graph. The figure gives a clear impression that feed-in tariffs and emission trading schemes contributes to larger abatement (compared to the counterfactual emissions in the electricity generation sector as a whole) than what subsidy schemes do – with an exception of the Estonian *Renewable Energy and Cogeneration Support*.[6]

Figure 3.5. **Estimated average effective carbon prices in the electricity sector, by instrument type**



Note: Ranges shown for some countries reflect different choices about assumptions used in the estimates. All the "Other regulations" covered in the electricity generation sector are renewable portfolio standards.

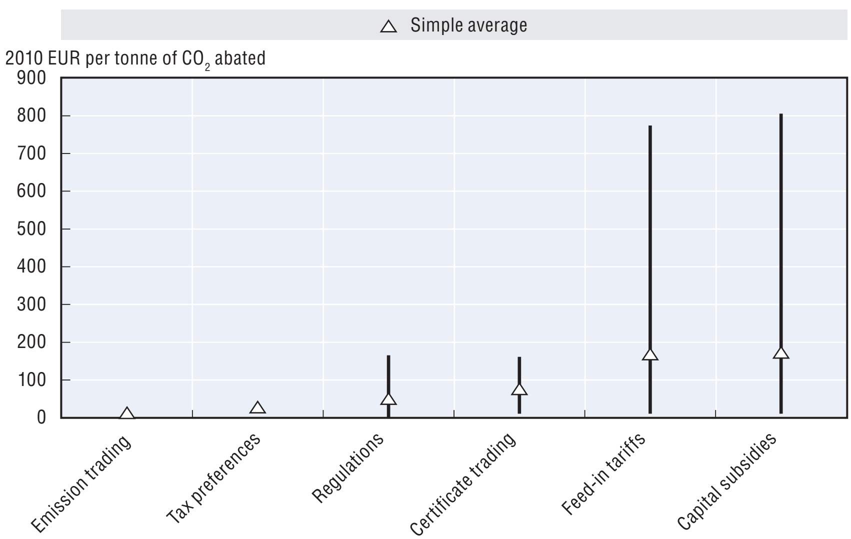
Figure 3.6. **Abatement achieved with individual instruments addressing electricity generation**



Note: Ranges shown for some instruments reflect different choices about assumptions used in the estimates. All the "Other regulations" covered in the electricity generation sector are renewable portfolio standards.

Figure 3.7 illustrates the differences that have been found in effective carbon prices in the electricity sector *on average* across the most common instrument categories. One can see that the – by far – highest costs *per tonne* of CO_2 abated are associated with various capital subsidies and feed-in tariff systems, both in terms of the averages calculated and the maximum values observed. The lowest costs per tonne abated are found for trading systems – a fact which tends to confirm "textbook suggestions" that trading systems (and broad-based carbon taxes) are the most economically efficient policy tools to mitigate climate change. This is especially so when the trading systems address the environmental externality as directly as possible – like with a trading system for GHG emission allowances.

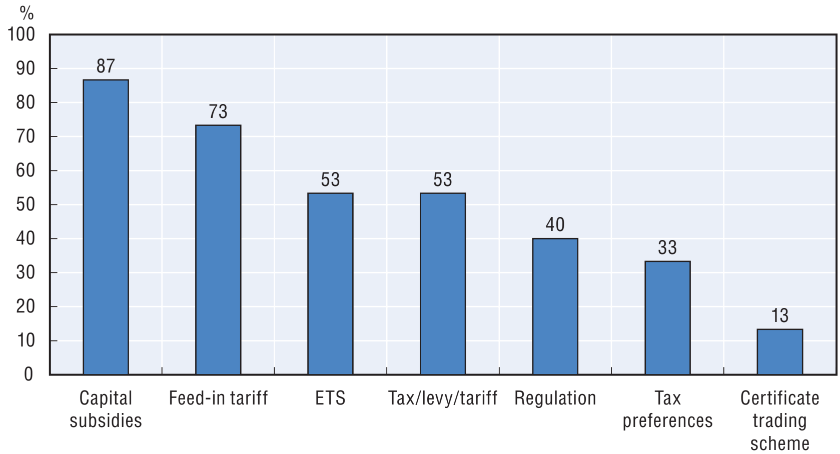
Figure 3.7. **Estimated effective carbon prices in the electricity sector, by instrument category**



Note: The height of the bars represents the range of effective carbon price estimates found for the different instrument categories; the triangles represent a simple average of these estimates. "Regulations" refers to renewable portfolio standards.

Figure 3.8 illustrates the extent of use of different types of policy instruments in relation to electricity generation across the countries covered. Capital subsidies were found in 87% of the countries in 2010, feed-in tariffs in about ¾ of them, while emission trading systems and taxes each were used in about half of the countries. It is a paradox that the two instrument categories with the by far highest average costs *per tonne* of CO_2 abated are the instrument categories that are most frequently used. A similar amount of abatement could most likely have been achieved at a lower cost – or a larger amount of abatement could have been obtained for the same cost – if countries had relied more on broad-based trading systems and carbon taxes, instead of some of the rather costly instrument categories that are in use at present.

Figure 3.8. **Share of countries in which a given instrument type is used in the electricity sector**



Note: The graph includes all instruments mentioned in the case studies, even if an effective carbon price for some reason has not been calculated. "Regulation" refers to renewable portfolio standards.

2. Road transport

Comparisons across countries

Table 3.2 presents the estimated effective carbon prices of policy measures addressing the road transport sector in the countries covered. The estimates *for individual policy instruments* in this sector vary even more than those in relation to electricity generation – and the abatement costs per tonne of CO_2eq abated are *very* high in certain cases, especially in relation to policies promoting biofuels.

Similarly to what Figure 3.1 did for the electricity sector, Figure 3.9 gives a graphical illustration of some of the same information, showing the range of effective carbon prices that has been estimated, as well as a weighted *average* transport sector carbon price for the different countries, where the amount of abatement that each instrument contributed to has been used as weights. While there are very large variations in the estimated carbon prices

Table 3.2. **Abatement and abatement costs related to the road transport sector**

2010 EUR

Country/policy	Total emissions in the sector, million tonnes CO_2e	Total abatement, million tonnes CO_2e	Abatement in % of counterfactual emissions	Total abatement cost, million	Cost per tonne CO_2eq abated	Total cost in % of GDP
Australia	69	6.4-21.4	8-24	358-923	43-54	0.04-0.1
Fuel taxes		*6-21*	*8-23*	*258-823*	*39-41*	*0.03-0.08*
Petrol		*5-16*	*7-18*	*199-635*	*40*	*0.02-0.07*
Diesel		*2-5*	*3-6*	*59-188*	*29-38*	*0.006-0.02*
Biofuel grants		*0.4*	*0.6*	*100*	*252*	*0.01*
Ethanol Production Grants		*0.2*	*0.2-0.3*	*75*	*368*	*0.008*
Cleaner Fuels Grants Scheme		*0.2*	*0.2-0.3*	*24*	*129*	*0.002*
Brazil	154.7	41.5	21	7 388	178	0.47
Fuel tax – petrol (CIDE)		*1.3*	*0.7*	*36.9*	*28.5*	*0.002*
Fuel tax – diesel (CIDE)		*1.2*	*0.6*	*9.3*	*7.7*	*0.0006*
Fuel mandate – hydrous ethanol		*23.7*	*12.1*	*4 231*	*179*	*0.27*
Fuel mandate – biodiesel		*4.4*	*2.2*	*907*	*205*	*0.06*
Fuel mandate – anhydrous ethanol		*10.9*	*5.6*	*2 204*	*202*	*0.14*
Chile	19	1.6-5.2	8-22	60-188	36-38	0.04-0.1
Fuel tax – petrol		*1.2-3.9*	*6-16*	*55-173*	*44-46*	*0.03-0.1*
Fuel tax – diesel		*0.4-1.3*	*2.0-5.4*	*5-15*	*12*	*0.003-0.009*
China	401	18.8-69	4-15	1 694-2 341		0.04-0.05
Fuel taxes		*20-68*	*5-15*	*311-958*	*14-16*	*0.007-0.02*
Tax preferences – ethanol		*–1.4 to 0.8*	*–0.33-0.17*	*1 383*	*–4 227*	
Tax preferences – biodiesel		*0.2*	*0.04-0.05*		*410*	*0.03*

Table 3.2. **Abatement and abatement costs related to the road transport sector** *(cont.)*

2010 EUR

Country/policy	Total emissions in the sector, million tonnes CO_2e	Total abatement, million tonnes CO_2e	Abatement in % of counterfactual emissions	Total abatement cost, million	Cost per tonne CO_2eq abated	Total cost in % of GDP
Denmark	12	1.6-5.2	12-30	362-483	93-212	0.15-0.21
Fuel tax – petrol		*0.6-2.2*	*5-13*	*68-222*	*102-106*	*0.03-0.10*
Fuel tax – diesel		*0.9-2.8*	*6-17*	*58-186*	*66-68*	*0.02-0.08*
Biofuel mandate – impact on petrol prices		*0.05-0.06*	*0.4*	*28-84*	*445-1 532*	*0.01-0.04*
Biofuel mandate – impact on diesel prices		*0.09-0.11*	*0.6-0.7*	*47-151*	*421-1 613*	*0.02-0.06*
Estonia	2	0.24-0.76	11-28	12.5-52.8	62-69	0.09-0.37
Fuel tax – petrol		*0.04-0.16*	*2-6*	*3-10*	*63-68*	*0.02-0.07*
Fuel tax – diesel		*0.2-0.6*	*7-22*	*8.5-41*	*56-66*	*0.06-0.3*
Support for electric vehicles		*0.0011-0.0015*	*0.05-0.07*	*1.0-1.8*	*932-1 205*	*0.007-0.01*
France	118	24-67	17-36	1 855-4 961	74-77	0.10-0.26
Fuel tax – petrol		*5-16*	*3.5-8.6*	*441-1 456*	*88-91*	*0.02-0.08*
Fuel tax – diesel		*14-46*	*10-25*	*932-3 023*	*66-67*	*0.05-0.2*
Fuel tax – LPG		*0.01-0.03*	*0.007-0.02*	*0.14-0.41*	*14*	*< 0.00001-0.00002*
Biofuel tax preferences – ethanol[1]		*0.9*	*0.47-0.61*	*151*	*172*	*0.008*
Biofuel tax preferences – biodiesel		*4.3*	*2.3-3.0*	*331*	*77*	*0.02*
Germany	141	24.5-107.5	20-43	3 565-9 142	85-103	0.14-0.37
Fuel taxes		*29-102*	*17-41*	*2 380-7 957*	*78-82*	*0.1-0.3*
Petrol		*14-50*	*8-20*	*1 397-4 722*	*94-100*	*0.06-0.2*
Diesel		*15-52*	*9-21*	*981-3 233*	*62-65*	*0.04-0.13*
LPG		*0.1-0.3*	*0.06-0.012*	*2-7*	*20-23*	*0.00008-0.0003*
Biofuels, tax exemption and fuel mandate[2]		*5.5*	*2.2-3.1*	*1 185*	*215*	*0.05*
Ethanol		*1.2*	*0.5-0.7*	*369*	*307*	*0.015*
Biodiesel		*4.1*	*1.6-2.3*	*782*	*190*	*0.031*
Vegetable oil		*0.2*	*0.08-0.11*	*33*	*168*	*0.001*

Table 3.2. **Abatement and abatement costs related to the road transport sector** *(cont.)*

2010 EUR

Country/policy	Total emissions in the sector, million tonnes CO_2e	Total abatement, million tonnes CO_2e	Abatement in % of counterfactual emissions	Total abatement cost, million	Cost per tonne CO_2eq abated	Total cost in % of GDP
Japan	201	21-73	9-27	1 589-5 094	70-75	0.04-0.12
Fuel taxes		*21-73*	*9-27*	*1 550-5 055*	*69-73*	*0.04-0.1*
Petrol		*20-70*	*9-26*	*1 515-4 946*	*71-76*	*0.04-0.12*
Diesel		*0.7-2.3*	*0.3-0.8*	*31-99*	*43-44*	*0.001-0.002*
LPG		*0.2-0.5*	*0.1-0.2*	*3.5-11*	*17-22*	*0.0001-0.0003*
Biofuel tax preferences – ethanol		*0.087-0.092*	*0.034-0.039*	*39*	*427-452*	*0.001*
Korea	82	12.2-41.5	13-34	860-2 512	60-68	0.11-0.33
Fuel taxes		*12-41*	*13-33*	*724-2 376*	*57-60*	*0.09-0.3*
Petrol		*5-17*	*5-14*	*375-1 247*	*73-75*	*0.05-0.16*
Diesel		*6-20*	*6-16*	*306-992*	*50-51*	*0.04-0.13*
LPG		*1-4*	*1-3*	*44-138*	*35-44*	*0.006-0.018*
Biofuel tax rebate		*0.2-0.5*	*0.2-0.4*	*136*	*287-575*	*0.02*
New Zealand	12	0.7-2.4	5.5-16.7	39-122	*50-54*	0.04-0.11
Fuel taxes		*0.7-2.4*	*5.5-16.7*	*37-120*	*49-51*	*0.03-0.1*
Petrol		*0.7-2.3*	*5.5-16*	*37-120*	*52-53*	*0.03-0.1*
Diesel		*0.02-0.07*	*0.2-0.5*	*0.07-0.14*	*2-3.5*	*0.00007-0.0001*
LPG		*0.01-0.03*	*0.08-0.2*	*0.14-0.48*	*14-16*	*0.0001-0.0005*
Fuel tax exemption – ethanol		*0.006*	*0.04-0.05*	*1.9*	*332*	*0.002*
Grants scheme - biodiesel		*0.002*	*0.01-0.02*	*0.3*	*113*	*0.0003*
South Africa	36					
Fuel tax – petrol		*2-7*		*490-600*	*73-270*	*0.22-0.26*
Fuel taxes – diesel		*2-6*		*419-436*	*61-221*	*0.19-0.18*
Fuel levy exemption – bioethanol					*68*	
Fuel levy exemption – biodiesel					*27*	

Table 3.2. **Abatement and abatement costs related to the road transport sector** *(cont.)*

2010 EUR

Country/policy	Total emissions in the sector, million tonnes CO_2e	Total abatement, million tonnes CO_2e	Abatement in % of counterfactual emissions	Total abatement cost, million	Cost per tonne CO_2eq abated	Total cost in % of GDP
Spain	85	120-170	59-67	10 036-14 443	87	1.0-1.4
Fuel taxes – leaded petrol		*32-46*	*16-18*	*3 053-4 397*	*96*	*0.3-0.4*
Fuel taxes – unleaded petrol 97 octane or more		*32-45*	*15-18*	*3 022-4 352*	*96*	*0.3-0.4*
Fuel taxes – other unleaded petrol		*29-41*	*14-16*	*2 541-3 643*	*89*	*0.2-0.3*
Fuel taxes – diesel		*22-32*	*11-12*	*1 414-2 003*	*63*	*0.1-0.2*
Fuel taxes – bioethanol		*1.1-1.5*	*0.5-0.6*	*6-8*	*5*	*0.0006-0.0008*
Fuel mandate + tax incentives for biodiesel[β]		*3.7*	*1.5-1.8*			
Fuel mandate + tax incentives for bioethanol		*0.3*	*0.1*			
United Kingdom	111	26-87	19-44	2 772-8 174	93-107	0.2-0.5
Fuel taxes		*24-85*	*18-43*	*2 301-7 703*	*90-96*	*0.1-0.5*
Petrol		*10-36*	*7-18*	*1 041-3 493*	*97-104*	*0.06-0.2*
Diesel		*14-50*	*10-25*	*1 257-4 206*	*84-90*	*0.07-0.25*
LPG		*0.02-0.08*	*0.01-0.04*	*1.3-4.2*	*53-65*	*0.00008-0.0003*
Renewable Transport Fuels Obligation		*2.0*	*1.0-1.5*	*471*	*232*	*0.03*
Ethanol		*0.5*	*0.3-0.4*	*145*	*287*	*0.008*
Biodiesel		*1.5*	*0.8-1.1*	*322*	*211*	*0.02*
United States	1 401	111-317	7-18	9 756-15 856	47-87	0.09-0.15
Fuel taxes – total		*92-291*	*6-17*	*1 121-3 754*	*13*	*0.01-0.03*
Fuel taxes – petrol		*70-221*	*5-13*	*932-2 888*	*13-17*	*0.009-0.03*
Fuel taxes – diesel		*20-70*	*1-4*	*278-861*	*12-14*	*0.003-0.008*
Fuel taxes – LPG		*0.1-0.3*	*0.01-0.02*	*1-5*	*10-17*	*0.00001-0.00005*
Biofuel policies		*19-26*	*1-2*	*8 635-12 102*	*418-465*	*0.08-0.11*

Table 3.2. **Abatement and abatement costs related to the road transport sector** *(cont.)*

2010 EUR

Country/policy	Total emissions in the sector, million tonnes CO_2e	Total abatement, million tonnes CO_2e	Abatement in % of counterfactual emissions	Total abatement cost, million	Cost per tonne CO_2eq abated	Total cost in % of GDP
Alcohol and biodiesel fuel credits				*4 598*		*0.04*
State tax preferences – ethanol				*2 077*		*0.02*
Renewable Fuel Standard				*5 396*		*0.05*
Federal Fleet Management Guide				*0.55*		*< 0.00001*
Production subsidy – biodiesel				*5*		*0.00005*
Production subsidy – ethanol				*5.5*		*0.00005*

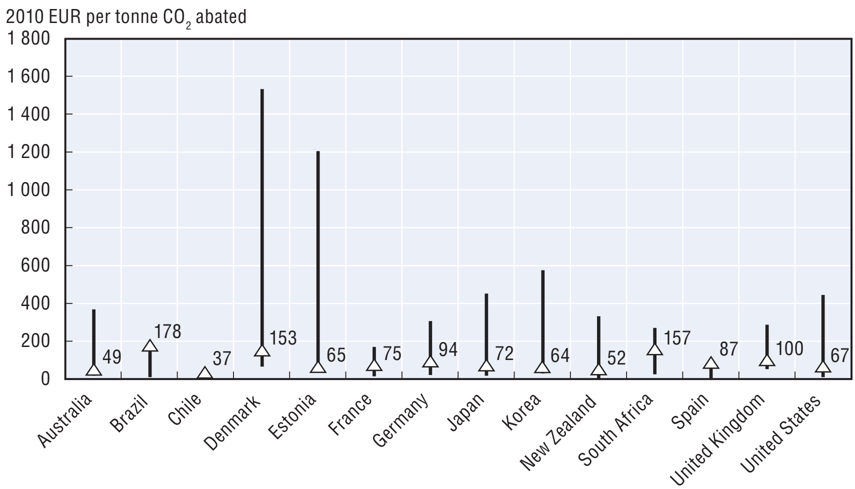
Notes: 1. France also has a fuel mandate for biofuels in place, but as it was found to be non-binding (i.e. the targets are far from being met), the effective carbon price was calculated for the tax preferences for biofuels only. 2. Although the effects of both tax exemptions and a fuel mandate were measured for Germany, the impact of the tax exemptions far outweighed that of the fuel mandate, therefore the policy is colour coded as a tax preference. 3. Since both biodiesel and bioethanol production are supported by a fuel mandate and tax incentives, and that abatement from these policies was estimated together, one row has been colour-coded as a fuel mandate, and the other as a tax incentive, even though support for both biodiesel and bioethanol support comes from a mixture of both policy instruments.

Sources: Productivity Commission (2011), estimates in case studies prepared for the OECD and IEA (2012).

in some of the countries, the differences across the estimated average effective carbon prices within the transport sector, in the respective countries, are much lower in relation to road transport than what was found for the electricity generation sector.

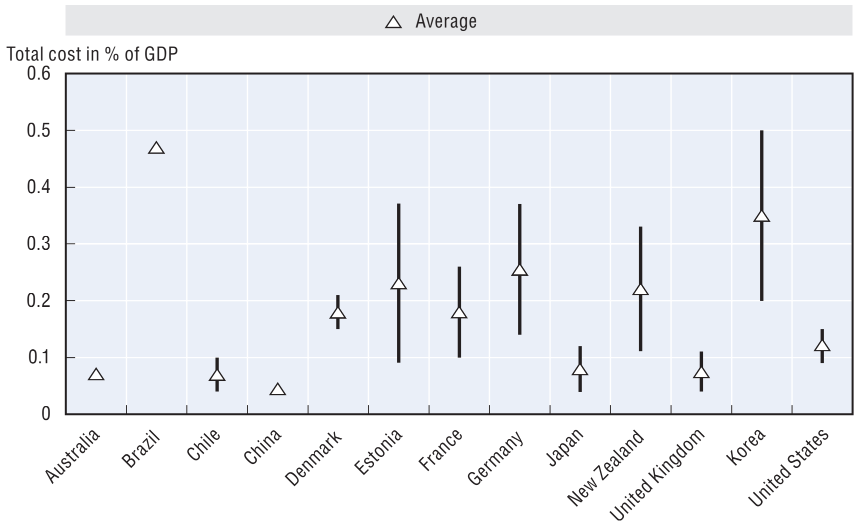
Figure 3.10 compares the total costs to society, measured in per cent of GDP, of all the relevant policies addressing the transport sector across the countries – and shows that these costs vary considerably, both across and within the countries. On average, the costs are more than twice as high as what was found for the electricity generation sector in the 12 countries for which both estimates are available.[7]

Figure 3.9. **Estimated effective carbon prices in the road transport sector, by country**



Note: See Table 3.2 for caveats regarding the different policy instruments.

Figure 3.10. **Total costs of policy instruments applied in the road transport sector**



Note: See Table 3.2 for caveats regarding the different policy instruments. Ranges shown for some countries reflect different choices about assumptions used in the estimates.

Figure 3.11 provides an additional illustration of the costs of policies compared to GDP; in this case on an instrument-by-instrument basis, sorted by country. The graph indicates that there are quite significant social costs related to some of the fuel taxes in application – via losses in consumer surpluses. The generally higher motor fuel taxes applied in Europe than elsewhere imply that the abatement incentives in this regard tend to be stronger there than in other parts of the World. However, also in the case of South Africa, the consumption losses related to the motor fuel taxes have been estimated to represent about 0.2% of GDP.

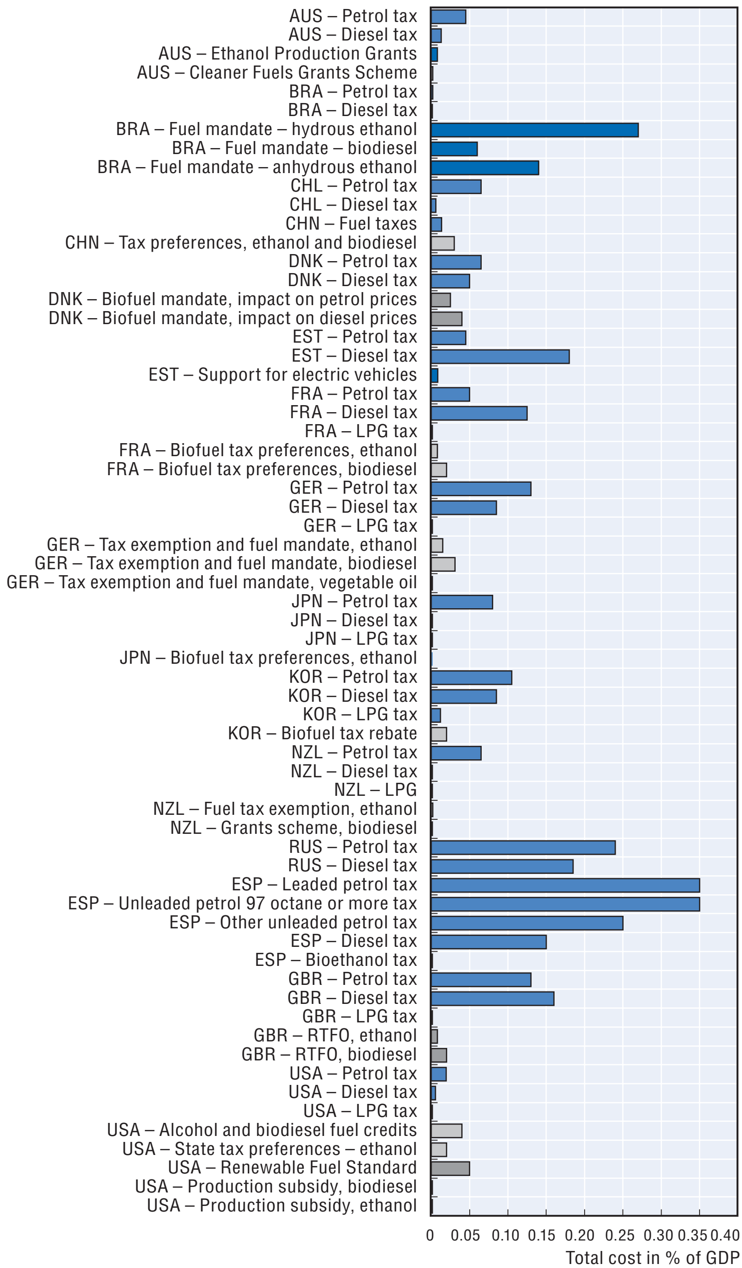
Also some of the policies promoting biofuels use entail total costs that are quite significant.

Figure 3.12 illustrates the amount of abatement that it is estimated that the policies covered have contributed to – compared to the counterfactual emissions in the sector.[8] The graph indicates that in most of the countries, CO_2 emissions from road transport would have been substantially higher if the policy instruments analysed in this report had not been in place. Only in China and the United States is the estimated abatement less than 10%, and in Germany and the United Kingdom it is estimated that the policies in place are likely to reduce the emissions by more than 30% – and more than 40% under some assumptions.

Comparisons across instrument types

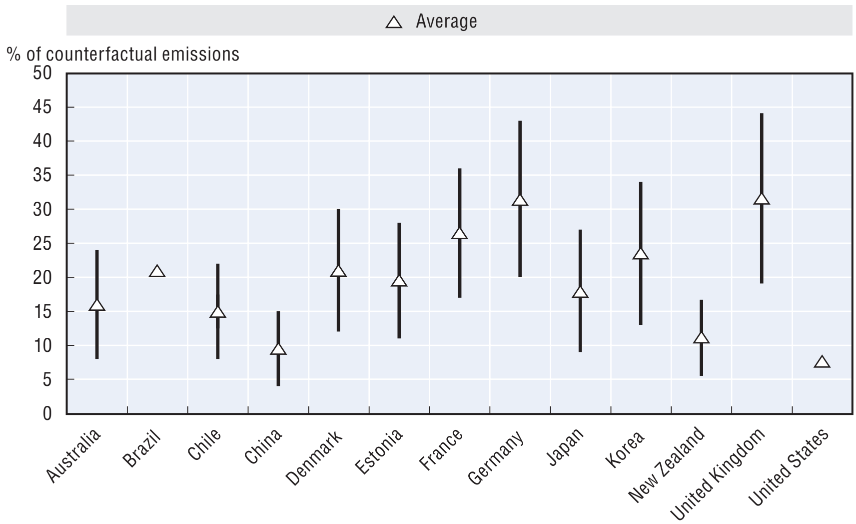
Figure 3.13 illustrates the estimated effective carbon prices for more than 60 individual policy instruments that are applied in the road transport sector

Figure 3.11. **Costs of individual policy instruments applied in the road transport sector**



Note: See Table 3.2 for caveats regarding the different policy instruments. The grey-shading of the bars reflects the shading used in Table 3.2. The graph includes the instruments for which it has been possible to estimate a total cost, measured as a share of GDP. Where Table 3.2 provides a high and a low value, a simple average of the two numbers has been used here.

Figure 3.12. **Abatement achieved with instruments addressing road transport, national averages**



Note: Ranges shown for some countries reflect different choices about assumptions used in the estimates.

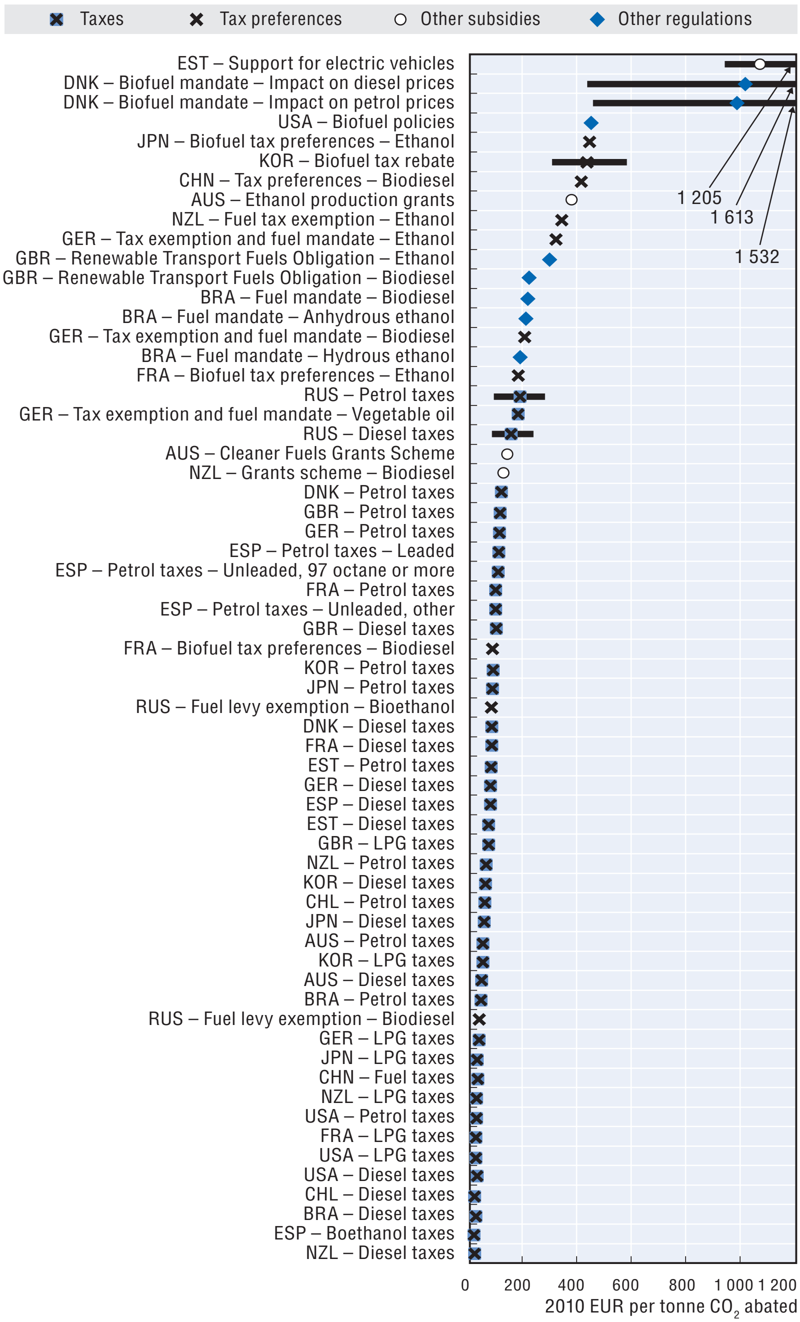
– with a coding that reflects the different instrument categories. With a few exceptions, fuel taxes dominate the low-cost, bottom of the graph. "Tax preferences", "Other subsidies" and "Other regulations" all entail higher costs to society per tonne of CO_2 abated – and in many cases, *very* substantially so.

With the exception of a support scheme for electrical vehicles in Estonia, various policies promoting biofuels are the most costly policies applied in relation to road transport, per tonne of CO_2 abated. In fact, the figures shown are likely to be underestimates, as much less "optimistic" assumptions could in many cases well have been applied as regards the net GHG abatement impacts of the substitution of biofuels for fossil fuels, compared to what has been done in the case studies.

Figure 3.14 shows a somewhat opposite picture, when the total costs of the various policy instruments are compared to GDP: In this sense, fuel taxes tend to be the most costly instruments. However, as highlighted in Figure 3.15, this is largely because the fuel taxes have a much broader application than most of the other policy instruments, and contribute to a large amount of abatement. Hence, as was shown in Figure 3.13, and as summarised also in Figure 3.16, the costs per tonne CO_2 abated is much lower when fuel taxes are applied than when any other type of policy instrument is applied in the road transport sector.

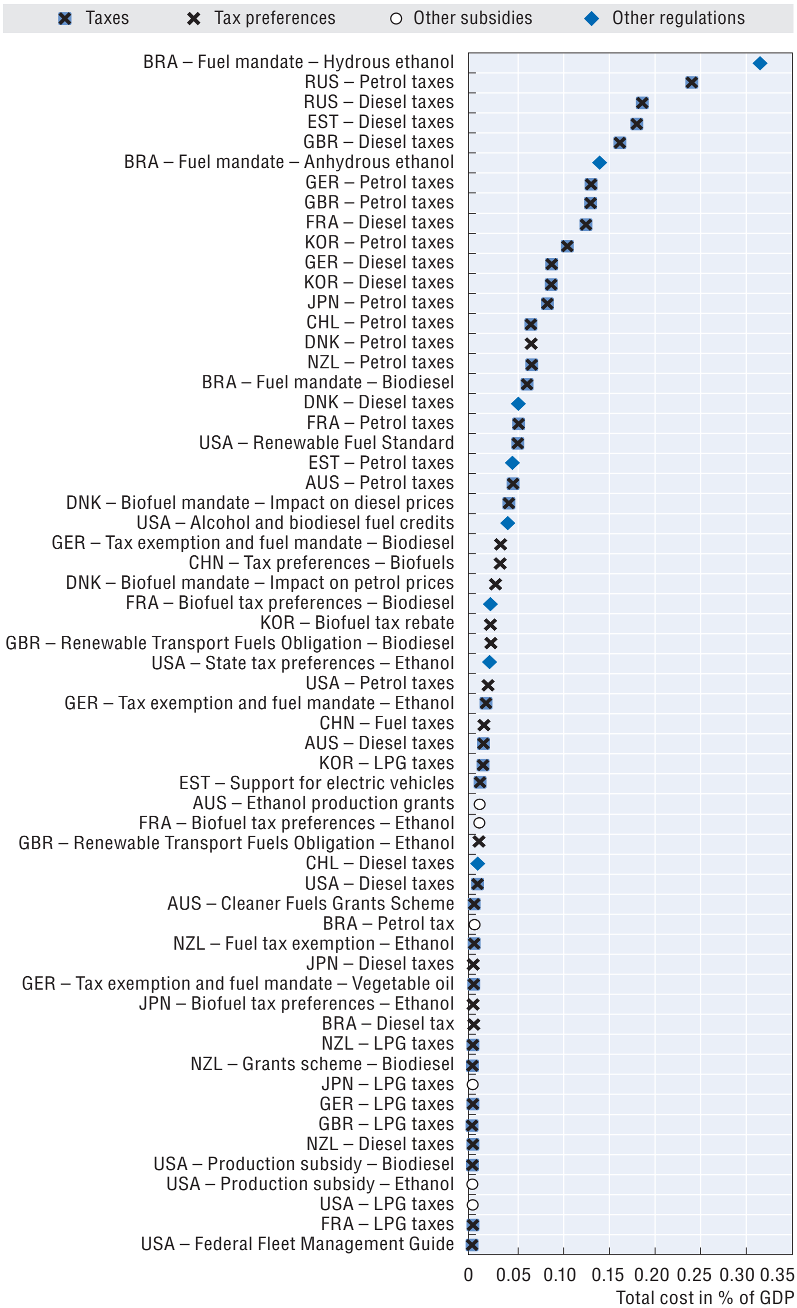
In the discussion of the methodology used in this project in Chapter 2, it was emphasised that many of the policy instruments discussed in this project were introduced for reasons other than to combat climate change. This can be the case for any instrument category – but it is certainly the case

Figure 3.13. Estimated effective carbon prices in the road transport sector, by instrument



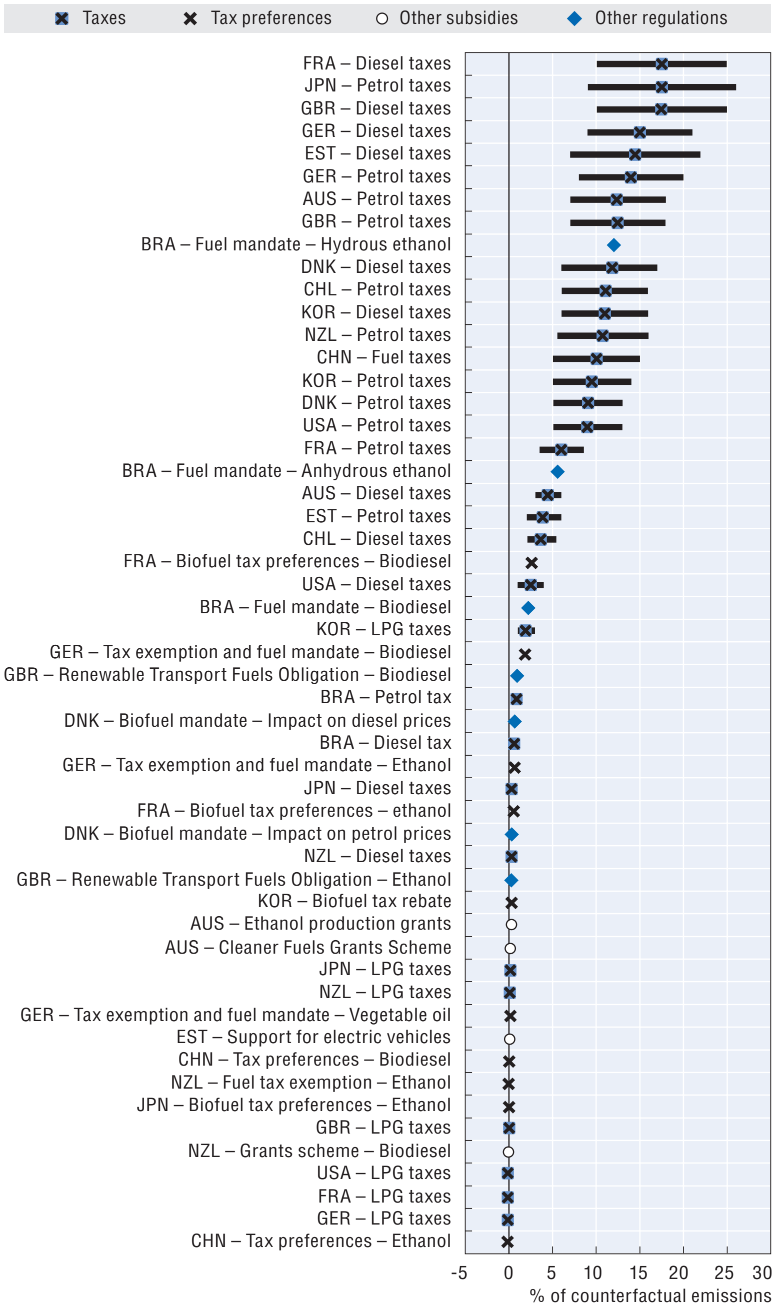
Note: Ranges shown for some instruments reflect different choices about assumptions used in the estimates.

Figure 3.14. **Costs of individual policy instruments applied in the road transport sector**



Note: Ranges shown for some instruments reflect different choices about assumptions used in the estimates.

Figure 3.15. **Abatement achieved by policy instruments applied in the road transport sector**

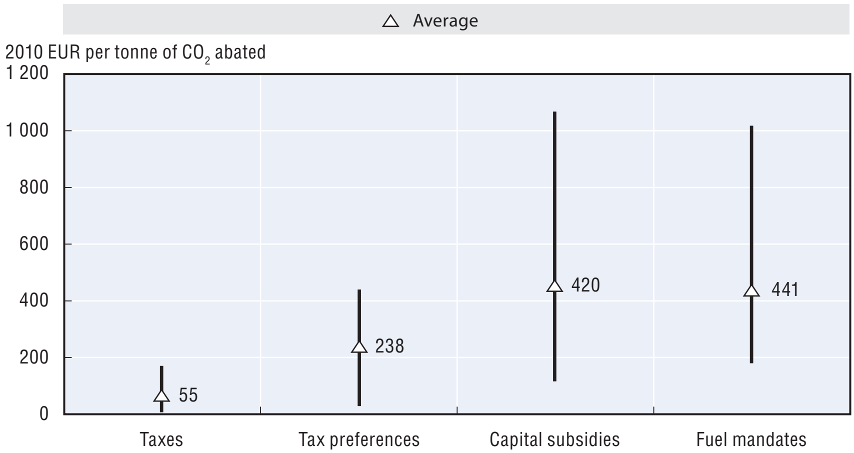


Note: Ranges shown for some instruments reflect different choices about assumptions used in the estimates.

for most of the motor fuel taxes covered here. To a large extent, they were primarily introduced in order to raise revenue – for road building in particular or for the government's lockers more generally. In spite of this, the present project clearly indicates that such taxes contribute to much cheaper CO_2 abatement than what other policy instruments do – even when the oft-forgotten losses in consumer surpluses are taken into account.[9]

Figure 3.17 illustrates the occurrences of various instrument categories across the countries covered. While all the countries have fuel taxes in place,[10] tax preferences (e.g. for biofuels) are used in about 70% of the countries, and fuel mandates (minimum requirements regarding the blending of biofuels in motor fuels) are used in almost 60% of the countries.

Figure 3.16. **Estimated effective carbon prices in the road transport sector, by instrument category**



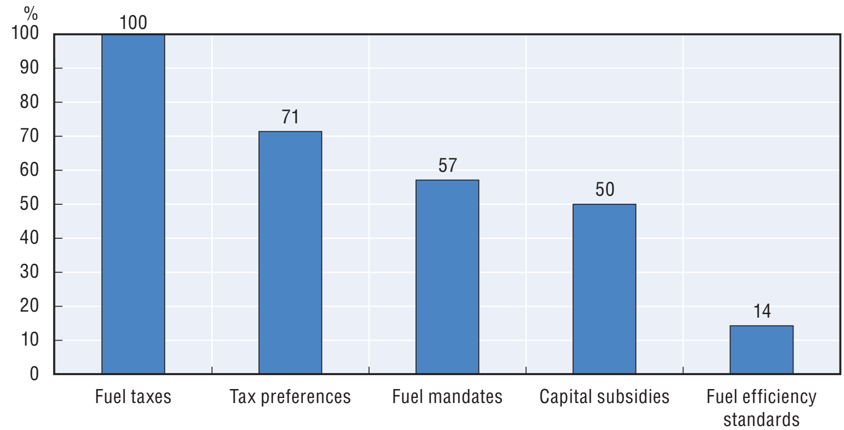
3. The pulp and paper sector

Comparisons across countries

Table 3.3 indicates that almost all the estimated carbon prices related to the pulp and paper sector are very modest, compared to what has been found for electricity generation and road transport.[11] The only exception is Estonia, with an estimated carbon price of almost EUR 800, which probably is due to a very low amount of abatement achieved by the policy in question.[12] In all other countries, the estimated carbon prices are below EUR 20 per tonne of CO_2eq – in most cases, much lower than that, see also Figure 3.18.

Measured in relation to GDP, the estimated costs of policies affecting GHG emission abatement in the pulp and paper sector are very modest – miniscule fractions of a percentage point in all cases, with the "largest" costs found in Germany, where the policies affecting this sector are estimated to entail costs to society equal to 0.004% of GDP, see Figure 3.19.

Figure 3.17. **Share of countries in which a given instrument type is used in the road transport sector**



Note: The graph includes all instruments mentioned in the case studies, even if an effective carbon price for some reason has not been calculated.

The amount of abatement currently achieved via these policies is, however, also estimated in most cases to be rather modest. Country averages are only available for a few countries, but Figure 3.20 indicates that in France and Germany, the policies in question have contributed to abatement in the order of 20-25% of the counterfactual emissions.

Comparisons across instrument types

Figure 3.21 illustrates the effective carbon prices estimated for individual policy instruments addressing the pulp and paper sector, with instrument categories indicated by the symbols used for each instrument. By far the highest estimate has been found for the German feed-in tariffs for biomass, with an effective carbon price of EUR 188 per tonne CO_2 abated. Also the German feed-in tariffs for combined heat and power (CHP) and for hydro-electric power show carbon prices above 20 EUR per tonne CO_2 abated. No other estimate is above EUR 15.

As regards other instrument types, also for emission trading systems some relatively significant effective carbon prices have been found – reflecting the price level of emission allowances in the European Union's Emission Trading System (EU ETS) in 2010. The carbon prices found in relation to the emission trading system in New Zealand are much lower – reflecting a lower degree of strictness in that system than in the EU ETS.

A cost of EUR 5 per tonne CO_2 abated has been found in relation to the natural gas excise tax in Korea. All other estimates in relation to taxes are lower than EUR 5. For subsidies, the highest estimate is found in relation the French biomass subsidies, with a cost of EUR 7 per tonne CO_2 abated. Both in Chile and in China, estimates lower than EUR 1 were found in relation to the impact of renewable support policies on the electricity prices that the pulp and paper sector pays.

Table 3.3. **Abatement and abatement costs related to the pulp and paper sector**

2010 EUR

Country/policy	Total emissions in the sector, million tonnes CO_2e	Total abatement, *thousand* tonnes CO_2e	Abatement in % of counterfactual emissions	Total abatement cost, *thousand*	Cost per tonne CO_2eq abated	Total cost in % of GDP
Australia	1.7	11-113	0.6-6.6	21-120	1.1-1.9	< 0.00001-0.00001
Impact of regulation on electricity prices		*11-113*		*21-120*	*1.1-1.9*	*< 0.00001-0.00001*
Brazil	3.6					
Chile	12.8	6.5-23	0.1-0.2	5.3-19	0.8	< 0.00001-0.00001
Impact of renewable energy support on electricity prices		*6.5-23*		*5.3-19*	*0.8*	*< 0.00001-0.00001*
China	130.6	61.5-348	0.05-0.3	20.5-95.9	0.3	< 0.00001
Impact of renewable energy support on electricity prices		*61.5-348*		*20.5-95.9*	*0.3*	*< 0.00001*
Denmark	0.23	4.4-13.5	1.9-5.5	32-98	7	0.00001-0.00004
Compared to no tax		*0.9-2.8*	*0.4-1.2*	*4.7-14.5*	*5*	*< 0.00001*
EU ETS		*3.5-10.7*	*1.5-4.4*	*27.0-83.4*	*8*	*0.00001-0.00004*
Estonia	0.064	2.9	4.5	2 272	792	0.02
Impact of taxes on electricity prices		*2.9*	*4.5*	*2 272*	*792*	*0.02*
France	2.3	220-1 564	9-40	1 609-11 955	7.6-8.0	0.0001-0.0006
EU ETS – demand-side effect		*63-1 383*	*2.5-36*	*500-10 500*	*8*	*0.00003-0.0005*
EU ETS – substitution effect		*10-34*	*0.4-0.9*	*139-485*	*14*	*< 0.00001-0.00003*
Subsidy – heat production using biomass		*147*	*3.8-5.8*	*970*	*7*	*0.00005*
Germany	9.4		7-37	53 690-93 069	19-25	0.002-0.004
Energy taxes – coal		*3.6-5.4*	*0.04*	*1.5-2.3*	*0.4*	*< 0.00001*
Energy taxes – gas		*2.7-4.3*	*0.03*	*0.3-0.5*	*0.1*	*< 0.00001*
EU ETS – coal		*140-223*	*1.4-1.5*	*953-1 519*	*6.8*	*0.00004-0.00006*
EU ETS – gas		*–10 to –11*	*–0.07 to –0.09*	*68-77*	*6.8*	*< 0.00001*

Table 3.3. **Abatement and abatement costs related to the pulp and paper sector** *(cont.)*

2010 EUR

Country/policy	Total emissions in the sector, million tonnes CO_2e	Total abatement, *thousand* tonnes CO_2e	Abatement in % of counterfactual emissions	Total abatement cost, *thousand*	Cost per tonne CO_2eq abated	Total cost in % of GDP
Impact of EU ETS and regulation on electricity prices		*545-5 371*	*5-36*	*8 824-47 625*	*9-16*	*0.0004-0.002*
Feed-in tariff – CHP		*985*	*6.6-9.8*	*20 416*	*21*	*0.0008*
Feed-in tariff – hydro		*11-23*	*0.11-0.15*	*310*	*13-28*	*0.00001*
Feed-in tariff – biomass		*124-254*	*1.2-1.7*	*23 363*	*92-188*	*0.0009*
Japan	20.3	385-694	1.9-3.4	686-1 446	1.8-2.1	0.00002-0.00003
Fuel tax – coal		*322-491*		*408-621*	*1.3*	*0.00001*
Fuel tax – petroleum		*29-45*		*84-129*	*2.9*	*< 0.00001*
Impact of fuel taxes and regulation on electricity prices[1]		*34-158*		*195-696*	*4-6*	*< 0.00001-0.00002*
Korea	3	35-54	1.2-1.8	167-253	5	0.00002-0.00003
Impact of low-sulphur fuel excise tax		*24-37*		*54-83*	*2*	*0.00001*
Impact of natural gas excise tax		*11-17*		*112-171*	*10*	*0.00002*
New Zealand	0.2	8.5-25	4.5-12.5	16-46	2	0.00001-0.00004
Impact of gas excise duty		*2.3-3.5*		*5-8*	*2*	*< 0.00001-0.00001*
Impact of ETS on electricity prices		*6-21*		*11-37*	*2*	*0.00001-0.00003*
Impact of ETS on gas		*0.4-0.6*		*0.15-0.28*	*0.4*	*< 0.00001*
South Africa						
Spain	4.4					
United Kingdom	2.3	122-569	5.3-24.7	1 911-6 708	8-12	0.0001-0.0004
Direct impact of the Climate Change Levy on gas		*7-11*		*7.7-12*	*1*	*< 0.00001*
Impact of EU ETS, the Renewables obligation, and the Climate Change Levy on electricity prices		*50-478*		*660-5 249*	*11-13*	*0.00004-0.0003*

Table 3.3. **Abatement and abatement costs related to the pulp and paper sector** *(cont.)*

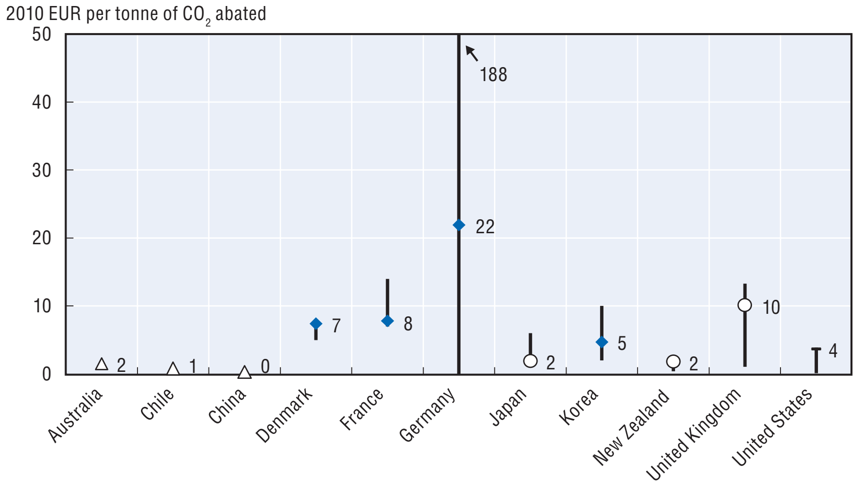
2010 EUR

Country/policy	Total emissions in the sector, million tonnes CO_2e	Total abatement, *thousand* tonnes CO_2e	Abatement in % of counterfactual emissions	Total abatement cost, *thousand*	Cost per tonne CO_2eq abated	Total cost in % of GDP
Direct impact of the EU ETS on gas		*53-80*		*389-590*	*7*	*0.00002-0.00003*
Direct impact of the Carbon Reduction Commitment		*12*		*853*	*14*	*0.00005*
United States	24.6	274-296	1.1-1.2	5 382-5 384	3.6-3.8	0.00005
Impact of CHP tax credit		*272*		*5 382*	*3.9*	*0.00005*
Impact of increased electricity prices		*2.4-24*		*0.4-2.4*	*0.1-0.2*	*< 0.00001*

Note: 1. The increase in electricity prices is brought about by fuel taxes, by regulation (the Renewable Portfolio Standard) and by subsidies to solar PV. The row is colour-coded as “regulation”, as fuel taxes are already explicitly colour-coded, and the abatement subsidy for the RPS is greater than for national PV subsidies (see Table 2).

Sources: Productivity Commission (2011) and estimates in case studies prepared for the OECD.

Figure 3.18. **Estimated effective carbon prices in the pulp and paper sector, by country**



Note: Please see the legend below for an explanation of the averages presented, and Table 3.3 for caveats regarding the various instruments. Being an *extreme* outlier regarding the estimated effective carbon price in this sector, Estonia has not been included in the graph.

Legend

	Minimum value	Maximum value	Average value
△	Impact of a group of policies	Impact of a group of policies	Average of the impact of a group of policies
◆	Individual policy	Individual policy	Average weighted average by abatement
○	Individual policy	Impact of a group of policies	Average weighted average by abatement
▬	Impact of a group of policies	Individual policy	Average weighted average by abatement

It has not been possible to single-out the effective carbon prices of the EU ETS and various regulations applied in Germany, but for the combination of policies (where the regulations are deemed to have contributed the most to the abatement), a carbon price of EUR 12.5 has been estimated.

In Figure 3.22 it is shown that the combination the EU ETS and various regulations in Germany is estimated to have caused 36% of the counterfactual emissions in the pulp and paper sector to be abated. An equally large share of abatement has been found in relation to the EU ETS in France. In all other cases, the estimated abatement is less than 10% of the counterfactual emissions.

Figure 3.19. **Total costs of carbon-related policies applied in the pulp and paper sector**

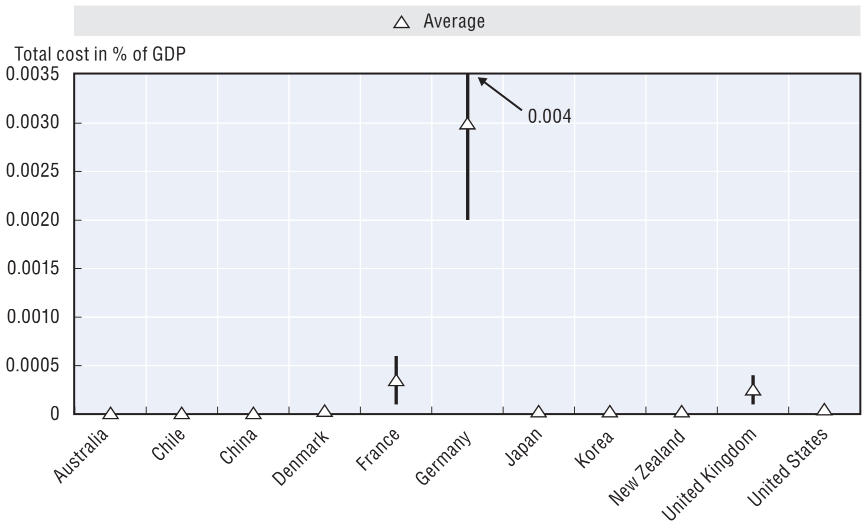


Figure 3.20. **Abatement achieved with instruments addressing pulp and paper, national averages**

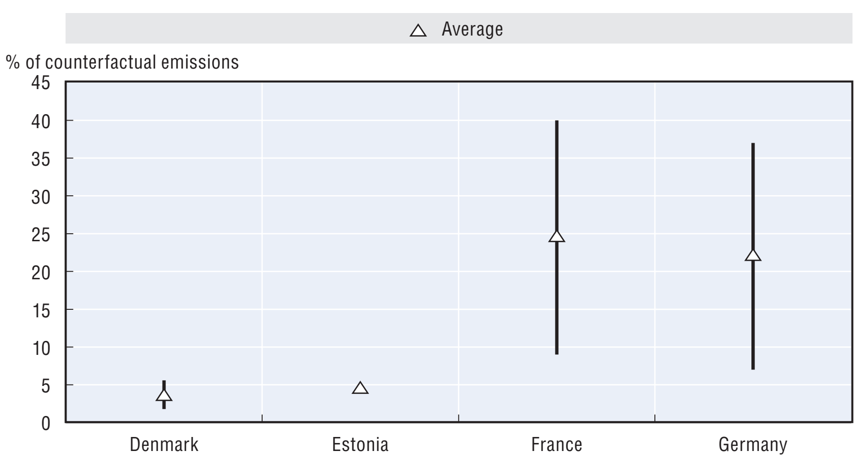


Figure 3.21. **Estimated effective carbon prices in the pulp and paper sector, by instrument type**

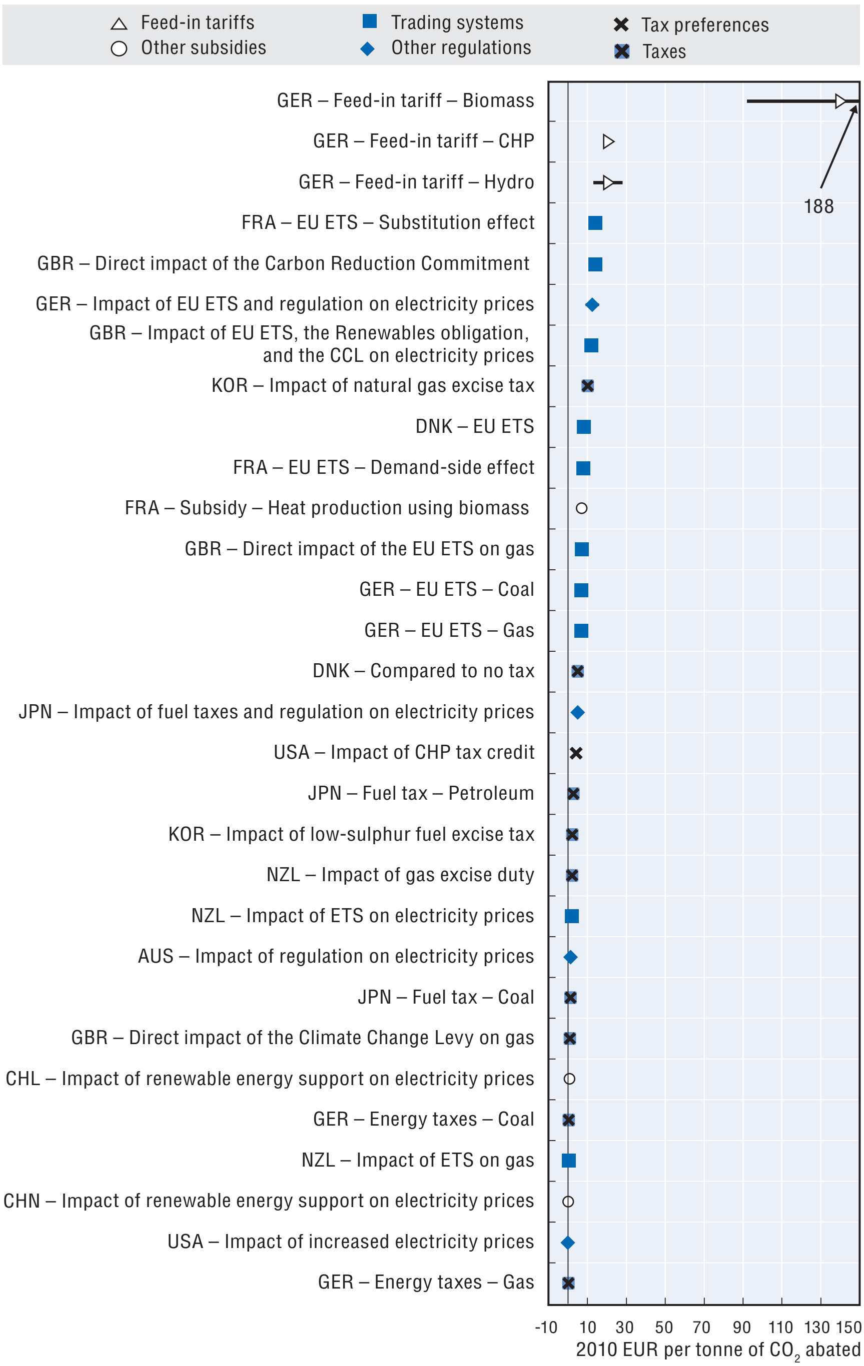


Figure 3.22. **Abatement achieved with instruments addressing pulp and paper, individual instruments**

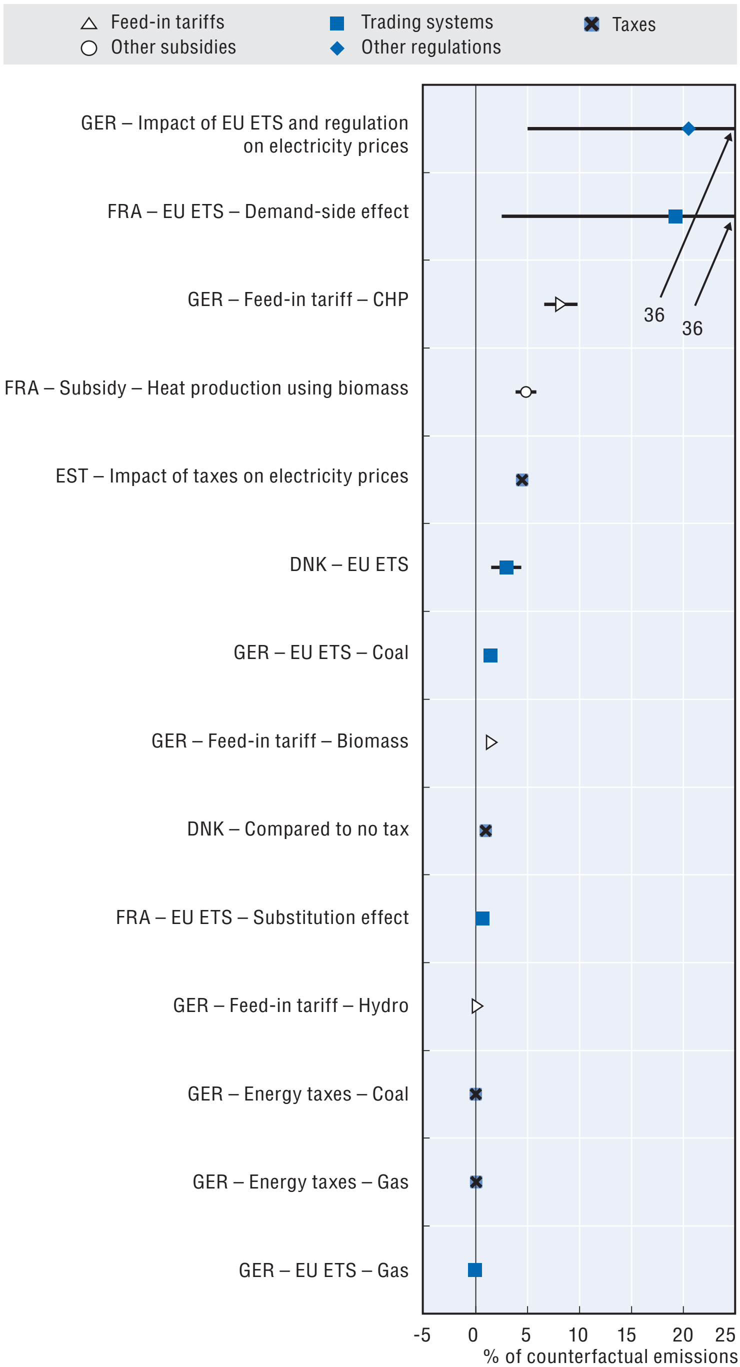
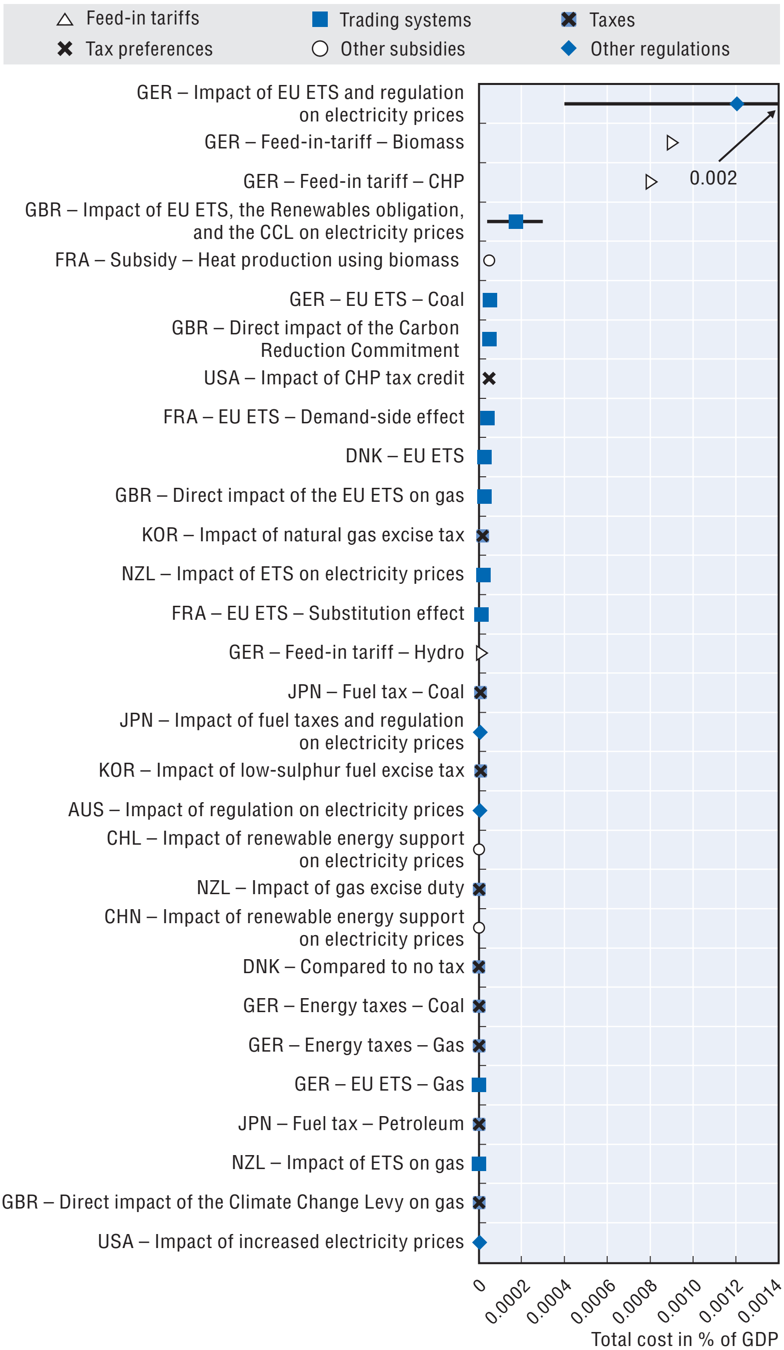


Figure 3.23. **Total costs of carbon-related policies in the pulp and paper sector, by instrument type**



Not surprisingly, the estimated costs of the policies addressing the pulp and paper sector are in all cases very modest, measured in per cent of GDP – but with nevertheless clearly the highest estimates found in relation to the combination of the EU ETS and various regulations, as well as the feed-in tariffs, in Germany. The estimated costs of the various emission trading systems and taxes are significantly lower, never exceeding 0.0002% of GDP.

4. The cement sector

Comparisons across countries

Table 3.4 shows that, like in the pulp and paper sector, and without any major exceptions, the estimated carbon prices facing the cement sector are generally very modest, for example when compared to the abatement incentives facing the electricity generation and the road transport sectors.[13]

In most cases, the estimates are well below EUR 10 per tonne of CO_2eq, and none of the country averages exceed EUR per tonne CO_2 abated – see Figure 3.24. Likewise, the costs of abatement in comparison to GDP are also very modest, with Germany being the only case where they exceed 0.0002% of GDP – see Figure 3.25.

Comparisons across instrument types

Figure 3.26 illustrates the effective carbon prices found for individual policy instruments addressing the cement sector, showing a strong dominance of emission trading systems among the high-end estimates. It is important to emphasise that this is *not* due any ineffectiveness of these instruments – but rather that the EU ETS is clearly the most "ambitious" of the policies that applied to the sector in 2010. In most of the other cases, the policies in place seem to have had very modest impact on the behaviour of the firms in the sector – although, unfortunately, too few estimates are available for it to make sense to present a separate graph regarding the abatement estimated to have been caused by the various policy instruments.

Figure 3.27 illustrates that, like in the pulp and paper sector, the costs of the policies applied are very limited, when compared to GDP. By far the highest impact was in relation to the use of lignite in the sector in Germany, due to the EU ETS – but also this cost was below 0.0006% of GDP. Like for the cost per tonne abated, emission trading systems dominate the high end among the estimates – for the reasons already mentioned.

Table 3.4. **Abatement and abatement costs related to the cement sector**

EUR 2010

	Total emissions in the sector, million tonnes CO_2e	Total abatement, *thousand* tonnes CO_2e	Abatement in % of counterfactual emissions	Total abatement cost, *thousand*	Cost per tonne CO_2eq abated	Total cost in % of GDP
Australia	7.2	1.4-14.8	0.02-0.2	2.6-14.6	1.0-1.9	< 0.00001
Impact of regulation on electricity prices		*1.4-14.8*		*2.6-14.6*	*1.0-1.9*	*< 0.00001*
Brazil	14.7					
Chile	1.6	0.8-2.9	0.05-0.2	0.7-2.3	0.8	< 0.00001
Impact of renewable energy support on electricity prices[1]		*0.8-2.9*		*0.7-2.3*	*0.8*	*< 0.00001*
China	36.2	259-1 427	0.7-3.8	150-614	0.4-0.6	< 0.00001-0.00001
Differential electricity pricing policy – "restricted category"		*1.3-5.9*		*0.9-3.2*	*0.6-0.7*	*< 0.00001*
Differential electricity pricing policy – "eliminated category"		*36.2-158*		*75-261*	*1.6-2.1*	*< 0.00001*
Impact of renewable energy support on electricity prices		*222-1 263*		*73-344*	*0.3*	*< 0.00001*
Denmark	1.1	37-115	3.3-9.5	204-624	5	0.00008-0.0003
Compared to no tax		*15-49*	*1.3-3.9*	*50-153*	*3*	*0.00002-0.00007*
EU ETS		*22-68*	*2.0-5.6*	*154-417*	*7*	*0.00007-0.0002*
Estonia	0.6					
France	15	19-366	1.3-19.5	156-2 825	7.8-8.5	< 0.00001-0.00001
EU ETS, demand-side effect		*16-358*	*1.1-19*	*120-2 700*	*7.6*	*< 0.00001-0.0001*
EU ETS, substitution effect		*2.5-8.8*	*0.16-0.47*	*36-125*	*14.3*	*< 0.00001*

Table 3.4. **Abatement and abatement costs related to the cement sector** *(cont.)*

EUR 2010

	Total emissions in the sector, million tonnes CO_2e	Total abatement, *thousand* tonnes CO_2e	Abatement in % of counterfactual emissions	Total abatement cost, *thousand*	Cost per tonne CO_2eq abated	Total cost in % of GDP
Germany	13.1	2 070-3 061	13.7-18.9	15 656-23 420	8	0.0006-0.0009
Direct impact of EU ETS (coal)		*203-232*		*1 462-1 667*	*7.2*	*0.00006-0.00007*
Direct impact of EU ETS (lignite)		*1 752-2 014*		*12 599-14 480*	*7.2*	*0.0005-0.0006*
Impact of EU ETS and regulation on electricity prices		*86-844*		*1 393 -7 483*	*9-16*	*0.0001-0.0003*
Japan	23.8	495-832	2.0-3.4	738-1 419	1.5-1.7	0.00002-0.00003
Direct impact of coal tax		*470-714*		*621-943*	*1.3*	*0.00001-0.00002*
Impact of fuel taxes, the Renewable Portfolio Standard, solar feed-in tariffs, and electricity excise duty on the price of electricity		*25-118*		*151-541*	*4.4-5.7*	*< 0.00001-0.00001*
Korea	37.1					
New Zealand	0.5	4.9-8.9	1.0-1.8	2.3-5.6	0.5-0.6	< 0.00001
Impact of ETS on electricity prices		*0.6-2.0*		*1.0-3.5*	*1.8*	*< 0.00001*
Impact of ETS on coal prices		*2.7-4.3*		*0.9-1.5*	*0.34*	*< 0.00001*
Impact of excise tax on coal		*1.7-2.7*		*0.3-0.6*	*0.21*	*< 0.00001*
South Africa						
Spain	17.8					
United Kingdom	5.7	298-557	5.0-8.9	2 109-4 194	7.1-7.5	0.0001-0.0002
Direct impact of Climate Change Levy on coal		*20-31*		*13-19*	*0.6*	*< 0.00001*
Impact of EU ETS, the Renewables obligation and the Climate Change Levy on electricity prices		*8-80*		*109-871*	*11-13*	*0.00001-0.00005*
Direct impact of EU ETS on coal		*269-446*		*1 960-3 249*	*7*	*0.0001-0.0002*

Table 3.4. **Abatement and abatement costs related to the cement sector** *(cont.)*

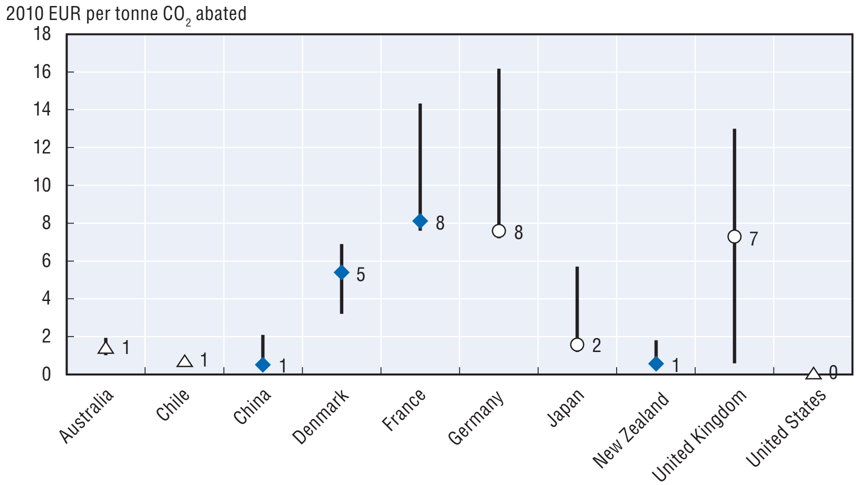
EUR 2010

	Total emissions in the sector, million tonnes CO_2e	Total abatement, *thousand* tonnes CO_2e	Abatement in % of counterfactual emissions	Total abatement cost, *thousand*	Cost per tonne CO_2eq abated	Total cost in % of GDP
United States	4.1	2.4-24	0.06-0.6	0.42-2.43	0.1-0.2	< 0.00001
Impact of the Regional Greenhouse Gas Initiative and the Renewable Portfolio Standards on electricity prices		*2.4-24*		*0.42-2.43*	*0.1-0.2*	*< 0.00001*

Note: 1. Support for renewable energy sources in Chile comes in the form of a transmission subsidy, capital subsidies, and a renewable portfolio standard. Since two of these three instruments are subsidy instruments, this row has been colour-coded as such.

Source: Productivity Commission (2011) and estimates in case studies prepared for the OECD.

Figure 3.24. **Estimated effective carbon prices in the cement sector, by country**



Note: Please see the legend below for an explanation of the averages presented, and Table 3.4 for caveats regarding the various instruments.

Legend

	Minimum value	Maximum value	Average value
△	Impact of a group of policies	Impact of a group of policies	Average of the impact of a group of policies
◆	Individual policy	Individual policy	Average weighted average by abatement
○	Individual policy	Impact of a group of policies	Average weighted average by abatement

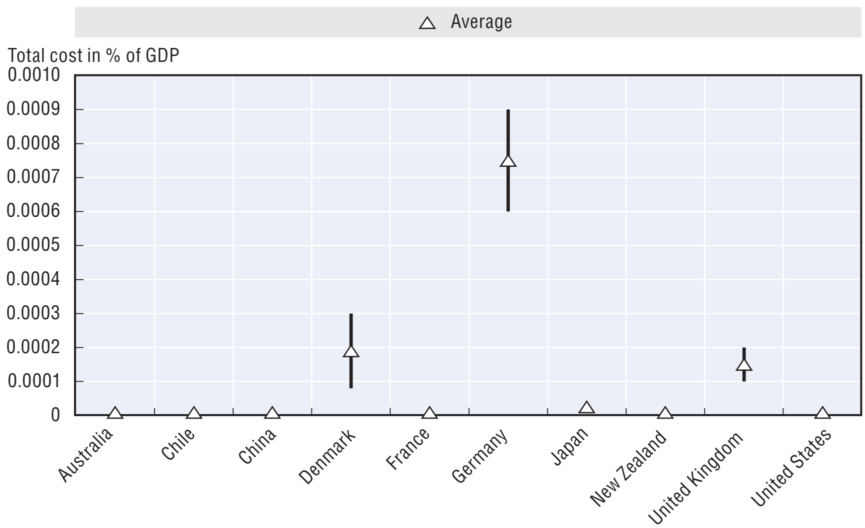
5. Households' energy use

Comparisons across countries[14]

Compared to the two industrial sectors covered in this project, as Table 3.5 shows, the household sector is facing quite significant GHG abatement incentives in many of the countries covered – well above EUR 100 in a number of cases. Figure 3.28 gives a graphical illustration of the ranges found – but, unfortunately, it has only been possible to provide national averages for some of the countries covered.

Figure 3.25. **Total costs of carbon-related policies applied in the cement sector, national averages**

In per cent of GDP



Comparisons across instrument types

Figure 3.29 illustrates the estimated carbon prices for individual instruments that are applied in the household sector. By far the highest estimates are found in relation to home insulation subsidies in New Zealand and in Chile.[15] More generally, subsidy schemes dominate the high-cost part of the graph, together with feed-in tariff schemes in United Kingdom and Australia.

Figure 3.26. **Estimated effective carbon prices in the cement sector, by instrument type**

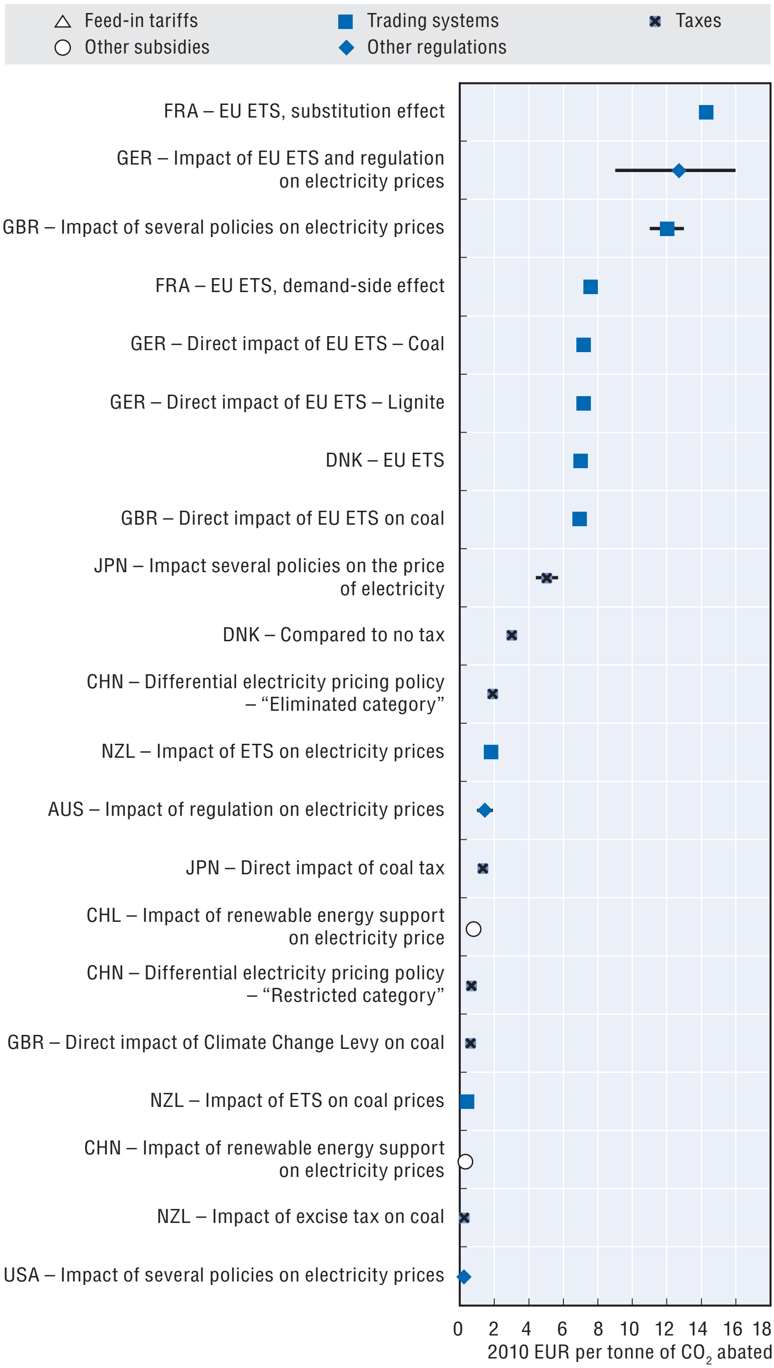


Figure 3.27. **Total costs of carbon-related policies applied in the cement sector, by instrument type**

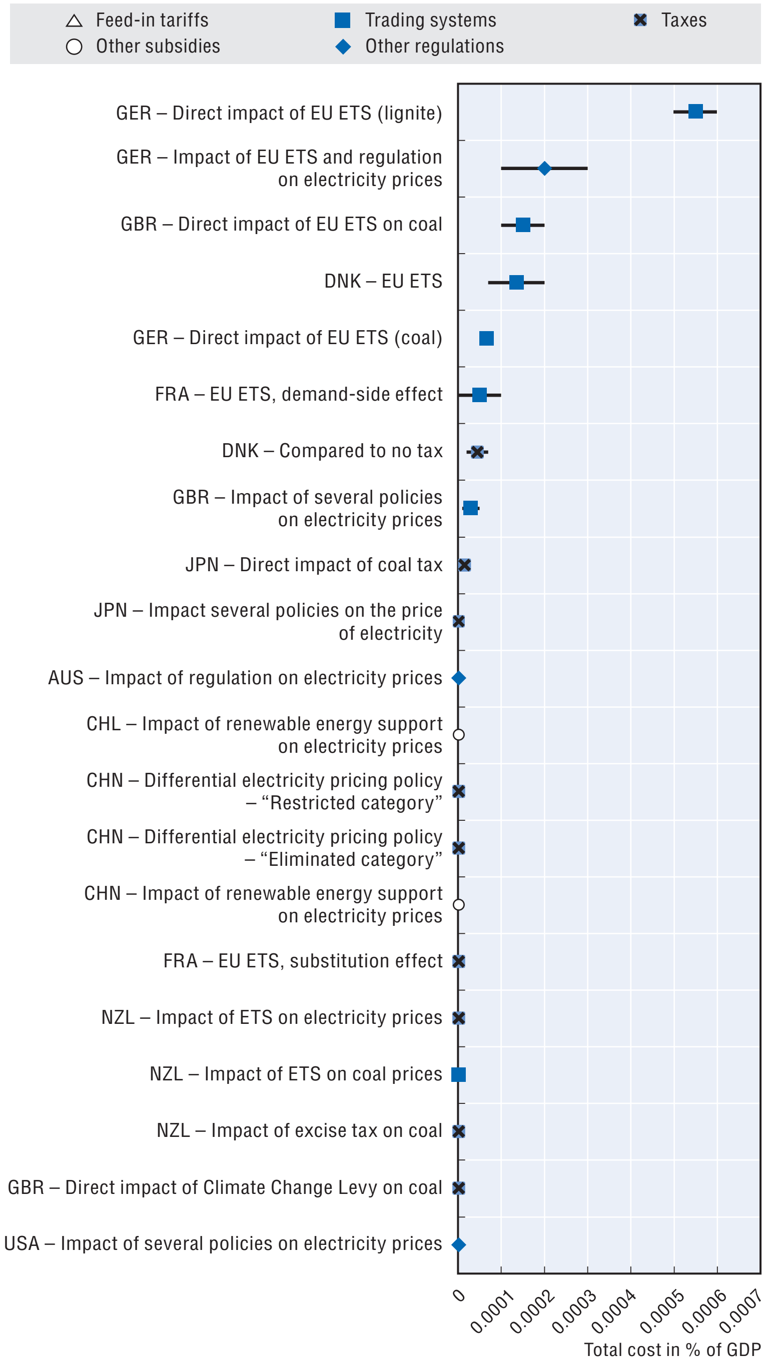


Table 3.5. **Abatement and abatement costs related to energy use in the household sector**

2010 EUR

Country/policy	Total emissions in the sector, million tonnes CO_2e	Total abatement, million tonnes CO_2e	Abatement in % of counterfactual emissions	Total abatement cost, million	Cost per tonne CO_2eq abated	Total cost in % of GDP
Australia	65.9					
Solar feed-in tariffs		*0.172-0.318*	*0.25-0.46*	*66.4*	*209-387*	*0.007*
Home insulation programme		*1.9*	*2.8*	*51-143*	*27-75*	*0.005-0.015*
Small-scale Renewable Energy Scheme (capital subsidy)		*0.317*	*0.46*	*36-50.5*	*114-159*	*0.004-0.005*
Brazil	27.6					
PROCEL energy efficiency programme[1]		*5.36*	*16*	*6*	*1.3*	*0.0004*
Chile	7.6					
Home insulation programme		*0.0033*	*0.04*	*1.9-2.6*	*577-808*	*0.0012-0.0016*
Light bulb exchange programme		*0.109*	*1.4*	*0.95-1.1*	*8-10*	*0.0006-0.0007*
China	873.3					
Denmark	13.7	0.96-3.19	7-19	104.2-338.9	106-109	0.044-0.14
Energy and CO_2 taxes (impact on heating)		*0.55-1.78*	*4-11*	*38.1-123.1*	*69-70*	*0.016-0.052*
Energy and CO_2 taxes (impact on electric appliances)		*0.41-1.41*	*3-8*	*66.0-215.8*	*154-161*	*0.028-0.092*
Estonia	6.8					
Tax – natural gas		*0.0015-0.0054*	*0.02-0.08*	*0.01-0.04*	*7*	*0.00007-0.0003*
Tax – electricity		*0.075-0.337*	*1-5*	*0.513-1.848*	*6-7*	*0.004-0.013*
Support for household renovation		*0.0064-0.0105*	*0.1*	*0.34*	*32-53*	*0.002*
France	74.4					
Tax – heating oil		*0.44-1.35*	*0.59-1.7*	*4.7-14.1*	*10.3-10.5*	*0.0002-0.0007*
Tax – LPG		*0.09-3.45*	*0.12-4.5*	*1.15-3.50*	*1-13*	*0.00006-0.0002*

Table 3.5. **Abatement and abatement costs related to energy use in the household sector** *(cont.)*

2010 EUR

Country/policy	Total emissions in the sector, million tonnes CO_2e	Total abatement, million tonnes CO_2e	Abatement in % of counterfactual emissions	Total abatement cost, million	Cost per tonne CO_2eq abated	Total cost in % of GDP
Germany	194.9					
Japan	199.2					
Korea	77.7					
New Zealand	2.8					
Home insulation programme		*0.0027*	*0.1*	*2.05-3.24*	*745-1 177*	*0.002-0.003*
South Africa	53.2					
Spain	40.3					
United Kingdom[2]	142.8					
Feed-in tariffs					*161-775*	
Carbon Emissions Reduction Target (utility obligation)		*5.6*	*3.6-3.7*	*259-364*	*47-65*	*0.015-0.021*
Community Energy Saving Programme (utility obligation) [3]		*2.32-5.8*	*1.5-3.8*	*375*	*65-162*	*0.022*
Northern Ireland – Energy Efficiency Levy[3]		*0.1*		*6.04*	*58*	*0.018*
England – Boiler Scrappage Scheme					*333*	
Scotland – Boiler Scrappage Scheme					*371*	
England – Warm Front fuel poverty scheme		*0.19*		*8.61-12.1*	*45-63*	*0.0007-0.0009*
Wales – Arbed capital investment scheme		*0.01*		*2.36-3.30*	*196-275*	*0.004-0.006*
Scotland – Energy Assistance Package		*0.3*		*2.9-4.08*	*94-133*	*0.002-0.003*
Scotland – Home Insulation Scheme		*0.003*		*0.62-0.98*	*272-317*	*0.0005-0.0007*
United States[4]	1 158.9					
State energy-efficient appliance rebate schemes		*Not estimated*			*47-582*	
California Solar Initiative		*0.25*		*21.1-29.4*	*82-116*	*0.0015-0.0021*

Table 3.5. **Abatement and abatement costs related to energy use in the household sector** *(cont.)*

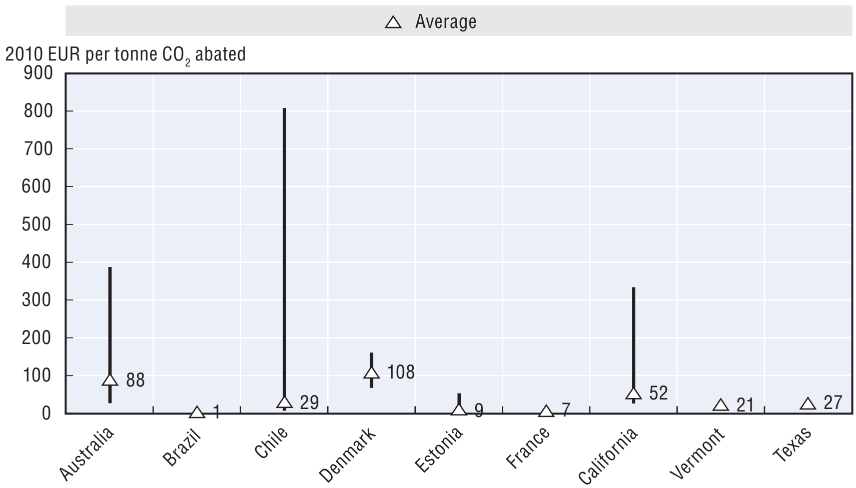
2010 EUR

Country/policy	Total emissions in the sector, million tonnes CO_2e	Total abatement, million tonnes CO_2e	Abatement in % of counterfactual emissions	Total abatement cost, million	Cost per tonne CO_2eq abated	Total cost in % of GDP
California – New Solar Homes Partnership		*0.06*		*1.5-2.1*	*238-334*	*0.00011-0.00015*
California – State-wide programme for residential energy efficiency[5]		*1.35*		*36.2-51.3*	*27-38*	*0.0026-0.0036*
Efficiency Vermont – (residential energy efficiency program)		*0.03*		*0.61-0.85*	*18-24*	*0.0032-0.0045*
Texas – Investor-owned utility energy efficiency programme		*0.15*		*3.37-4.73*	*22-31*	*0.0004-0.0005*

Notes: 1. PROCEL is an energy efficiency programme that also covers energy generation and industrial sectors, not just the household sector. Since the programme is largely funded by an electricity levy, it is colour-coded as a tax instrument. 2. For programmes specific to England, Scotland or Wales, the percentage of GDP is calculated as a percentage of that administrative division's GDP (or GVA when GDP figures are not available), not of total UK-wide GDP. 3. Cost and abatement data is over the lifetime of the policy, not only in 2010. 4. For State-based schemes in the United States, percentage of GDP is calculated as a percentage of that State's GSP (gross state product) instead of as a percentage of US GDP. 5. Although California, Vermont and Texas all have residential energy efficiency programmes written into legislation, the difference in colour coding reflects how these programmes are funded. *Efficiency Vermont* is funded by way of a tax per kWh on household electricity use, called the "Energy Efficiency Charge (EEC)", whereas California's energy utilities are told to deliver energy efficiency measures within a specific legislated annual budget, and Texas utilities do not have a specified budget with which to meet their energy saving targets.

Sources: Productivity Commission (2011) and estimates in case studies prepared for the OECD, IEA (2012), UK Office for National Statistics, California Department of Finance, Texas Comptroller, US Department of Commerce.

Figure 3.28. **Estimated effective carbon prices in the household sector, by country**



Note: Please see Table 3.5 for caveats regarding the various instruments.

At the other end of Figure 3.29, various taxes dominate – together with a couple of "Other regulations". Although there are exceptions, the graph clearly indicates that a given reduction in CO_2 emissions in the household sector can be achieved at a lower cost to society (in the terms of a loss in consumer surplus) through the use of taxes on energy products than via various forms of subsidies.

Figure 3.30 provides part of the explanation for this: Generally the taxes contribute to much larger emission reductions in the sector than what the subsidies manage to do. Only one of the subsidy schemes covered (the Australian home insulation scheme) is estimated to have reduced counterfactual emissions more than 2%. Hence, the costs per unit abated tend to be lower for taxes than for subsidy schemes.

Given the quite significant emission reductions they trigger, it is not so surprising that two taxes show the highest social costs, measured as a share of GDP, as can be seen in Figure 30. The shares are generally low compared to what was found in the transport sector – but they are much higher than what was found regarding the two industrial sectors covered.

Figure 3.29. **Estimated effective carbon prices in the household sector, by instrument type**

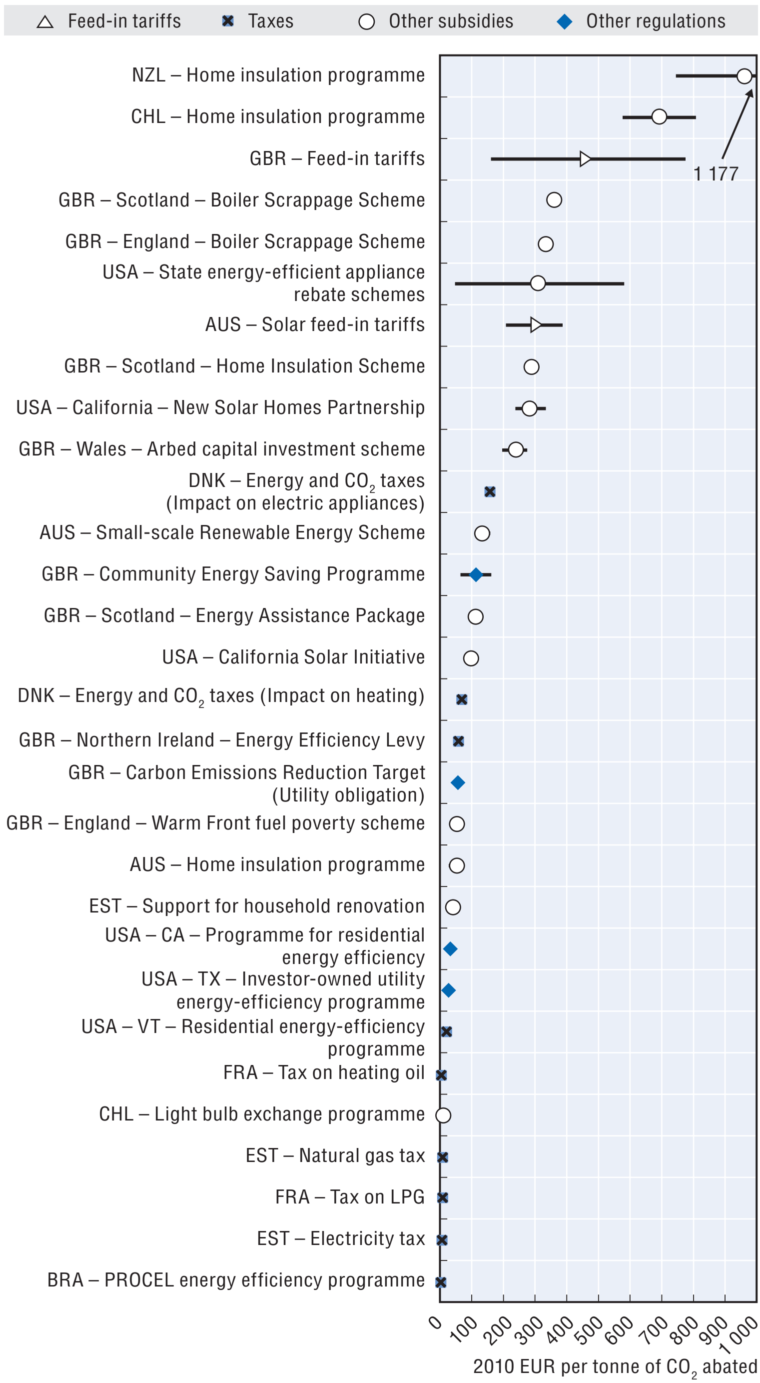


Figure 3.30. **Abatement achieved with instruments addressing the household sector, by instrument type**

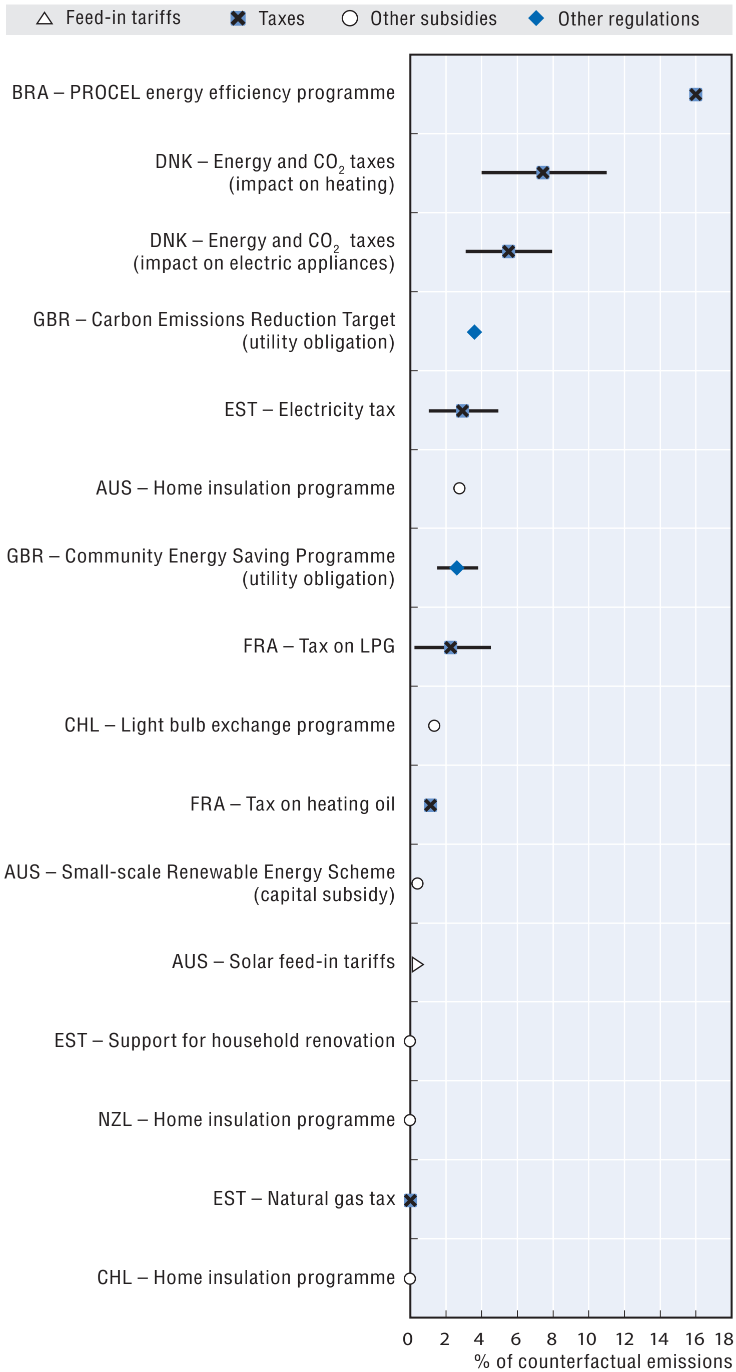


Figure 3.31. **Total costs of carbon-related policies applied in the household sector, by instrument type**

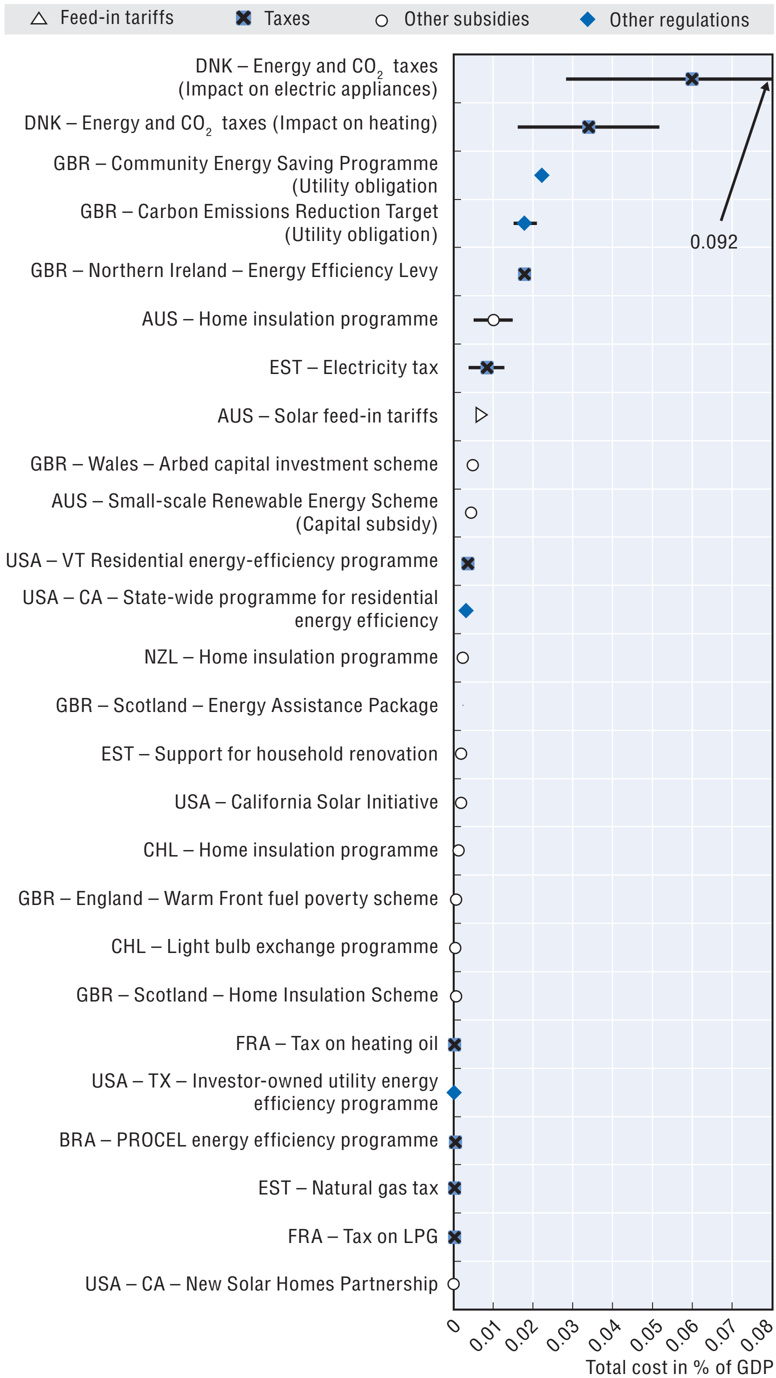
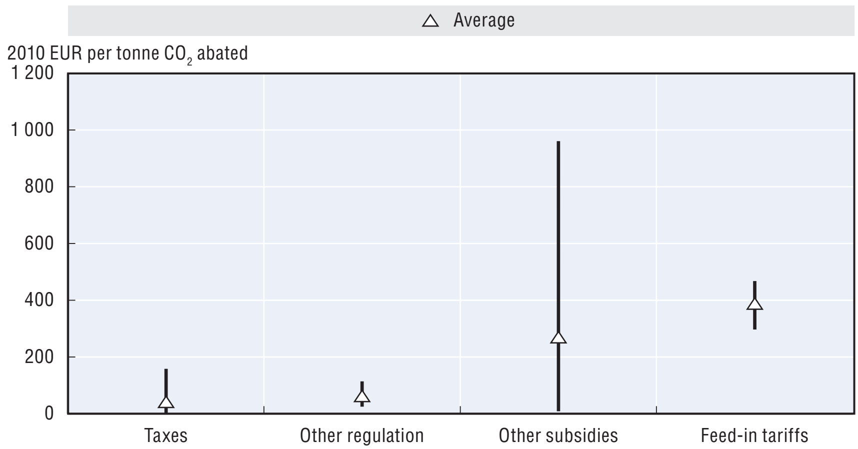
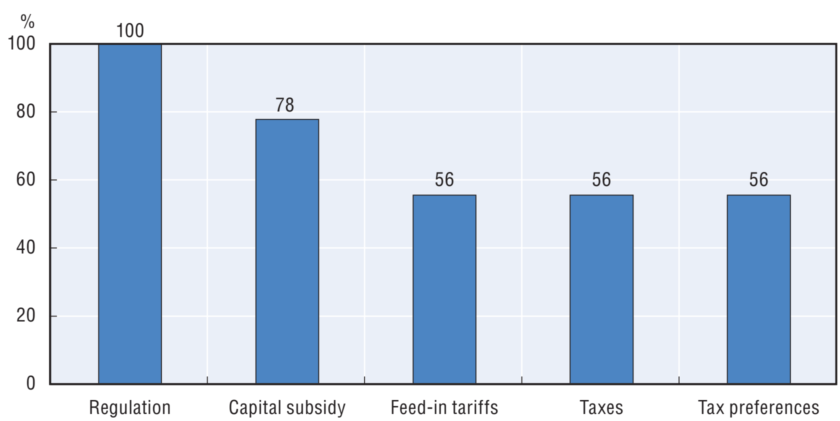


Figure 3.32. **Average effective carbon prices in the household sector, by instrument type**



Note: Please note that there are only two estimates behind the average calculated regarding feed-in tariffs.

Figure 3.33. **Share of countries in which a given instrument type is used in the household sector**



6. General discussion of the estimated effective carbon prices

While the preceding sections presented estimated carbon prices sector by sector, this section discusses more generally the estimates that have been prepared.

Clear differences have been found in effective carbon prices:

1. *within* a given sector, *across* the countries covered;
2. *across* the different sectors, *within* in each of the countries;
3. *across* the different instrument types, *across* all the countries covered.

In many respects, the last two findings are perhaps the most interesting, and the most robust ones. As emphasised in the discussion of the methodology used, there are a number of caveats that should be kept in mind when analysing the estimates elaborated in this study. However, while there can be some uncertainty regarding the "ranking" of carbon prices within a given sector across countries (which probably also can vary somewhat, depending on which year the analysis focusses on), it is very unlikely that any of the caveats could "explain away" the latter two main findings – and they seem not very sensitive to the exact year of study.

It was pointed out in the methodology discussion that a high (or a low) effective carbon price can be caused by a very ambitious (or not so ambitious) policy, or by the use of a cost-*in*effective (or an effective) instrument. Examples of both cases have emerged in this analysis. Some countries do seem to have been more ambitious in their climate policies than what other countries have had, applying "stricter" policies in some sense. And, clearly, most countries apply more ambitious policies in relation to (the often sheltered) electricity generation, road transport and household sectors than what they do in relation to the pulp and paper and cement sectors – which face more international competition.

Looking across instrument types, it seems very likely that the (often much) *lower* effective carbon prices found for taxes and emission trading systems than for other instrument categories in relation to electricity generation, road transport and the household sectors are caused by a (much) *higher cost-effectiveness* of these two instrument categories than for most of the other instrument types that countries apply. Some of the other instrument types in current use are simply not effective in reducing CO_2 emissions, so average costs when (only) measured per tonne of CO_2 abated tend to be very high.

In some cases, for example in relation to subsidies for house insulation (e.g. occupied by low-income households), abating CO_2 emissions never was a priority objective of the policy in question, so only "judging" their "performance" in terms of costs per tonne of CO_2 abated can seem "unfair". Since these policies do have an impact on CO_2 emissions, they have nevertheless been included in the analysis. For a number of the other instruments with very high effective carbon prices (e.g. measures put in place to promote biofuels and other renewable energy sources), carbon abatement has indeed been one of the main arguments applied in public debates in favour of their introduction.

The comparison across instrument types used in the two industrial sectors under study (pulp and paper and cement) gave a more mixed picture than what was found in the three other sectors covered, especially for cement, where emission trading systems showed the *highest* effective carbon prices. This is *not* likely to be due to any lack of cost-effectiveness of emission trading systems, but rather a reflection of the fact that most countries have hardly addressed greenhouse gas emissions from these (and most other industrial) sectors at all. Hence, the comparatively high carbon prices found in these cases are most probably due to a higher level of "ambition" in the policies applied vis-à-vis these sectors within (in particular) the European Union than in the other countries covered.

In all the countries (also in the EU countries), the effective carbon prices in the industrial sectors are just a small fraction of what was found in the other sectors, see Figure 3.33. And Figure 3.34 shows that the costs of the policies addressing the industry sectors are very small compared to the costs of policies applied in other sectors, measured in relation to GDP.[16] The project has not focused on the motivations behind the policy approaches applied in the different countries, but it is easy to speculate that an important factor contributing to the modest carbon prices facing the industrial sectors is a fear of loss of international competitiveness.

From an economic efficiency point of view, it is unfortunate that different sectors face very different incentives to reduce their carbon emissions. It is also unfortunate that countries not to a larger extent apply the most cost-effective types of policy instruments to limit CO_2 emissions. To the extent that the purpose of applying a number of other instrument types that *do* have an impact on CO_2 emissions indeed is to abate such emissions, they have here been demonstrated to be cost-*in*effective.

The challenge facing the World community in relation to climate change is so enormous that it is unlikely that it can be adequately met unless countries apply as cost-effective instruments as possible, as broadly as possible. This report demonstrates that there is a large scope for improvement in this respect.

Figure 3.34. **Estimated effective carbon prices in the different sectors, by country**

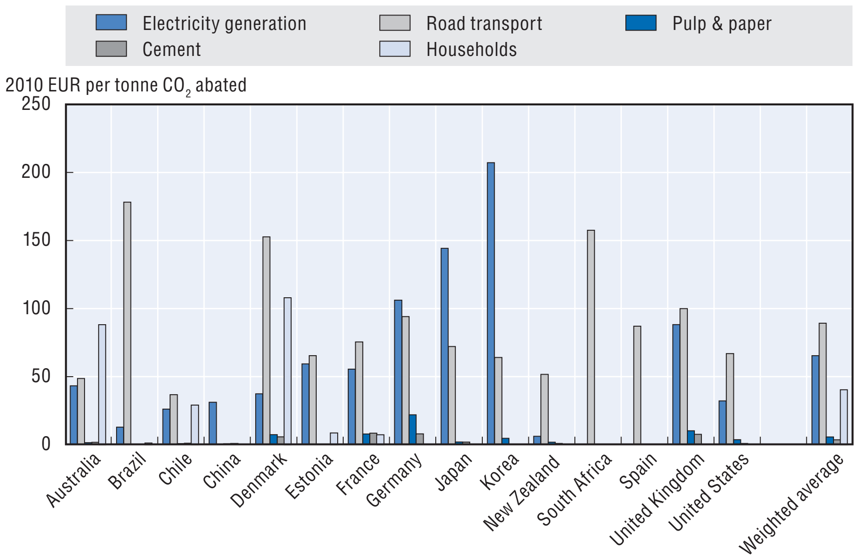
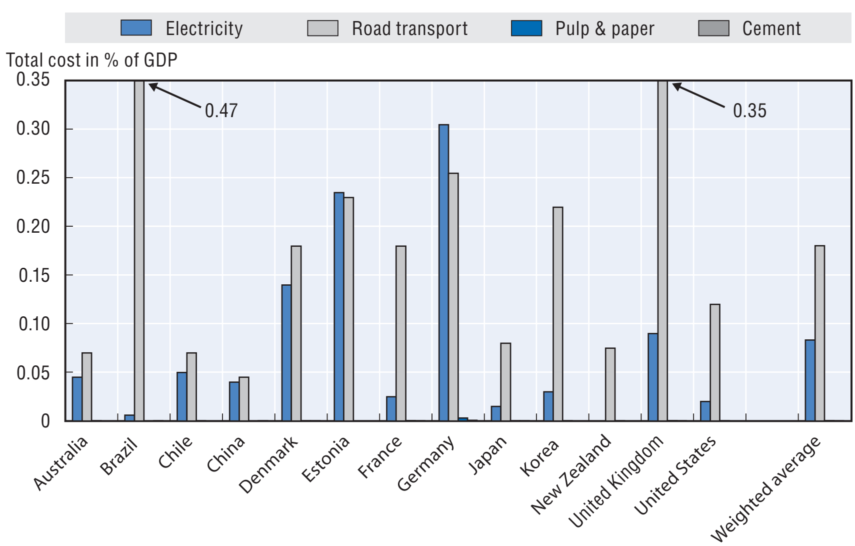


Figure 3.35. **Total costs of carbon-related policies applied in the different sectors, by country**



Notes

1. With respect to United States, in addition to Federal policies, policies applied in California, Vermont and Texas have also been examined.
2. In many cases, the figures are presented as ranges, reflecting different assumptions regarding price elasticities, the source of energy used to generate marginal units of electricity, discount rate, etc.
3. There is, of course a 500% difference between 0.01 and 0.05 – so the word "relatively" is indeed emphasised.
4. The policy is estimated to have contributed to about 70 million tonnes CO_2eq of abatement. As an illustration, this is about the same amount as the total GHG emissions in countries like New Zealand or Portugal (respectively), and significantly larger than the total GHG emissions in e.g. Norway.
5. Calculated as the emissions in the sector, plus the estimated abatement
6. One should be careful when interpreting the amount of abatement estimated for individual sectors in relation to trading systems in particular. In the case of cap-and-trade systems covering several sectors and / or countries, it is the overall cap for the whole scheme that (directly) defines the total amount of abatement that will take place (assuming that the cap is enforced). Variations in the amount of abatement across sectors (and countries) covered by the scheme are of limited environmental significance – and they ought ideally to reflect differences in abatement costs from sector to sector.
7. 0.19% of GDP as regards road transport, 0.08% of GDP as regards electricity generation.
8. Defined as the current emissions plus the estimated amount abated.
9. Many different policies can entail losses in consumer surpluses. For example, a ban on certain products or activities entails a cost to consumers who are "forced" to change their behaviour. However, such losses have only systematically been covered in this project in relation to various environmental taxes.
10. But there is certainly scope for increasing the tax rates applied in a number of the countries covered.
11. In the countries covered in the initial study by the Australian Productivity Commission, "low" and "high" in the table headings refer, for abatement, to different emissions intensities used, while for consumption costs, the terms refer to different elasticities used. Low abatement was then coupled with low consumption cost to calculate the lower-bound estimate for the effective carbon price, and the same for high abatement or consumption cost and effective carbon price. For Denmark, Estonia and France, "low" and "high" refer to price elasticities in all columns. For Chile, "high" and "low" refer to the different discount rates used.
12. Note that total abatement in Table 3.3 is given in thousands tonnes of CO_2 (not million tonnes, as in the preceding tables), and that total abatement costs are shown in thousands of euro.
13. In the countries covered in the initial study by the Australian Productivity Commission, "low" and "high" in the table headings refer, for abatement, to

different emissions intensities used, while for consumption costs, the terms refer to different elasticities used. Low abatement was then coupled with low consumption cost to calculate the lower-bound estimate for the effective carbon price, and the same for high abatement or consumption cost and effective carbon price. For Denmark, Estonia and France, "low" and "high" refer to price elasticities in all columns. For Chile, "high" and "low" refer to the different discount rates used.

14. The household sectors in China, Germany, Japan and Korea were not covered by the case studies.

15. It is, however emphasised that neither of these schemes where intended to limit carbon emissions. They were primarily introduced in order to provide improved comfort for the households covered.

16. The bars in figures 3.34 and 3.35 represent *weighted averages* of the effective carbon price found for different instruments applied in a given sector in the different countries. The amounts of abatement that each instrument is estimated to have contributed to are used as weights in the calculation of the averages. The bars on the far right end of each graph show *weighted averages* of these averages, calculated across the countries for which effective carbon prices have been calculated, using emissions in the various sectors in the given countries as weights.

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