International
Energy Agency

SUMMING UP THE PARTS

Combining Policy Instruments for Least-Cost Climate Mitigation Strategies

INFORMATION PAPER

Christina HOOD

2011 September

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This information paper was prepared for the IEA Standing Group on Long-Term Cooperation in May 2011. It was drafted by the IEA Climate Change Unit. This paper reflects the views of the International Energy Agency (IEA) Secretariat, but does not necessarily reflect those of individual IEA member countries. For further information, please contact Christina Hood, Climate Change Unit at: christina.hood@iea.org

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Executive Summary

Meeting the enormous challenge of decarbonising world energy systems will require a rapid expansion of investment in clean technologies on a global scale. Mobilising these resources will be a daunting task, and it is important to undertake the transition at the lowest cost possible. This paper seeks to provide some guidance on climate change policy-making within real-world constraints, focusing on the justification of policies to supplement a carbon price (arising from an emissions trading system or carbon tax), interactions between carbon pricing and supplementary policies, and management of these interactions to enable a least-cost policy response.

Defining "least-cost"

The economy-wide costs of decarbonisation are expected to result in only a small reduction in overall economic growth rates.[1] However, the absolute size of these costs can still be large, can fall primarily on specific sectors, and should be minimised. Lowering costs not only eases the implementation of a given emissions target, it can also make it more feasible for decision makers to take on more ambitious goals.

From a narrow perspective, a least-cost response entails deploying abatement options with the lowest implementation costs per avoided tonne of CO_2 over the duration of the transition. This leads to three broad criteria for a cost-effective policy package (Duval, 2008; OECD, 2009):

- The policies bring forward abatement actions broadly and evenly across different sectors of the economy (delivering static efficiency). This means equalising marginal abatement costs (i.e. exploiting opportunities in all sectors up to the same level of cost), including unlocking barriers to cost-effective energy-efficiency potential. If cheap opportunities are neglected in some sectors, more expensive actions will be needed elsewhere, increasing the total economy-wide cost of emission reductions.
- It encourages innovation and diffusion of clean technologies in order to lower future abatement costs (delivering dynamic efficiency).
- It copes effectively with uncertainties. It is not possible to predict accurately all abatement opportunities or how their costs will change, or foresee economic conditions. Policies that have built-in flexibility (particularly measures that put a price on emissions) are therefore more likely to find the lowest-cost mix of abatement options.

In addition to direct implementation costs, a macro-economic view is necessary to assess costs to the economy as a whole, e.g. through the rise of energy prices, and economic benefits from the recycling of revenues from carbon pricing policies. These macro-economic effects can be large, and could influence the choice and design of mitigation options pursued. The distribution of costs on different segments of society and the political acceptability of certain policies or technology options are also often of key concern to policy makers.

This paper proposes taking the widest view possible: it defines the most cost-effective policy as one that achieves the environmental objective at least cost to the economy as a whole over the decarbonisation transition, while securing public acceptance. The question is therefore how to implement policies to exploit as much abatement opportunity as possible up to a particular cost level, but taking into account a range of additional constraints: the need to minimise costs both

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[1] For example, US EPA modeling shows GDP reaching USD 34.9 trillion in 2050 under a scenario of 83% emissions reduction, compared to USD 35.4 trillion in the baseline scenario (2010 GDP is USD 13.2 trillion). This corresponds to 2.46% average annual GDP growth compared to 2.50% in the baseline scenario (EPA, 2010).

in the short and long term (static and dynamic efficiency), minimising transaction costs, addressing distributional issues, and taking into account impacts on wider welfare.

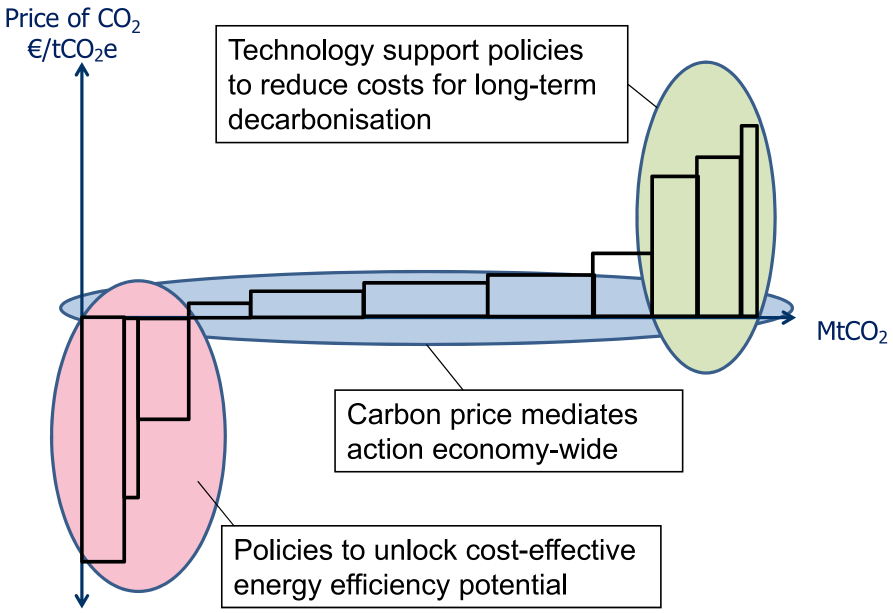
Policies for climate mitigation

In an ideal market setting, carbon pricing is the key element of a least-cost response. Pricing policies are inherently efficient, providing an incentive for abatement where it is most cost-effective, have wide reach throughout the value chain, and cope well with uncertainty by not locking in particular technology choices.

However carbon pricing needs to be flanked by supplementary policies to fully realise its least-cost potential in light of the known market barriers and imperfections. Together with carbon pricing, the two supplementary measures that should form the "core" policy set are: 1) cost-effective energy efficiency policies to unlock abatement potential otherwise untapped by the carbon price signal (Ryan et al., 2011); and 2) RD&D (research, development and demonstration) and technology deployment policies[2] to bring forward new mitigation options (OECD, 2009).

This core policy set could either be structured as a set of separate but aligned policy targets in the three areas, or as a policy package to most cost-effectively deliver a single overarching emissions target. The cost-effective potential for energy efficiency and technology policies will vary in different national contexts, so it is important to assess the costs and benefits of these policies, and their interactions with the carbon pricing mechanism, when designing the core policy package. The purpose of the various elements of this core policy set of carbon pricing, energy efficiency and technology policies is shown schematically in Figure 1.

Figure 1 The core policy mix: a carbon price, energy efficiency and technology policies



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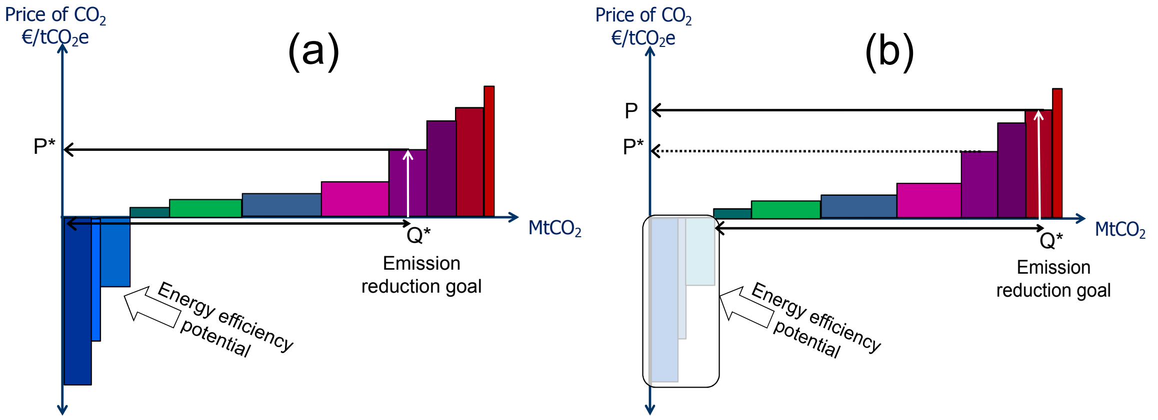
[2] Policies such as feed-in-tariffs or tradeable obligations that drive a significant scale-up of technology deployment to further lower costs.

If cost-effective energy efficiency opportunities are not exploited, a higher carbon price is needed to deliver the same level of emissions reductions, increasing the cost of the policy response (In Figure 2, the carbon price required is increased from P* to P if energy efficiency is left untapped). Technology deployment policies increase costs in the short term, but their purpose is to deliver significant reductions in the cost of new technologies over the coming decades, with the goal of significantly lowering the long-term cost of achieving deep emissions reductions.

Figure 2 Ignoring energy efficiency potential can lead to higher carbon prices



Justifications can be made for further supplementary policies beyond this core set. Such policies could be designed to address areas not covered by pricing policies, prevent lock-in of high emissions infrastructure, overcome barriers to financing, minimise costs to consumers, compensate for policy uncertainty, integrate the climate policy package with a wider set of policy priorities, and improve political acceptability. However, before implementing such further supplementary policies, their costs and benefits, and interactions with the core policy set need to be assessed. The transaction cost or negative interactions of certain policies may outweigh their benefit, even when the policies may be theoretically justified.

As one example, prices for international carbon offsets could be lower than optimal due to incomplete global coverage of carbon markets and a lack of demand. If this led to prices in an emissions trading system collapsing, it could undermine clean investment and upset the appropriate balance between domestic economic transformation and making lower-cost reductions elsewhere through crediting. Ideally, this could be addressed through limiting offset use or adjusting the trading system cap (Hood, 2010), but if this is not feasible countries could also consider the costs and benefits of supplementary policies to provide support for low-carbon investment beyond the carbon price.

In the absence of a domestic carbon price policy, a country may need to implement a greater number of policies to cover the same range of abatement opportunities, at higher administrative cost and with the inevitable sacrifice of some emissions reductions. Policy can nonetheless be guided by similar principles as in the presence of a carbon price: attempting to deploy as much cost-effective mitigation potential as possible, up to a target shadow carbon price.

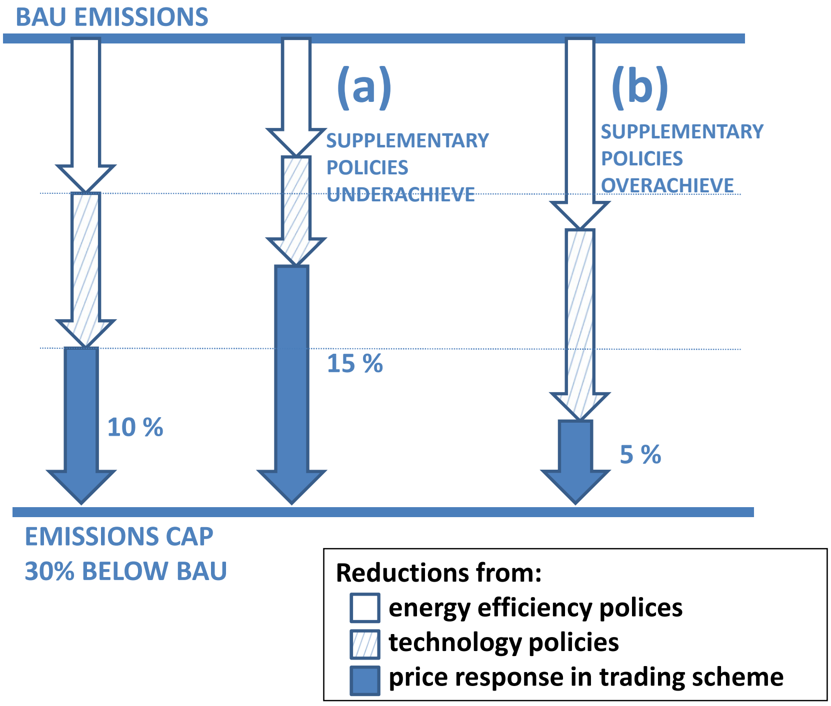
Policy interactions

Policies can be mutually reinforcing, can work against one another, or can be redundant depending on how they are designed and implemented.

There are particular issues of supplementary policy interactions with emissions trading systems. Because supplementary policies deliver some of the required abatement under the cap, they reduce the abatement needed in response to the price signal, reducing allowance prices. Particularly where current caps are known to be inadequate in terms of the long-term 2°C target, further undermining price signals for clean investment is likely to be detrimental. However, some supplementary policies are usually justified to improve the cost-effectiveness of the policy response (in the short term for energy efficiency, and in the long term for technology policies), so the issue is how to manage interactions through good design, rather than rejecting the use of supplementary policies.

Uncertainty in the delivery of emissions reductions from supplementary policies also creates uncertain demand for allowances in the capped system, and hence more uncertain carbon prices (Figure 3). In this example, a 30% emissions reduction target is delivered in part by supplementary energy efficiency and technology policies,[3] with the price response delivering the balance. If supplementary policies over- or under-deliver on their expected level of emissions reductions, the abatement required from the price mechanism can be significantly higher or lower, leading to added uncertainty in carbon prices that could be a deterrent to investors.

Figure 3 Supplementary policies can significantly impact carbon prices



In a similar effect, if supplementary policies deliver a significant proportion of the abatement required under the cap, modest fluctuations in the economic conditions affecting capped sources can lead to significant changes in the abatement required from the price mechanism, and hence fluctuations in carbon prices (see Figure 4.2 in Chapter 4). Such fluctuations have been shown to delay investment decisions, requiring a higher price on emissions to trigger investment.

With a carbon tax, because additional emissions reductions arising from supplementary policies do not change the level of the tax, the abatement incentive seen by covered entities is

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[3] For example, a renewable-energy or carbon capture and storage mandate, or policies to underwrite nuclear construction.

unchanged when supplementary policies are introduced. The inclusion of energy-efficiency policies can allow a lower tax level to be set than would otherwise be the case to achieve a given level of abatement, or alternatively there will be greater abatement for a given tax level. Renewable-energy or other technology support policies still result in higher abatement costs in the short term; however, the primary justification for technology support is long-term cost reductions, so this additional short-term investment can be justified from an economic perspective. Cost-benefit analysis can guide the level of investment appropriate to each of these supplementary policies.

Policy interactions can still occur without a carbon price. In particular, permit prices for quantity-based instruments (such as a renewable or clean energy quota obligation) can be affected by overlapping policies (such as a subsidy or mandate) that deliver some of the quantity obligation. Interactions between jurisdictions (for example state and federal climate policies) can also be problematic.

There are competing influences in the interaction between climate policies and competitive electricity markets. Introducing low-running-cost renewable energy into the market reduces market electricity prices by displacing higher-running-cost fossil-fuelled generation that would otherwise determine the market price (this is known as the “merit order effect”). On the other hand, the pass-through of carbon prices raises electricity prices, as long as fossil-fuelled plants are setting the market price. These competing effects introduce further uncertainty for electricity sector investors, and lead to the conclusion that electricity market structure may need to be reassessed to better match the characteristics of low-carbon generation.

The policy process

The policy process for managing interacting policies consists of five key steps, outlined in Figure 4. Throughout the process, building a constituency for climate change action is critical, as political acceptability can be a key constraint to a cost-effective response.

The “core” policy set consists of a carbon price, supplemented by energy efficiency and technology support policies. These policies interact, so need to be aligned with one another. Grouping these policies as a core set does not necessarily mean that separate explicit policy targets are necessary for energy efficiency and technology deployment; some governments may choose to focus on a single overall emission reduction target. In this case, for investment certainty, it is still important to understand the cost-effective contribution that supplementary policies are likely to deliver toward the overall target.

Where an emissions trading scheme is the pricing policy, the trading scheme cap should be set to ensure a reasonable degree of scarcity remains after emissions reductions from the supplementary policies are taken into account.[4] Decisions are also needed on the desired balance between domestic abatement and the use of international offsets. Testing cap settings over a reasonable range of varying circumstances (delivery of supplementary policies, BAU emissions) is important. Supplementary policies also need to be set taking the carbon price into account. Whenever possible, they should allow for a phase-out as the carbon price increases, and be designed for certainty of delivery of CO_2 reductions, in order to reduce unnecessary uncertainty in the trading scheme.

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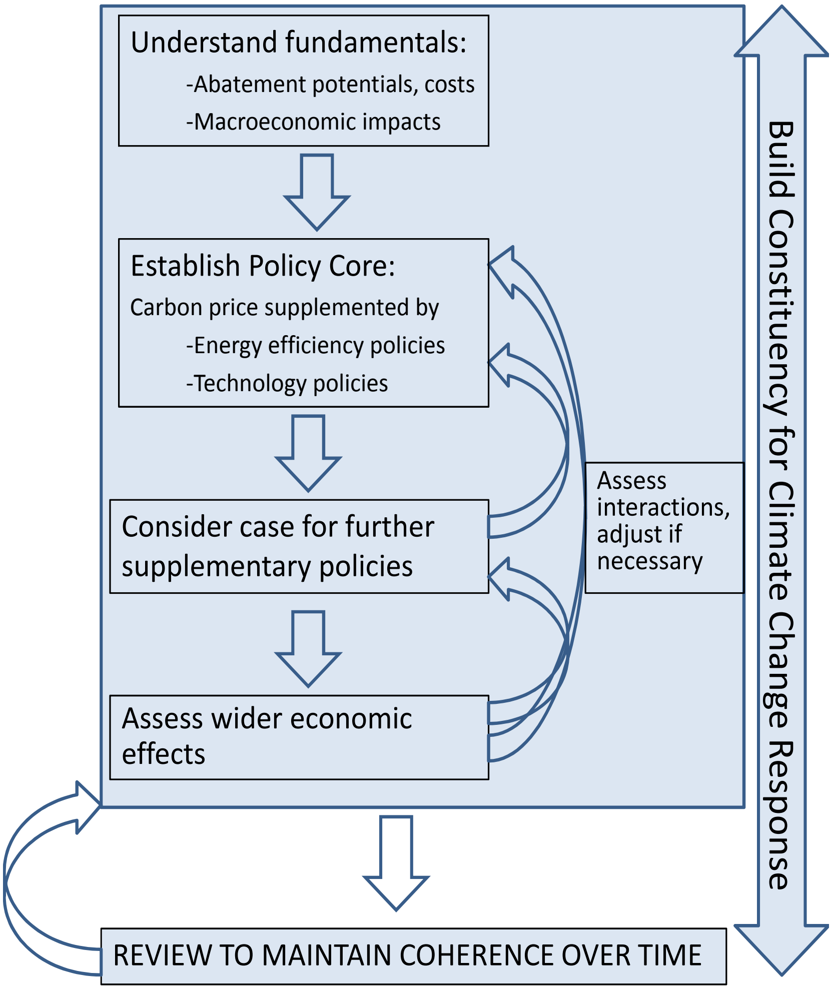
[4] There is “scarcity” in an emissions trading system if there are fewer permits available than the level of emissions, so the scheme is enforcing a reduction in emissions.

Figure 4 Establishing and maintaining a cost-effective policy package



Policy alignment is simpler with a carbon tax, as the price level does not change in the presence of supplementary policies. For cost-effectiveness, however, the tax level should still be set taking the emissions reductions from supplementary policies into account, and supplementary policies designed to phase out as the tax increases.

In the absence of a carbon price, policies can be designed to attempt to mimic the effect of a carbon price, by deploying abatement options as broadly as possible up to a given "shadow" price level of abatement. If broad-based, policies such as a clean energy standard[5] could provide a reasonably effective (though higher-cost) response.

Beyond this core set of policies, further measures to address infrastructure lock-in and the need for increased investment capital are likely to be needed. However, the case for further supplementary policies to bolster a weak carbon price signal – which could be caused by a number of factors, from lack of international coverage to political unacceptability – is more complex. In general, because of their potential to undermine long-term cost-effective action, policies that second-guess market prices for carbon should be avoided. However, there is a

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[5] A regulation requiring a certain proportion of electricity or energy to come from non-fossil sources. Such policies generally allow for trading of obligations, which improves efficiency and reduces costs.

conflicting necessity for significant short-term emissions reductions if the 2°C global target is to remain achievable. If short-term measures to supplement a weak carbon price are introduced, it should be made clear that any such policies are transitional, and their phase-out could be linked to progress in implementing a trading scheme. The number of supplementary policies should be minimised, as the difficulty in maintaining policy coherence increases with the number of policies.

Impacts on the wider economy, and wider policy priorities, also need to be considered: it is possible that some policies, though efficient, could have wider macro-economic or social implications that make them more costly or politically unacceptable, meaning adjustments to the policy package are needed. In this case, the "core" settings may need to be tightened to deliver the same level of emissions reductions.

Finally, given the strong interactions within the policy package, any initial calibration is likely to drift out of alignment over time, or become significantly misaligned by unforeseen shocks, such as the recent global financial crisis. In general, for investment certainty, resetting emissions caps and allocations should only occur at scheduled reviews, and be subject to criteria well-understood by all involved. Supplementary policies can be tracked and updated more frequently to help them remain effective and cost-effective. However, it is also possible that a misalignment between emissions trends, an emissions cap and supplementary policies could be so severe that the benefits of re-establishing policy balance outweigh the damage to investment certainty caused by intervening in the market. In this case, having pre-established criteria for when such interventions would be contemplated could help maintain investor confidence.

Conclusions

Carbon pricing is a cornerstone policy in climate change mitigation, but it is not a complete solution on its own. The short- and long-term efficiency of carbon pricing can be enhanced where barriers to energy efficiency deployment can be overcome cost-effectively, and by accelerating the development of new technologies that can allow lower carbon costs in the future. In addition, in real-world implementations of carbon pricing there will always be incomplete coverage or design compromises that may warrant further supplementary policies.

However, if poorly implemented, policies in such a package can undermine one another. Policy interactions must be understood and accounted for in initial policy design, and the package must be regularly reviewed and updated to maintain calibration over time.

As global emissions continue to rise, the window for taking action that will allow temperatures to stay within the 2°C target set in Cancún in December 2010 is narrowing. The time for action is now, but concerns about costs are often seen as a barrier. Combining policies to give least-cost, realistic policy responses can assist governments both in lowering the costs of action, and in stepping up the rate of emission reductions.

Box 1 Key conclusions

- Carbon pricing, supplemented by cost-effective energy efficiency and technology policies to improve its short- and long-term efficiency are the "core" policies in a least-cost climate mitigation package. Without these supplementary policies, a higher carbon price than necessary would result. Policies to address infrastructure lock-in and investment barriers may also be needed.
- Supplementary policies and carbon pricing (particularly emissions trading schemes) interact and have the potential to undermine one another, so policies need to be designed as a package, taking interactions into account. In emissions trading systems, supplementary policies that deliver too much of the required emissions reductions introduce uncertainty in the carbon price: the price has increased vulnerability to economic conditions, and to the delivery of the supplementary policies. Similarly, high use of international offsets introduces uncertainty in the level of domestic abatement that will be required.
- In addition to direct implementation costs of the policy package, macro-economic impacts (for example of energy price rises and the positive impacts of recycling carbon pricing revenue) and the distribution of costs should be considered.
- In the absence of a carbon pricing policy, overall cost-effectiveness will be reduced due to missed abatement opportunities, but the same principles apply: the most cost-effective package will include energy efficiency and technology policies, and seek to mobilise abatement as broadly as possible across sectors up to a target "shadow" carbon price level.
- Policy packages should be regularly reviewed to maintain coherence over time, particularly if policies interact strongly. To promote investment certainty, reviews should generally be limited to scheduled intervals and follow understood criteria. In the event of a major unforeseen shock, a judgement is needed on whether the benefits of restoring policy balance outweigh the damage to investment certainty caused by intervening. Having pre-established criteria for such interventions could assist in maintaining confidence.
- The case for further supplementary policies (for example to bolster a modest or uncertain carbon price) is more complex. There is a trade-off between the benefits of early action in reducing the cost of the decarbonisation transition, and the potential to undermine the carbon pricing policy which underpins least-cost action over the longer term.

1. Introduction

This paper attempts to provide some guidance on climate change policy-making within real-world constraints, focusing in particular on when policies to supplement a carbon price are justified, interactions between carbon pricing and supplementary policies, and how to manage these interactions.

A broad-based carbon price signal can go a long way towards delivering cost-effective mitigation policy, but even a perfectly implemented carbon price is insufficient. There are known market barriers which prevent appropriate response to price signals (particularly in energy efficiency), and long-term mitigation costs can be reduced by supporting technologies that can be critical in the future. Real-world implementation of carbon pricing will also have design compromises and uncertainties that may justify further supplementary policies.

These factors can justify the use of multiple policy instruments, but the experience to date has been that the interactions between policies have not been well understood, and therefore not well managed (OECD, 2007). Here we seek to explore how policies can be better combined to achieve low-cost emissions reductions.

With the agreement in Cancún in December 2010 to aim to limit temperature rise globally to less than 2°C, the issue at hand is how to deliver emissions reductions in the most cost-effective manner, rather than continuing to weigh the costs and benefits of action. There will still be some interplay between targets and policies, particularly given that current national emissions pledges are insufficient to deliver the 2°C goal: developing cost-effective policy packages will make it easier for governments to both implement climate policies and potentially to take on targets closer to meeting the 2°C trajectory.

This paper builds on a series of previous IEA works on complementing carbon pricing with energy efficiency policies (Ryan *et al.*, 2011), the interactions between renewable energy and climate policies (Philibert, 2011), and emissions trading scheme design (Hood, 2010). It will not address how to best select individual carbon pricing, energy efficiency or technology policies, as these issues have been covered extensively elsewhere. Rather, it seeks to give guidance on interactions between policies, and how to manage these in policy design.

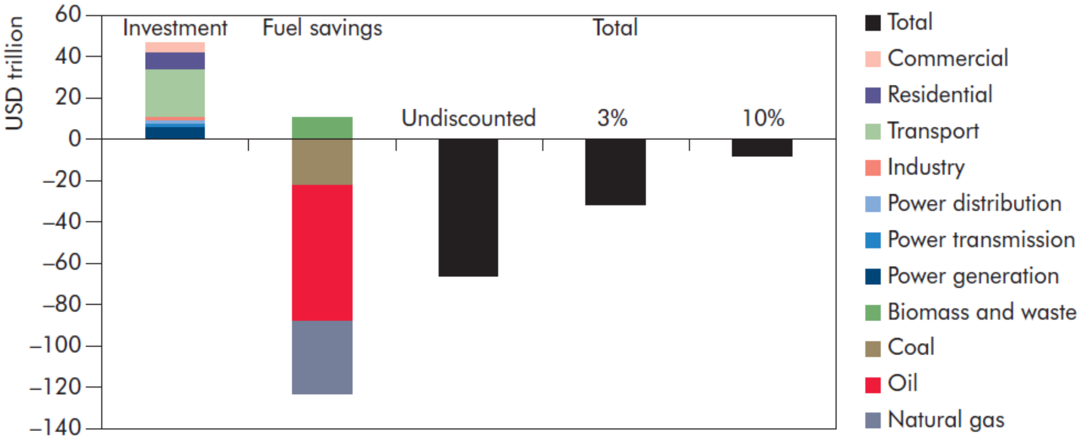
2. Defining least-cost in climate mitigation

The nature of the decarbonisation challenge means that a renewal of our energy systems is needed, requiring a substantial scaling-up of investment in clean technologies. Clearly, mobilising these resources will be a significant challenge, and it is important to undertake the transition at the lowest cost possible. But what does least-cost mean in the context of climate mitigation policy?

The first element is to distinguish clearly between costs and investment needs. The low-carbon transition will entail a shift to an energy system with higher up-front capital costs, but lower ongoing running costs. Examples include buildings with increased energy efficiency performance, renewable electricity generation, and electric vehicles. It will be important to ensure that financing mechanisms are in place to allow the deployment of least-cost options.

The move to higher-capital-cost infrastructure implies mobilising significant additional investment capital, but does not necessarily mean additional cost. In Energy Technology Perspectives 2010 (ETP 2010), the total investments are USD 46 trillion higher in the low-carbon BLUE Map scenario compared to the Baseline scenario; however, these are more than offset by (undiscounted) fuel savings of USD 112 trillion (Figure 2.1). Even when a 10% discount rate is used, the increased investment results in overall net savings compared to the Baseline scenario (IEA, 2010a).

Figure 2.1 Investment requirements and savings in a low-carbon scenario



Note: Additional investment and fuel savings in the BLUE Map scenario compared to Baseline, 2010-50.

Source: IEA, 2010a

There are also wider economic costs and benefits beyond these direct implementation costs and fuel savings. Even taking these into account at an economy-wide level, implementation of ambitious climate change mitigation policies are expected to result in only a small reduction in overall economic growth rates.[6] For example, modelling of a cap-and-trade proposal considered by the US Congress in 2010 showed that emissions could be reduced by 83% by 2050, while GDP growth still increases from USD 13.2 trillion in 2010 to USD 34.9 trillion in 2050 (compared to USD 35.4 trillion in 2050 in the reference scenario) (EPA, 2010).

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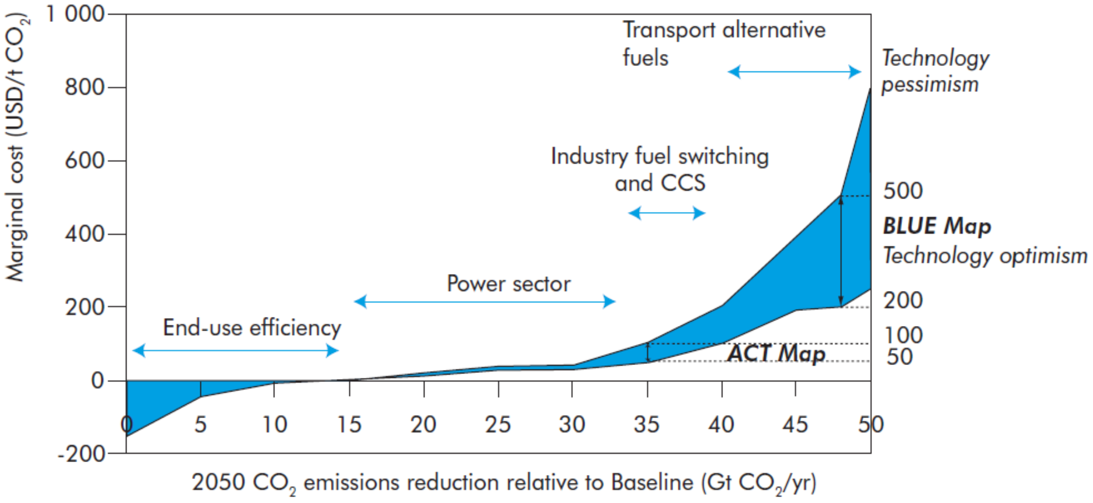
[6] Hood (2010) summarises some of these findings.

This low modelled impact does not necessarily mean that the transition will proceed smoothly, however. There could be important transition difficulties that are not captured by the economic models, particularly in helping the adjustment of local communities that are currently heavily dependent on fossil-fuel-intensive industries.

Minimising costs: the narrow view

Even though total costs are expected to be small relative to overall economic growth rates, they can still be large in absolute terms and it is obviously beneficial to reduce them where possible. Seeking a cost-effective policy mix starts with an understanding of the abatement opportunities that exist within economies, and their costs. This data is often represented by marginal abatement cost (MAC) curves, which quantify and rank the costs of various emissions reduction actions (Figure 2.2). These calculations are not definitive, as it is impossible to know precisely *a priori* all abatement options or their costs and how these will evolve over time: the carbon price will likely trigger abatement opportunities that are currently not foreseen. Abatement investments are also made by different economic actors with different budgets. Some will have higher cost options than others, so investment in some high-cost options may take place before lower-cost options even with perfect information. Nonetheless, abatement cost curves are a useful basis for starting to understand what mix of policies can be implemented to deliver the lowest-cost mix of abatement.

Figure 2.2 Marginal emissions reduction costs for the global energy system, 2050



Source: IEA, 2008a

There are several points to note from the MAC curve shown in Figure 2.2. There is an area of negative-cost emission reduction opportunities: these are actions that would save money if implemented, and are primarily energy-efficiency opportunities.[7] Next there is a large volume of moderate-cost actions, primarily in the power sector. This shows that a significant level of emissions abatement could be achieved with existing technologies, at carbon prices of less than USD 50/tCO_2. However, the deeper emissions reductions necessary for delivering a 2°C target will

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[7] This MAC curve is for 2050, so assumes many energy-efficiency options have already been implemented. The negative-cost potential in a MAC curve for 2010 or 2020 is much higher.

require new technologies that have much higher and much more uncertain costs,[8] such as carbon capture and storage (CCS) in industry, and alternative transport fuels. In ETP 2010, technologies up to USD 175/tCO_2 are needed to achieve the BLUE Map scenario. This leads to another element of a least-cost response: because some of the new technologies that will be needed to achieve significant decarbonisation are expensive, early actions to support these technologies and bring down their costs can mean significant savings in the long term.

Following Duval (2008) and OECD (2009), a set of climate policies is likely to bring forward the lowest-cost mitigation measures if it:

- Brings forward abatement actions broadly and evenly across different sectors of the economy (delivering static efficiency). This means equalising marginal net abatement costs (i.e. exploiting opportunities in all sectors up to the same level of cost), including unlocking barriers to cost-effective energy-efficiency potential. If cheap opportunities are neglected in some sectors, more expensive actions will be needed elsewhere, increasing the total economy-wide cost of emission reductions.
- Encourages innovation and diffusion of clean technologies in order to lower future abatement costs (delivering dynamic efficiency).
- Copes effectively with uncertainties. It is not possible to predict accurately all abatement opportunities or how their costs will change, or foresee economic conditions. Policies that have built-in flexibility (particularly measures that put a price on emissions) are therefore more likely to find the lowest-cost mix of abatement options.

Minimising costs: the wider view

Real-world circumstances and other priorities will place further constraints on policy design. Wider economic costs (beyond the direct costs of the mitigation measures themselves) and the distribution of these costs within society are also important.

Policy makers generally have a wider range of potential objectives that they wish to balance, beyond direct implementation costs. For example, Konidari and Mavrakis (2007) propose such a hierarchy, after reviewing a number of actual real-world policy-making processes (Figure 2.3). This type of policy assessment framework is often designed to score policy options according to a list of weighted criteria, a technique generally known as Multi Criteria Decision Making analysis. In this way, policy makers can get a qualitative sense of which policies, or policy packages, are likely to deliver best on their broad set of objectives.

In this process, the political acceptability of climate change policy will loom large – as witnessed by substantial public and political debate around emissions pricing policies in particular. The direct costs faced by residential consumers (particularly low-income consumers), and trade-exposed energy-intensive industries may be politically important.

Given the short time frame left to reduce global greenhouse gas emissions if a 2°C trajectory is to remain feasible,[9] governments may also prioritise policies that have greater certainty of delivery: it may be lower-cost to act quickly than to accept delays in order to act perfectly.[10]

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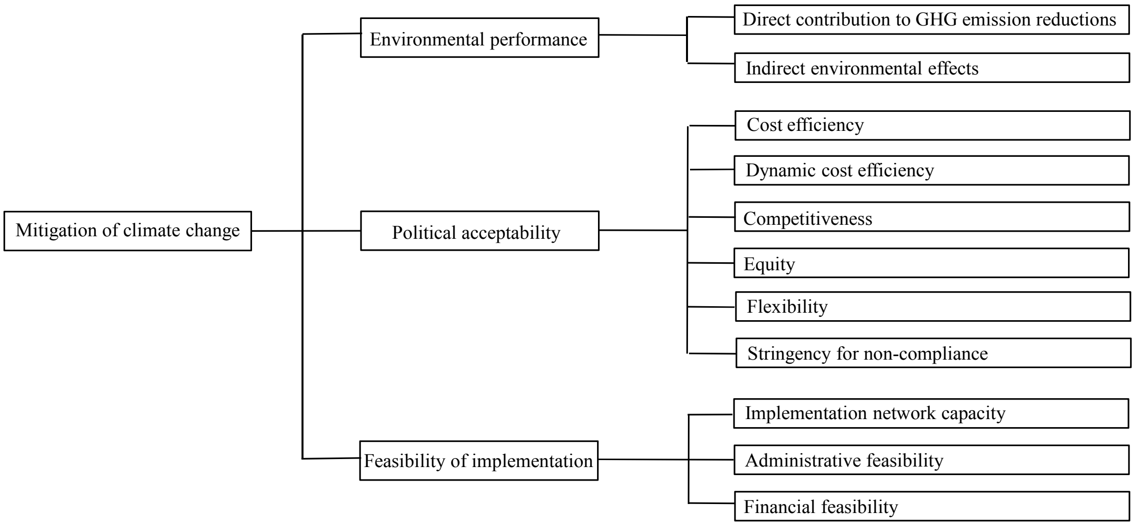
[8] In Figure 2.2, the cost uncertainty for the most expensive technologies is USD 200/tCO_2 to USD 500/tCO_2.

[9] In the 450 Scenario, global emissions peak before 2020.

[10] *WEO 2010* estimates the GDP impact of the 450 Scenario to be 1.9% by 2030, compared to 0.9% in the *WEO 2009*. Part of this difference relates to the *WEO 2010* assuming delayed action, in line with Copenhagen pledges, instead of a more optimal abatement trajectory that makes deeper cuts earlier (IEA, 2010b).

Figure 2.3 A hierarchy of criteria for developing climate policy packages



Source: Konidari and Mavrakis, 2007. Reprinted from Energy Policy 35/12, P. Konidari and D. Mavrakis, A multi-criteria evaluation method for climate change mitigation policy instruments, pg. 6241 (2007) with permission from Elsevier.

From this perspective, "least-cost" can be interpreted more broadly as "the least-cost policy that also meets a range of broad acceptability criteria". This becomes even more complicated when considering interactions between policies as well as their individual impacts – to be discussed further in Chapter 4.

Another very important aspect of the wider view is to consider costs to the economy as a whole, rather than simply the direct cost of implementing abatement measures. Where policies affect significant inputs to the wider economy (e.g. electricity, transport fuels), the knock-on effects of price increases on employment, GDP, and welfare can be significant. Conversely, if emissions pricing policies (emissions trading or carbon taxes) are introduced, these generate revenue during the transition to decarbonisation which can be used in economically beneficial ways, such as to lower labour taxes.[11]

These economy-wide effects can be very significant, so the detailed design of policy matters, in particular decisions pertaining to the allocation of any revenue raised. One key effect is the pass-through of carbon prices to consumers, which leads to an effective reduction in real household wages, affecting labour supply (the "tax interaction effect"). Recycling carbon price revenue to reduce labour taxes can substantially offset this negative impact on the wider economy, and even result in net positive welfare impacts. On the other hand, if revenue is returned via lump-sum payments, these wider positive economic impacts are not seen (Goulder *et al.*, 1998; Parry and Williams, 2011). The analysis finds that in this case, a price-based approach without revenue recycling through the tax system can be even more expensive than using regulation such as an emissions standard. This type of analysis could influence the mitigation options pursued: it could turn out that higher marginal cost abatement actions are lower-cost overall, if they have less impact on wider economic welfare.

However, these striking macro-economic results should also be taken with some caution, as these models have limitations: they don't model electricity prices well; they posit the absence of any negative cost mitigation potential, as market barriers are difficult to represent within such

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[11] With successful decarbonisation this revenue reduces with time, so is of transitional benefit.

frameworks; and assumptions around trade balances, required to make the model work, can significantly affect the results. Macro-economic analysis cannot be the sole guide to policy: there needs to be analysis and policy development at the micro-economic level as well, and qualitative assessments of policy like those of Figure 2.3 above.

This paper proposes taking the widest view possible: it defines the most cost-effective policy as one that achieves the environmental objective at least cost to the economy as a whole over the decarbonisation transition, while securing public acceptance. The question is therefore how to implement policies to generally exploit as many abatement opportunities as possible up to a particular cost level, while taking into account the need to minimise costs both in the short and over the long term (static and dynamic efficiency), minimising transaction costs, addressing distributional issues, and considering impacts on wider welfare.

3. Policies for climate mitigation

There is a wide, perhaps bewildering, selection of policies that can be implemented for climate change mitigation purposes (Table 3.1), including carbon pricing (carbon taxes, emissions trading), regulation (performance standards, technology standards), direct support (subsidies), research, development and deployment policies, and clear long-term target setting. These policies are reviewed in a number of sources: Duval (2008), OECD (2009), Goulder and Parry (2008), Twomey (2010), Stern (2006) and Aldy *et al*. (2009), so will not be described in detail here.

Table 3.1 A wide range of policies can be applied for climate change mitigation

Policy Type	Policy options
Price-based instruments	Taxes on CO_2 directly Taxes/charges on inputs or outputs of process (e.g. fuel and vehicle taxes) Subsidies for emissions-reducing activities Emissions trading systems (cap and trade or baseline and credit)
Command and control regulations	Technology standards (e.g. biofuel blend mandate, minimum energy performance standards) Performance standards (e.g. fleet average CO_2 vehicle efficiency) Prohibition or mandating of certain products or practices Reporting requirements Requirements for operating certification (e.g. HFC handling certification) Land use planning, zoning
Technology support policies	Public and private RD&D funding Public procurement Green certificates (renewable portfolio standard or clean energy standard) Feed-in tariffs Public investment in underpinning infrastructure for new technologies Policies to remove financial barriers to acquiring green technology (loans, revolving funds)
Information and voluntary approaches	Rating and labelling programmes Public information campaigns Education and training Product certification and labelling Award schemes

Source: Based on de Serres, Murtin and Nicolleti (2010).

Different policies have their strengths and weaknesses. Depending on the policy criteria seen as most important, different packages will emerge. For example, the evaluation of Goulder and Parry (2008) concludes that no single instrument is clearly superior along all main dimensions (cost effectiveness, distributional impacts, addressing uncertainty). They note that the use of multiple or hybrid instruments may be justified, and that assuring a reasonable degree of fairness or political feasibility will often require a sacrifice of cost effectiveness.

Given this array of possibilities, the question arises as to how to put together least-cost policy packages. The starting point is the cornerstone policy of climate mitigation: pricing greenhouse gas emissions.

Carbon pricing: the cornerstone of climate mitigation policy

Putting a price on greenhouse gas emissions is the cornerstone policy in climate change mitigation. It is widely accepted that without measures that put a price on emissions, it will be significantly more difficult and expensive to implement the economic transformation required to put the world on track to meet the Copenhagen goal of limiting temperature rise to two degrees (OECD, 2009).

Negative externalities associated with the generation and use of energy, for example excessive greenhouse gas emissions and their associated impacts, impose a cost on society and decrease social welfare. If the costs of these negative environmental consequences are not borne by those who produce and consume energy, more energy is used than is socially desirable, while the level of investment in energy efficiency will be less because there is less incentive. Fiscal or market instruments that increase the price of energy or of pollutants associated with energy use (such as CO_2) can act, at least partly, as a means to internalise the cost of negative externalities. In theory, therefore, carbon pricing through an emissions trading scheme or a tax set at the right level can compensate for this market failure.

A key strength of these mechanisms is that they have wide reach: by pricing pollution appropriately, producers and consumers throughout the economy see the right incentives, without second-guessing technical and business solutions to reducing greenhouse gases. Pricing mechanisms are inherently cost-effective, as they encourage abatement to be made first where it is cheapest. They engage all actors in all parts of the value chain, providing incentives for efficient investment decisions, operational decisions, and consumption choices, with none paying more for mitigation at the margin than anyone else – providing theoretical cost effectiveness across the board.

The ability of carbon pricing to cope effectively with climate and economic uncertainties is also very important, allowing innovative responses, compared to regulatory command-and-control approaches that run the risk of freezing technologies.

Mechanisms to price emissions come in two forms: emissions trading schemes (where the quantity of emissions is fixed, but the price is determined by the market and is therefore uncertain) and carbon taxes (where the price is fixed, but the quantity of emissions reductions is uncertain). In the absence of uncertainty on the cost and benefit of environmental control, taxes and trading schemes would be broadly equivalent: an appropriately-struck tax or trading system should deliver the same emissions reductions for a given price (for example, see OECD, 2009).

For a review of the main design elements of emissions trading schemes, see Hood (2010), and for a general review of climate mitigation policy instruments, see Duval (2008). Trading schemes are important, as they provide certainty in meeting targets, create a clearing mechanism, and offer the potential for internationally-linked action. Taxes impose a much more transparent and stable cost on sources. Hybrid trading schemes, with price caps and floors, contain elements of both emissions trading and carbon taxes (Philibert, 2009).

Using price mechanisms can lead to significant gains in cost effectiveness. Goulder and Parry (2008) cite a range of studies showing costs in the order of 50% lower with pricing policies rather than technology mandates. In some cases, this is due to lack of incentive for demand reduction in the absence of a price signal.[12] Design details matter significantly in the cost effectiveness of pricing policies: a poorly designed price-based measure can even be more expensive than

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[12] This analysis does not consider the wider macro-economic impacts associated with energy price rises and revenue recycling, which can be significant.

regulation (Parry and Williams, 2011). For example, Bovenberg, Goulder and Jacobsen (2007) explore the cost-effectiveness of policy instruments in the case where industry compensation is required, and find that where there is lump-sum compensation to industry, an emissions tax can be more costly than command-and-control regulation.[13]

There is a clear theoretical appeal to price instruments in an idealised setting. However, the calculated efficiency and effectiveness of pricing policies rely on the assumption of efficient and competitive markets, both in the short and long term. This includes the assumptions that energy production and consumption decisions are based on economically rational price responses, and that market prices find their way to decision makers throughout the energy value chain, from producers to final consumers. For example, for an efficient allocation of abatement efforts over the long term, a clear forward-price path would need to be visible in line with investment time frames (which can be very long).

But it is clear from numerous studies that this idealised neoclassical model does not apply in real-world applications of emissions pricing, where multiple market barriers and failures exist (Bennear and Stavins, 2007; Twomey, 2010; OECD, 2009; Duval, 2008; De Serres, Murtin and Nicoletti, 2010; Stern, 2006 ; Matthes, 2010; Boot and van Bree, 2010). In this “second-best” setting, a package of multiple policy instruments can be justified to deliver least-cost outcomes.

This does not mean that just any combination of policies is useful or desirable. In general, there should be no more than one policy instrument for each policy goal (Tinbergen, 1952). Where policies overlap, interactions can be complex and may be constructive or damaging, as discussed further in Chapter 4. The policy process for developing a robust combined package of policies is discussed in Chapter 5.

The two most important issues that justify policies to supplement emissions pricing are barriers to the uptake of cost-effective energy efficiency, and the need to bring forward and lower the cost of advanced technologies (renewables, CCS, industry, buildings) to minimise decarbonisation costs over the long term (Stern, 2006). This core policy set could either be structured as a set of separate but aligned policy targets in the three areas, or as a policy package to most cost-effectively deliver a single overarching emissions target. These two key supplementary policies are discussed in turn in more detail below. In addition to these two key issues, a number of other secondary market, policy or political barriers could justify policies to supplement an emissions price; these are reviewed subsequently.

Energy efficiency policies to complement carbon pricing

Improvement in energy efficiency is often claimed to be the most cost-effective way to reduce energy consumption and carbon emissions, increase economic growth and improve energy security. The IEA, among others, puts energy efficiency at the core of the policy response to rising energy-related carbon dioxide (CO_2) emissions. To overcome barriers to cost-effective implementation of energy-efficiency actions, the IEA has produced recommendations on 25 key actions (IEA, 2008b) that could collectively reduce CO_2 emissions by 20% in 2030. The BLUE Map scenario featured in Energy Technology Perspectives 2010 (IEA, 2010a), in which global energy-related CO_2 emissions would be cut by half by 2050, shows energy-efficiency improvements delivering the largest share of CO_2 emission reductions (38%) by that date.

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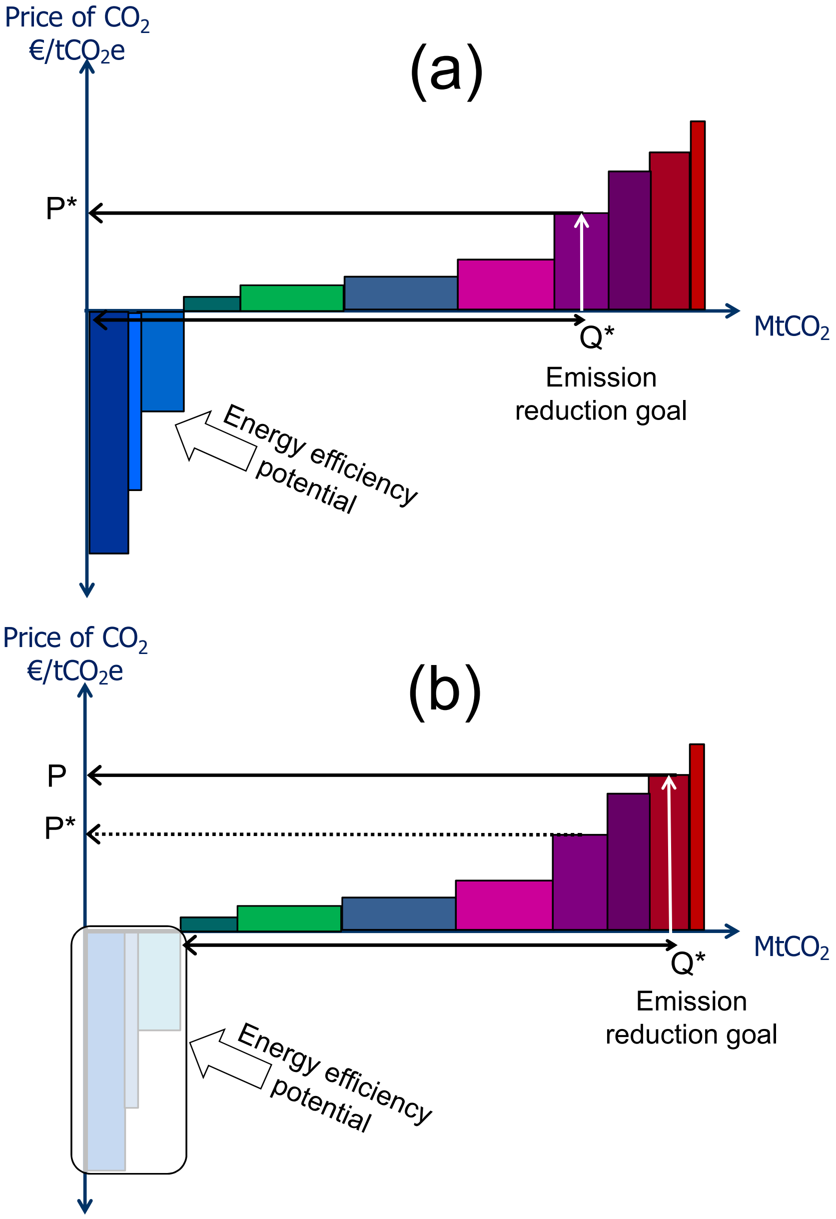
[13] In this macro-economic analysis, because the economic stimulus effect of labour tax cuts is foregone by giving lump-sum compensation, the negative impact of energy price rises dominates.

If the cost-effective energy-efficiency potential is not exploited (for example in Figure 3.1(b)), higher-cost actions are needed instead to deliver a given quantity of emissions reductions (Q*). If a carbon price is used to drive this deployment, the higher-than-necessary carbon price (P instead of P* in Figure 3.1(b)) will also have wider macro-economic impacts.

Figure 3.1 Schematic representation of cost savings arising from unlocking energy-efficiency potential



The question for commentators, then, is why energy-efficient technologies and practices that are apparently cost-effective are not more widely used. The answer to this question lies in the types of barriers that exist to the delivery of energy efficiency, some of which cannot be addressed by a carbon price at any level. The remainder of this section is a summary of a more in-depth discussion of another IEA paper dedicated entirely to this issue (Ryan *et al.* 2011).

According to Jaffe and Stavins (1994), the barriers to energy efficiency can be separated into non-market-failure barriers – private information costs, high discount rates, heterogeneity among potential adopters, hidden costs, access to capital – and market-failure barriers such as imperfect information, principal-agent relationships, split incentives and adverse selection. Behavioural science shows us other barriers, such as the form of information available, the credibility of information sources, inertia, and culture or values. Organisational theory provides another barrier: the power or status issue within an organisation associated with energy efficiency and its management. Transaction cost economics and behavioural economics also deliver arguments fort the barriers to energy efficiency, bringing more realistic models of economic organisation and decision-making to the restrictive assumptions and idealised markets of orthodox economics (Golove and Eto, 1996; Sorrell *et al.*, 2004). The existence of market failures is a minimum requirement for public policy intervention and therefore we focus, as a starting point, on the situations where market failures act as barriers improvements in energy efficiency.

In the context of energy efficiency, the presence of a market failure would imply that more energy is being consumed for the associated level of service than a rational allocation of resources would justify, in light of consumer and producer preferences. Given the list of ideal conditions necessary for markets to operate,[14] market failures are pervasive; hence public intervention is not justified solely by its existence, but also by the benefits of intervention exceeding the costs. In the absence of market failure, limited investment in energy efficiency may be logical, given the risk-adjusted rate of return on an investment under current economic conditions and hidden costs (Sorrell *et al.*, 2004).[15] There is ample evidence of market failures with respect to energy efficiency in the literature (Geller and Attali, 2005; Sorrell *et al.*, 2004; Golove and Eto, 1996). The remainder of this section will look more closely at these market failures and demonstrate the need for targeted policies to address them even in the presence of carbon pricing.

Imperfect information: Insufficient, inaccurate or costly information on the energy performance of different technologies, and the costs and benefits of energy-efficiency measures, leads to sub-optimal decisions by consumers and investors, and generally results in under-investment in energy efficiency. Accurate and sufficient information is difficult to obtain easily (at little cost) since energy efficiency comprises a wide range of products and services that are not always separately available. A survey on appliance use in Japan found that very few consumers knew the level of energy efficiency of their appliances (Yamamoto *et al.*, 2008). Therefore, even when energy prices are high, price signals do not influence purchasing behaviour as expected because the purchaser may not have sufficient information to interpret the impact of the energy price on the operational costs of one product relative to others.

Informational and energy market failures exist in the efficient use of equipment also. Yamamoto *et al.* (2008) show that when consumers are faced only with aggregated monthly electricity bills, they do not have sufficient information to optimise individual appliance use. However, it is possible that high energy prices may encourage energy users to overcome the transaction costs of obtaining information on the energy consumption of different pieces of equipment. Therefore, we postulate that while carbon pricing does not address informational failures related to energy

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[14] According to neoclassical economic theory, markets efficiently allocate resources when:

- There are sufficiently large numbers of firms so that each firm believes it has no effect on price;
- All firms have perfect information;
- There are no barriers to enter or exit the market place;
- Firms are rational profit maximisers and individuals are rational utility maximisers;
- Transactions are costless and instantaneous (IEA, 2007a).

[15] Sorrell *et al*. (2004) also argue that public policy intervention may be justified in some cases of organisational failure, where the barrier to energy efficiency is due to organisational structure, procedures and routines, and the incentives these provide.

efficiency directly, at higher prices it indirectly promotes the acquisition of information related to energy use.

Split incentives: Split incentives occur when the two parties to a transaction have different goals or incentives. Split incentives may be a result of asymmetrical information. They can also be understood as a classic principal-agent problem, where the benefits of an investment (e.g. to lower energy costs) are not appropriated by the party making the investment. The landlord-tenant example is often given since the tenant (the principal) most often pays the electricity bill but it is the landlord (agent) who selects and installs major appliances affecting energy use, such as refrigerators and washing machines, or heating systems.[16] Murtishaw and Sathaye (2006) attempted to quantify the magnitude of this problem for four end uses in the United States: space heating, refrigerators, water heating, and lighting. They found that the principal-agent problem is potentially relevant to 77% of water-heating energy use, 48% of space-heating energy use, and is negligible (2%) for lighting energy use. Other evidence shows that homeowners have lower heating bills than tenants since they can invest in energy efficiency measures such as insulation (Gillingham, Newell and Palmer, 2009).

Split incentives can also occur in the use of energy. An example is the case where tenants' electricity use is included in the rent. In this situation, though landlords may have an incentive to purchase energy-efficient appliances, the tenant has no incentive to control energy use.

Behavioural failure: Bounded rationality is where decision makers do not make choices rationally, as generally assumed in classical economic theory. Energy equipment purchasers and users may have "limitations of both knowledge and computational capacity" (Simon, 1997) that affect their consumption of electricity by appliances. The evidence that consumer decisions are not always perfectly rational is quite strong (Gillingham, Newell and Palmer, 2009). Behavioural failures may be relevant as an explanation for irrational behaviour and choices, and these may reinforce existing market failures.

The main policy measures targeted at energy-efficiency market failures are regulations, such as minimum energy performance standards (MEPS) or "white certificate" obligations, provision of information, i.e. energy performance labelling and consumer feedback tools such as smart meters, and financial instruments such as grants, subsidies and financing public-private partnerships. As an example, Table 3.2 summarises the market failures, and the policies most appropriate to address them, for the cases of appliances and buildings heating. A distinction can be drawn between purchase decisions and efficient-use decisions: these involve different barriers, and therefore may need different policy instruments. In the detailed design of such policies, it is clearly essential that the benefits of energy savings outweigh the costs of policy implementation.

Ryan *et al.* follow the methodology of Boonekamp (2005) to examine whether there is policy overlap between carbon pricing and energy efficiency policies in the appliance and building heating sectors. The authors find that there is little policy overlap in the appliance sector with standards or information provision, and in the buildings sector little overlap between pricing and other policies (building standards, labelling/information, fiscal policies and target measures for new construction). There appears to be the highest chance of overlap between energy-efficiency economic instruments and carbon pricing, since in some cases both sets of policies address the same market failure, namely the higher upfront cost of energy-efficient technology.

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[16] This problem may also arise in other settings, for example in companies where different parts of an organisation are responsible for operational and capital budgets.

Table 3.2 Energy-efficiency policies and market failures in energy use in electric appliances and building heat demand

Market failures	Appliances electricity use	Building heating energy use
Information failures	Energy labelling Consumer feedback tools Awareness-raising measures Minimum energy performance standards	Building energy performance standards Energy performance certificates Energy audits and other consumer feedback programmes
Principal-agent problems • **Asymmetric information** • **Split incentives**	Energy labelling Minimum energy performance standards	Building standards Energy performance certificates Targeted contractual measures for new construction
Behavioural failures • **Bounded rationality**	Minimum energy performance standards	Building standards Energy performance certificates Targeted contractual measures for new construction Economic instruments

Source: Ryan *et al.*, 2011.

As a result of these market failures, when behavioural failure, split incentives and informational failures prevail, high carbon prices alone are unlikely to directly influence investment in energy efficiency or energy-efficient behaviour. Targeted policies such as those discussed above are necessary to overcome these market failures and unlock this cost-effective energy-efficiency potential, and these policies generally have little direct overlap with carbon pricing policies.

Technology policies to complement carbon pricing

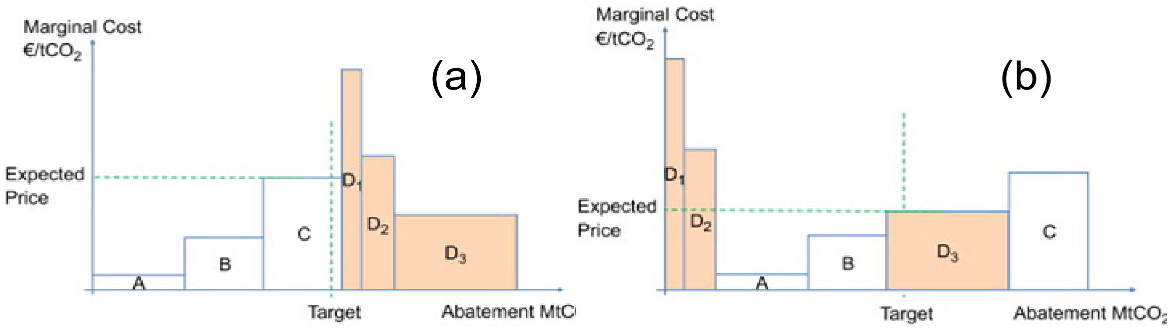
Combining policies for research, development and demonstration (RD&D) and deployment of new technologies with carbon pricing can significantly lower the cost of transition over the long term (Sandén and Azar, 2005; Lehmann, 2010; Duval, 2008). This is driven by two factors:

- The knowledge and learning benefits of RD&D and early deployment of technologies cannot be fully commercially captured by the entity undertaking the research or deployment: there are spill-over benefits to other developers. This acts as a disincentive to sufficient levels of investment in these areas.
- There is currently insufficient certainty around climate change mitigation goals and polices to guide appropriate levels of investment in technology development.

As a result, numerous analyses have found that long-term costs can be significantly reduced by combining technology policies with carbon pricing. For example, Fischer and Newell (2008) develop an empirical model based on the United States electricity sector and find that using one instrument alone to reduce emissions may entail considerably higher costs than a portfolio of instruments including emissions pricing, RD&D support, and deployment policies. In this case, the emissions reductions are attributable primarily to the price mechanism, but the RD&D and learning policies have a considerable impact in reducing cost by making cheaper abatement options available. In their model, however, the optimal subsidy to internalize the learning externality is small, so caution needs to be taken over what level of support is justified theoretically.

The benefits of technology learning are well illustrated by Blyth *et al.* (2009), who model total costs and marginal prices for scenarios with carbon market only, and with added early technology support (Figure 3.2). Schematically, Blyth *et al.* consider an abatement technology "D", whose costs can be lowered by deployment in three steps, D1, D2 and D3. If only the carbon price mechanism is used (Figure 3.2 (a)), the early deployments D1 and D2 are never undertaken, so low-cost abatement in D3 cannot be accessed and higher-cost technology "C" is needed. If early deployment D1 and D2 are supported by supplementary policies, then the lower-cost D3 actions become cost effective, delivering a lower marginal carbon price (labelled "Expected Price" in Figure 3.2) than would otherwise have been the case.

Figure 3.2 Early support for technology can lower long-term costs



Source: Blyth *et al.*, 2009. Reprinted from Energy Policy 37/12, W. Blyth, D. Bunn, J. Kettunen and T. Wilson, Policy interactions, risk and price formation in carbon markets, pg. 5194-95 (2009) with permission from Elsevier.

Whether the support policy is cost effective over the long term will depend on the level of support required, and the learning rate demonstrated,[17] compared to the costs of technologies that would otherwise have been deployed. Successful technology policies have the potential to significantly lower the carbon prices required in the coming decades, and hence both the direct costs and wider economic costs of climate mitigation.

Different key technologies (renewable energy options, CCS, electric vehicles) are at different stages of development, and have different learning rates. This implies that optimal support policies for bringing forward these technologies will need to be targeted, rather than remaining technology-neutral. Grubb and Ulph (2002) point out that not all carbon-reducing investments have the same potential for long-run innovation, and Acemoglu *et al.* (2011) argue that RD&D is already dominated by certain sectors, so additional targeted RD&D support to clean industries is required to overcome these locked-in innovation patterns.[18]

It is also inevitable that some technologies will not prove successful. This implies that a broad portfolio of technologies must be supported, and there will need to be criteria for phasing out support for those technologies that are not progressing, and for those that have reached cost effectiveness with a carbon price alone. Barriers associated with public acceptance of technology will also be an issue in some cases, for example nuclear technology in some countries.

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[17] The reduction in unit cost for every doubling of the cumulative production of a good.

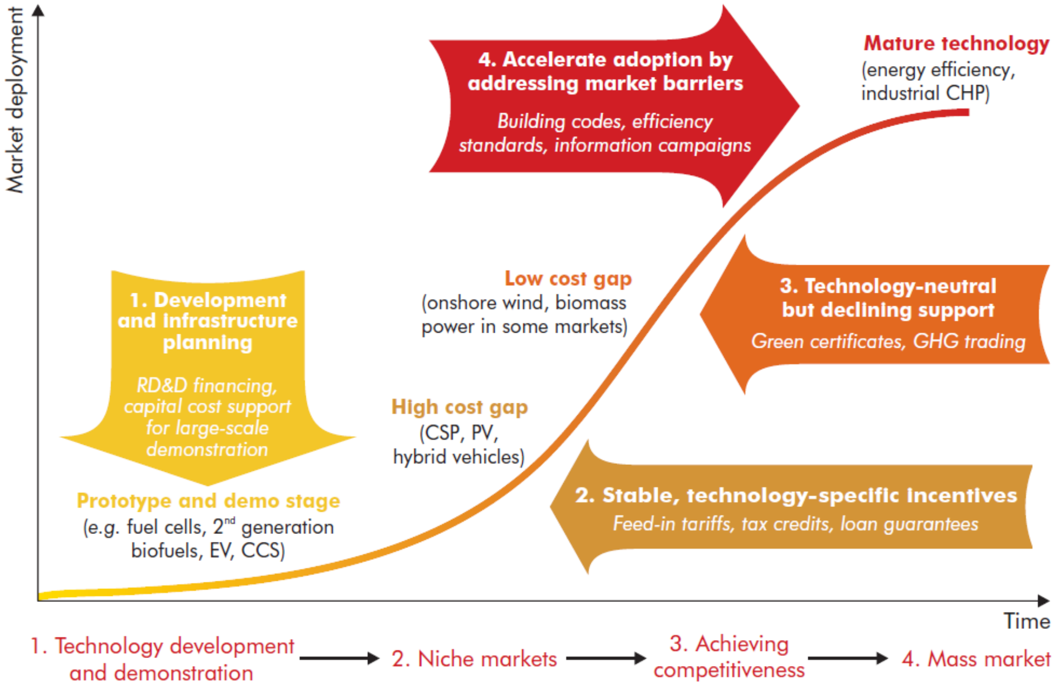
[18] In this model, if only an immediate carbon tax is used, it needs to be 20 times higher than in the case of the combined instruments.

Box 2.1 Example: Reducing long-term costs through technology support

In an electricity-industry-sponsored study of the European power sector, if a carbon price alone was used to drive decarbonisation, the price needed was EUR 128/tCO_2 in 2030 and EUR 304/tCO_2 in 2050, compared to EUR 52/tCO_2 and EUR 103/tCO_2 in the main scenario – which includes renewable energy support policies until 2020, strong energy-efficiency policies throughout the scenario, support for carbon capture and storage development, and support for electrification of the transport sector (Eurelectric, 2010).

The IEA's Energy Technology Perspectives (IEA, 2010a) incorporates RD&D and support for early technology deployment – to eventually bring costs down to the point where technologies are viable with only the carbon price signal. Specific technology roadmaps have been developed for a series of key technologies, mapping out the RD&D and deployment milestones to deliver these technologies to the marketplace and allow an overall least-cost transition, and outlining the policy approaches that are appropriate in each phase of technology deployment, including RD&D financing, tax credits, loan guarantees, feed-in tariffs, trading schemes, standards, and information measures (Figure 3.3).

Figure 3.3 Policy support appropriate to different stages in technology development



Source: IEA, 2010a.

Supplementary policies for renewable energy development

A particular area of technology policy is support for renewable energy technologies. Philibert (2011) finds that the strongest argument for renewables policies supplementing a carbon price is dynamic efficiency, as support today allows learning that will unlock long-term climate mitigation potential by lowering long-term costs. In the ETP 2010's least-cost BLUE Map scenario, renewable sources generate 48% of electricity in 2050, made cost effective by ambitious early support policies (IEA, 2010a).

While renewables deployment also contributes to other objectives (energy security, hedging fossil fuel prices, reducing local pollution, employment), these additional objectives can often be met by other, more cost-effective means including energy efficiency (Philibert, 2011).

A focus on dynamic efficiency as the principal justification for renewables support policies argues for a portfolio approach, as some technologies will not proceed, and for targeted support (such as feed-in tariffs, rather than technology-neutral policies) as different technologies will be at different stages of development.

Provided policies are well designed and costs kept under control, incentives for renewable energy R&D and for deployment can be justified, as well as policies to address other non-economic barriers. In Deploying Renewables: Principles for Effective Policies (IEA, 2008c), five key principles are proposed for effective renewables deployment policy:

- The removal of non-economic barriers, such as administrative hurdles, obstacles to grid access, poor electricity market design, lack of information and training, and the tackling of social acceptance issues – with a view to overcoming them – in order to improve market and policy functioning;
- The need for a predictable and transparent support framework to attract investments;
- The introduction of transitional incentives, decreasing over time, to foster and monitor technological innovation and move technologies quickly towards market competitiveness;
- The development and implementation of appropriate incentives guaranteeing a specific level of support to different technologies based on their degree of technology maturity, in order to exploit the significant potential of the large basket of renewable energy technologies over time; and
- The due consideration of the impact of large-scale penetration of renewable energy technologies on the overall energy system, especially in liberalised energy markets, with regard to overall cost efficiency and system reliability.

Together, these principles aim to bring the costs of reducing emissions down over the long term. If an appropriate level of policy support to renewable energy is not included in the mix, the long-term costs of abatement, and carbon prices, will be much higher. Carbon prices that are higher than necessary cause avoidable negative impacts on the wider economy, so early intervention is important (Acemoglu *et al.*, 2011).

Justifications for further policies to supplement a carbon price

Many abatement measures also have benefits other than reducing greenhouse gas emissions (for example, improved health, reduced road congestion), so the marginal cost of CO_2 abatement will be only part of the selection criteria. For example, home insulation programmes can have a greater impact on health outcomes than on energy savings (Howden-Chapman *et al.*, 2008). Because some subsidiary benefits can be achieved at lower cost by other means (for example, local air quality can be improved by fitting pollution-control technologies), care needs to be taken in what weighting to give these benefits in cost-benefit analyses (OECD, 2007).

On the other hand, climate policies can interact or conflict with existing public policies (subsidies, taxes, trade policies), so climate policy may need to be adjusted to deliver a least-cost outcome overall. For example, introducing a carbon tax on transport fuels will have different effectiveness depending on the levels of existing fuel taxes: equalising the carbon tax alone across jurisdictions will not necessarily lead to equalising marginal abatement costs if the existing taxes are not set at optimal levels. The adjustment of these external policies could be considered a supplementary policy.

Alignment with sectors not covered by the price mechanism

Least-cost abatement options should be exploited as widely as possible throughout the economy, so if some sectors are not covered by the price mechanism, complementary policies should be considered. A useful guide to aligning these with the price measure is to regulate or subsidise abatement up to the same effective carbon price level (the "shadow price").

If, however, industries covered by the price mechanism have competitors in jurisdictions that do not face a carbon price, potential issues of competitiveness and carbon leakage arise. Supplementary policies such as border tax adjustments or reduced obligations under the price mechanism could be considered to alleviate the effects of competitiveness distortions (OECD, 2010a).

Investment and access to financing

The increase in capital-intensive investment that will be required raises the question of whether financing and capital market structures are aligned with these needs. Neuhoff (2007) reports that different actors have different risk perceptions and tools for assessing risk in investment decisions: oil companies use scenario planning and care less about current prices/policies, technology developers need external targets to satisfy investors, utilities are mainly guided by current policy frameworks and current prices, and banks have measures to ensure undue risk isn't taken, so prefer historical data or simple transparent credible policies. Similarly, Rogge, Schmidt and Schneider (2011) and Neuhoff (2011) assess the importance of various policy interventions to entities in different parts of the energy system. Given the varying risk assessment practices and responses to policy of different actors in the value chain, these studies suggest that the availability of appropriate financing should not be taken for granted, and that different policy responses may be needed to target different actors in the investment process.

Policy uncertainty

IEA analysis (IEA, 2007b) shows that providing certainty over the trading scheme's environmental goals – and related CO_2 prices – for ten years increases low-carbon investment: with less than this it is in investors' interests to wait. In the case of investment in carbon capture and storage (CCS) technology, the analysis finds that a price 37% higher is needed if policy certainty spans only five years compared to the case of perfect certainty. In one specific example, Nelson *et al.* (2010) argue that current policy uncertainty in Australia favours investment in low-capital-cost plants, so more open-cycle than combined-cycle gas turbines would be built, leading to a sub-optimal mix of plants and raising electricity prices. However, Blyth *et al.* (2009) build on the IEA analysis to consider how system uncertainties will accumulate over time, and find that resetting system caps may be needed more frequently to maintain policy coherence; this procedure needs to be balanced against the certainty of a long allocation.

Matthes (2010) goes further, arguing that the European Emissions Trading System (EU ETS) may not be capable of producing credible long-term scarcity signals, due to the potential for ongoing political revisions and operational realities, such as private discount rates diverging from social rates. There is also the potential for radical uncertainties,[19] which Twomey (2010) argues justifies a portfolio policy approach, providing a backstop against uncertainty.

A wide range of supplementary policies have been suggested to mitigate risks of uncertainty, including government-backed long-term contracts for low-carbon electricity generating capacity, and regulatory backstops such as emissions performance standards (EPS) or CCS mandates.

Cost containment and distributional impacts

In the case of very expensive abatement options, there may be a trade-off to consider between the efficiency of price-based measures and potential negative impacts of high energy price rises on the wider economy. "Cost containment" policies aim to reduce the carbon price by using alternative policies to achieve some of the required abatement.

For example, in electricity markets where marginal costs set the wholesale price of electricity, if small volumes of very expensive low-carbon technologies set the price of all electricity generated, the flow-on effect of price rises could be significant. Matthes (2010) argues that this will be an issue of growing importance as increasingly expensive abatement options are implemented.

Impacts on consumers – particularly low-income groups – are a key issue for political acceptability. Pricing policies are often supplemented by targeted revenue recycling to offset distributional effects. For example, Blonz, Burtraw and Walls (2011) find that policies to recycle revenue to low-income households in proposed United States emission trading schemes would have fully compensated those consumer groups. Rausch *et al.* (2010) show that two carbon pricing proposals considered by the United States Congress in 2010 would both have been progressive: the Waxman-Markey proposal (with rebates targeted to low-income groups) and the Cantwell-Collins proposal (with rebates returned on a per-household basis).[20] Parry and Williams (2010) find a stark trade-off between distributional impacts and policy efficiency. They model a carbon restriction with a direct cost of USD 9 billion per year in 2020, but find overall welfare impacts ranging from USD -6 billion per year to USD 53 billion per year, depending on how revenue is distributed.

Infrastructure and overcoming path dependency, economic transition issues

Unruh (2000) explores path dependency, which sets up infrastructure and institutional frameworks that favour existing technologies. Policies to overcome this type of technological lock-in could include infrastructure funding, knowledge development, supply-chain redesign, and public education about new energy forms. Nelson (1994) studies co-evolution of technology, industrial structure and institutions and suggests that the dominant order will bring forward a supporting network that could be a powerful blocking influence against new technology.

Particular examples where intervention may be required are in electricity transmission (greater interconnection to facilitate renewable generation, and smart grids to manage intermittency and demand), electric-vehicle infrastructure, and pipeline and regulatory infrastructure for CCS. Current electricity market structures are well suited to a fossil-fuel-dominated mix, but many are

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[19] We cannot foresee the range of possible events either in a changing climate or such a radical economic transition, so uncertainties go beyond the usually-considered smooth variations in fuel prices, economic cycles and carbon prices.

[20] Because low-income households generally use less energy, returning revenues on a per-household basis is generally positive for these groups.

now arguing that they need major reform to be suited to systems with high levels of capital-intensive plants (these arguments are reviewed in Hood, 2011). Policies could also be designed to address the entry of new firms and industries, and exit of old firms in declining industries, with redeployment of labour: governments could evaluate the costs and benefits of more proactive policies to facilitate the development of clean industry, to lower financing risks and reduce the risk of labour market stagnation (De Serres, Murtin and Nicoletti, 2010).

As one example of transition policy, Wooders (2010) proposes a range of potential policies for the steel sector that would be complementary to carbon pricing, including payments for early closure of inefficient plants, improving energy efficiency, investment credits for installing best available technology (BAT), payments to encourage use of recycled scrap, funding CCS demonstrations, and funding R&D.

Political acceptability

Political acceptability issues may mean pricing policies are implemented weakly, so they won’t deliver the full range of appropriate mitigation actions. There is a short time frame remaining to reverse the growth in global emissions if the goal of limiting temperature rise to 2°C is to remain feasible, which may justify supplementing carbon prices in their early stages. If there is a risk of high-emissions investment being locked in for the long term, the costs and benefits of supplementary policies, such as subsidies or regulatory backstops to constrain investment choices (such as EPS or CCS mandates), could be considered.

As one example, prices for international carbon offsets could be lower than optimal due to incomplete global coverage of carbon markets and a lack of demand. If this led to prices in an emissions trading system collapsing, it could undermine clean investment and upset the appropriate balance between domestic economic transformation and making lower-cost reductions elsewhere through crediting. Ideally, this could be addressed through limiting offset use or adjusting the trading system cap (Hood, 2010), but if this is not feasible countries could also consider the costs and benefits of supplementary policies to provide support for low-carbon investment beyond the carbon price.

Political unacceptability may also rule out some cost-effective actions. For example, economic models assume that many existing coal-fired generating plants will be retired early due to carbon constraints. If this is not considered politically feasible, supplementary policies to more tightly constrain new investment may be needed to stay within the same emissions budget (Guivarch and Hood, 2011). Similarly, technology development and deployment may be constrained due to the public unacceptability of particular technologies in some countries.

De Serres and Llewellyn (2011) argue that political economy considerations are the main barrier to implementing a least-cost transition path, particularly given the resistance to carbon pricing, so creating a constituency for change is therefore critical to introducing policy. This argues for public engagement policies as part of any least-cost approach. Bartle (2009) goes further, arguing that a range of policies may be needed to appeal to different rationales. The idea is that an economic instrument appeals to just one type of human rationality, so a policy mix may be needed for broad political acceptability.

Mitigation policies without carbon pricing

If the “real-world” implementation of carbon pricing is not ideal, trying to put together a cost-effective mitigation response without a price measure at its core will be even more difficult. But in the absence of a carbon price, the same basic principles still apply: the goal is still to mobilise as much of the low-cost abatement as possible across all sectors, to maximise cost-effectiveness.

The absence of a carbon price is likely to result in reduced innovation (OECD, 2010b), as the future developments in technologies that a price mechanism would bring forward cannot necessarily be foreseen, and ill-designed regulation can tend to freeze innovation by basing mandates on current technologies. In this regard, careful design can help: regulations based on outcomes are preferable to technology mandates.

It will also be the case that some cost-effective mitigation opportunities will be missed, reducing the overall cost effectiveness of policy. To cover the same ground, a greater number of policy instruments will be needed, implying greater administration costs,[21] and potentially even more complex interaction and coordination issues.

A useful practise in formulating a least-cost response is to mirror as far as possible what would have been achieved by carbon pricing. If there is reasonable knowledge of the MAC curve, regulatory and subsidy policies can be designed to deploy as many of the known abatement opportunities as are feasible, up to a given target price level. Given the inefficiencies in this policy approach, for a given level of emissions reduction this "shadow price" may need to be set higher than the corresponding carbon price would have been.

Mirroring the effects of a carbon price may change the nature of policy design significantly. For example, renewable energy support policy would now not *only* be for technology deployment: it would also be for emissions reductions, so a technology-neutral aspect to the policy (mirroring what a price signal would have delivered) may be appropriate, combined with technology-specific elements to deliver technology learning. Some energy-efficiency policies will likely be less effective in the absence of a carbon price, due to the greater rebound in energy consumption.

Spreading policy coverage as broadly as possible is important. For example, studies comparing renewable-energy certificate schemes to a carbon price find they are less effective as an emissions reduction tool because they don't address the emissions of fossil fuel plants. To better mimic a price signal, a renewable-energy support policy would need to be supplemented by policies addressing emissions from thermal generation.

One study of the United States electricity system found a broad "clean energy standard" (CES)[22] for the power sector to be reasonably effective and cost-effective (RFF, 2010). This is because it can be designed to be a close substitute for a carbon price: it misses some abatement opportunities as it doesn't address demand reductions or operational efficiencies in the same way as a price measure, but it does provide a trading mechanism that gives an incentive for switching thermal generation from coal to gas. For the same level of emissions reductions, the CES policy required implementation of measures up to an effective carbon price of USD 14, compared to USD 8 for a pure carbon price policy, and notably didn't increase electricity prices above reference levels (compared to pricing instruments which result in 2-3c/kWh increases). If this type of broad-based scheme were used, it would still need to be complemented by policies to overcome barriers to cost-effective energy efficiency improvements, and by targeted technology policies to lower costs in the long term.

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[21] Emissions trading markets for sulphur dioxide (SO_2) in the United States cost less to manage than all pre-existing command and control regulations that EPA was operating (Ellerman *et al*., 1997)

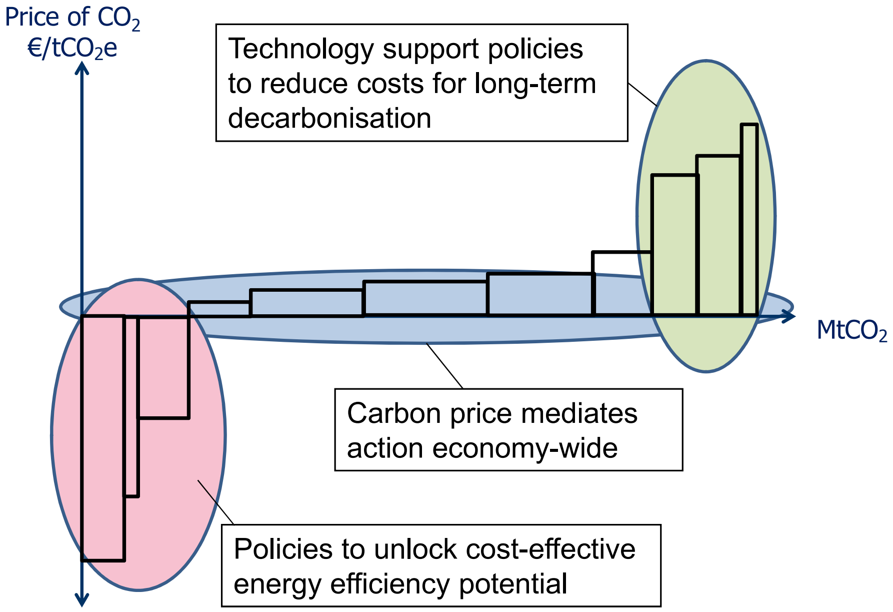
[22] A requirement for a certain percentage of electricity generation to come from clean sources: renewable energy, nuclear or using carbon capture and storage, with partial credit for gas-fired generation. Power companies would be able to trade obligations to allow for cost-effective delivery of the target.

Chapter summary: policy mixes with and without carbon pricing

Carbon pricing is the key element of least-cost response, but it needs to be flanked by other measures to fully realise its least-cost potential in light of the known market barriers and imperfections, and must be implemented with good design. The two supplementary measures that, together with carbon pricing, form the "core" policy set are: 1) energy-efficiency policies to unlock cost-effective abatement potential, and 2) RD&D and technology deployment policies to bring forward new technological options (OECD, 2009). Supplementing carbon pricing in this way avoids the wider economic impacts of unnecessarily high carbon prices that would otherwise be needed – lowering the cost of transition, and enabling governments to implement policy more easily and potentially take on more ambitious reduction targets. The details of a cost-effective policy package will vary among countries and regions: costs and benefits of each supplementary policy and their interactions with the pricing mechanism need to be assessed to design an appropriate mix. Some governments may set specific policy targets for energy efficiency and technology deployment, others may focus on an overall emissions goal. In both cases, understanding the cost-effective contribution of policy elements, and their interactions, is critical.

This core policy set is illustrated below (Figure 3.4): a carbon price mediates cost-effective actions throughout the economy and across all measures, flanked by targeted measures to unlock energy-efficiency potential where it is cost effective to do so, and reduce the cost of new technologies.

Figure 3.4 The core policy mix: a carbon price, energy efficiency and technology policies



Justifications can be made for further supplementary policies beyond this core set, to address incomplete coverage, infrastructure lock-in, financing, cost containment, policy uncertainty, wider policy integration, and political acceptability. However, before implementing such policies, their costs and benefits and interactions with the core policy set need to be assessed. Just because a justification exists for policy intervention does not mean that the benefits outweigh the costs.

In the absence of a carbon price policy, a greater number of policies will likely be needed to cover the same range of abatement opportunities, at higher administrative cost and with the inevitable sacrifice of some emissions reductions. Policy can nonetheless be guided by similar principles as in the presence of a carbon price: attempting to deploy as much cost-effective mitigation potential as possible, up to a target shadow carbon price.

In a background paper for the OECD's "Green Growth Strategy," De Serres, Murtin and Nicoletti (2010) summarised that policies to achieve low-cost mitigation are

> likely to be characterised by having i) a mix of policy instruments, but with a strong carbon price at the core; ii) instruments that have undergone cost-benefit analysis and are applied as widely as possible; iii) incentives that assure wide adoption; iv) minimum distortion that reduces effectiveness; v) appropriate timeframes; vi) low administrative cost and effective enforcement mechanisms.

For all policy packages, pricing and non-pricing alike, policy interactions will further complicate the situation. This will be addressed in more detail in Chapters 4 and 5.

4. Interactions among combined policies

Chapter 3 reviewed a number of arguments for deploying multiple policies as the least-cost option for climate change mitigation. However, these justifications considered policies in isolation: the situation is more complex when the interactions between policies are taken into account. Policies can be mutually reinforcing, can work against one another, or can be made redundant, depending on how they are designed and implemented. Uncoordinated policy can not only raise costs, but also waste political capital, change distributional equity and undermine credibility (Fankhauser, Hepburn and Park, 2011).

Duval (2008) puts forward three types of policy interactions: direct overlaps, indirect interactions (for example, a downstream consumer energy tax combined with a cap-and-trade scheme), and trading interactions. He notes that instrument combinations can be desirable if they address different market imperfections or different target groups, but otherwise double regulation generally implies loss of flexibility and higher administrative costs. The OECD's review *Instrument Mixes for Environmental Policy* (OECD, 2007) notes that existing instrument mixes have not necessarily been implemented as a result of a coherent policy process; rather, they are often the result of ad-hoc evolution. In a number of cases, overlapping instruments have reduced the efficiency and effectiveness of policy. Although instruments can mutually reinforce one another (e.g., energy-efficiency labelling enhances consumer responsiveness to a carbon tax, and a carbon tax draws attention to efficiency labels), and instruments addressing the same externality but different target groups can increase efficiency but not effectiveness (e.g., the combination of the EU ETS and energy-efficiency policies), the authors conclude that overlaps should generally be avoided.

Oikonomou and Jepma (2008) and Oikonomou, Flamos and Grafakos (2010) establish a framework for assessing climate and energy policy interactions, dividing possible types of policy interactions into ten categories.[23] They then assess impacts of policy interactions according to five criteria (effectiveness, efficiency, impacts on energy and market prices, impacts on society, and innovation; each with many sub-categories). The framework then proposes a weighted scoring system to assess interactions. Interactions can be inherently complementary (e.g. voluntary action + command and control), inherently counterproductive (e.g. technology standards + pricing), or context specific. This framework assumes, however, that a high level of detail can be meaningfully assigned to what are essentially subjective rankings.

For simplicity, we will consider several specific cases which illustrate different types of policy interactions: supplementary policy interactions with an emissions cap, supplementary policy interactions with a carbon tax, and policy interactions in the absence of measures that put a price on emissions. Finally, the specific issues surrounding the interaction between carbon pricing and electricity markets are examined.

Supplementary policy interactions with emissions caps

In the presence of a pre-existing cap on total emissions, the introduction of additional policies (such as energy efficiency or renewable-energy deployment policies) will not reduce total emissions any further, at least in the short term. This is because the emissions level is fixed by the

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[23] Interactions are classified as internal or external (interacting with other climate policies or non-climate policies); horizontal or vertical (applying within the same or different levels of governance); operational (where the target group shifts due to policy interaction); sequencing (one policy affecting the form of a subsequent one); trading; integration (such as nested schemes); separation (stand-alone measures); and one-way or double fungibility.

cap: any reduction delivered by the additional policies simply means that emissions will increase elsewhere up to the level of the cap, or else surplus emissions allowances will be banked to enable these emissions to occur in the future. Consequently, such policy combinations can improve the cost effectiveness of emissions reductions, but not increase the total level of reductions (OECD, 2007).

A number of authors have pointed out that the addition of new overlapping policies could therefore have significant impacts on the supply/demand balance of allowances in emissions trading systems. For example, Deutsche Bank's forecasts for Phase III of the EU ETS[24] show that if the European Union's supplementary energy efficiency and renewables targets were to be achieved in full, they would deliver over 2 gigatonnes (Gt) of additional emissions reductions to 2020, enough to meet the emissions cap with no additional abatement from the trading scheme participants (Deutsche Bank, 2010). Deutsche Bank assumes only partial achievement of these supplementary targets, meaning that some emissions reductions are required from the trading scheme participants to meet the cap. A similar analysis has led the European Commission to propose that if efforts to achieve the energy-efficiency targets are stepped up, allowances may need to be "set aside" from the EU ETS to avoid undermining the trading scheme (European Commission, 2011). Höhne *et al.* (2011) calculate that the EU ETS cap should be tightened to 29% - 43% below 2005 levels to be consistent with the energy-efficiency and renewable-energy targets.

If the trading system cap is not set taking reductions from these supplementary policies into account (or is not adjusted in light of the supplementary policies' introduction), the resulting fall in allowance prices will undermine the incentives for action in the trading scheme, such as fuel-switching from coal to gas in electricity generation and investment in low-emissions plants. This could upset the balance of effort across the economy, as the sectors covered by the trading scheme would now face a lower carbon price than is being used to guide policy in other parts of the economy. This would reduce static efficiency, and run the risk of locking in high-emissions infrastructure that could increase costs in the long term. Particularly where current caps are known to be inadequate in terms of the long-term 2°C target, further undermining price signals for clean investment is likely to be detrimental.

These effects have been understood for some time. In a study for the European Commission in 2005, NERA considered issues arising from the overlap between the EU ETS and green and white certificate schemes (NERA, 2005). This study noted that addition of these supplementary policies would reduce CO_2 prices and electricity market prices, though increase the overall cost of meeting the cap due to the higher cost of renewable energy supported through the green certificate scheme. It also noted that the trading scheme cap could be tightened corresponding to the increased abatement, maintaining greater stability in the trading scheme.

Energy-efficiency policies are likely to target energy use both inside and outside the emissions trading scheme boundaries. For example, a programme targeting commercial boilers in Europe (where the EU ETS covers larger sites only) would lead to some emissions reductions that overlap with the trading scheme, and some that do not. Similarly, building-efficiency policies would create some savings in electricity, which is covered by the EU ETS, and some in direct fuel use, which is not. In order to align the trading scheme cap with energy-efficiency targets (and vice versa), it is therefore important to distinguish savings that will affect the trading scheme cap from those that do not.

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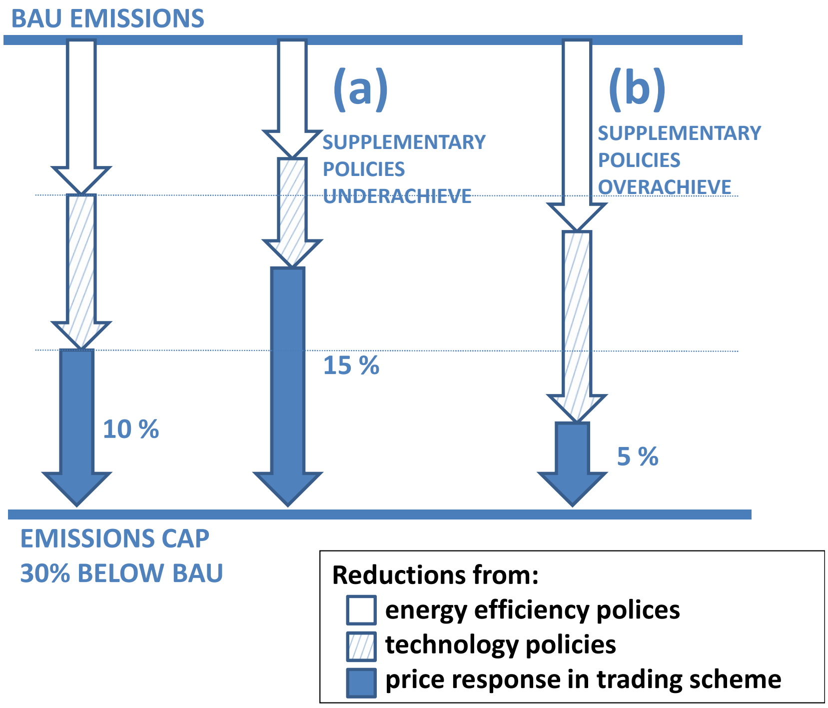
[24] Phase III runs from 2013 to 2020.

A further implication of the interaction between a cap and supplementary policies is that any uncertainty in the level of delivery of abatement from energy efficiency and technology policies could add to uncertainty in the carbon price, as the market will be unsure what level of additional price-driven abatement is likely to be necessary. In the hypothetical example shown in Figure 4.1 below, an emissions cap is set at 30% below anticipated BAU emissions levels. Supplementary energy efficiency and technology deployment policies are each expected to contribute one-third of the reductions towards the cap, leaving a 10% reduction to be delivered by the price mechanism. However, if the package of supplementary policies over- or under-achieves, the pressure on the trading scheme can be changed markedly. In this example, if supplementary policies deliver only 75% of their expected emissions reductions, the pressure on the trading scheme increases by 50%, and if the supplementary policies deliver 25% greater emissions reductions than forecast, pressure on the trading scheme halves.

This variation in demand for abatement from the trading scheme could have a significant impact on permit price, and hence incentives to investors. This points to a further criterion for supplementary policy design: that certainty of their level of emissions reductions is maximised, with monitoring and verification to ensure delivery.

In this example, if the supplementary policies were to significantly over-achieve (50% greater abatement than forecast), there would be no emissions reductions required from the trading scheme, which could cause a complete collapse of the carbon price.[27]

Figure 4.1 Impact of supplementary policy delivery on emissions trading system



Note: Under- or over-achievement of supplementary policies can significantly affect the need for emissions reductions from the emissions trading system.

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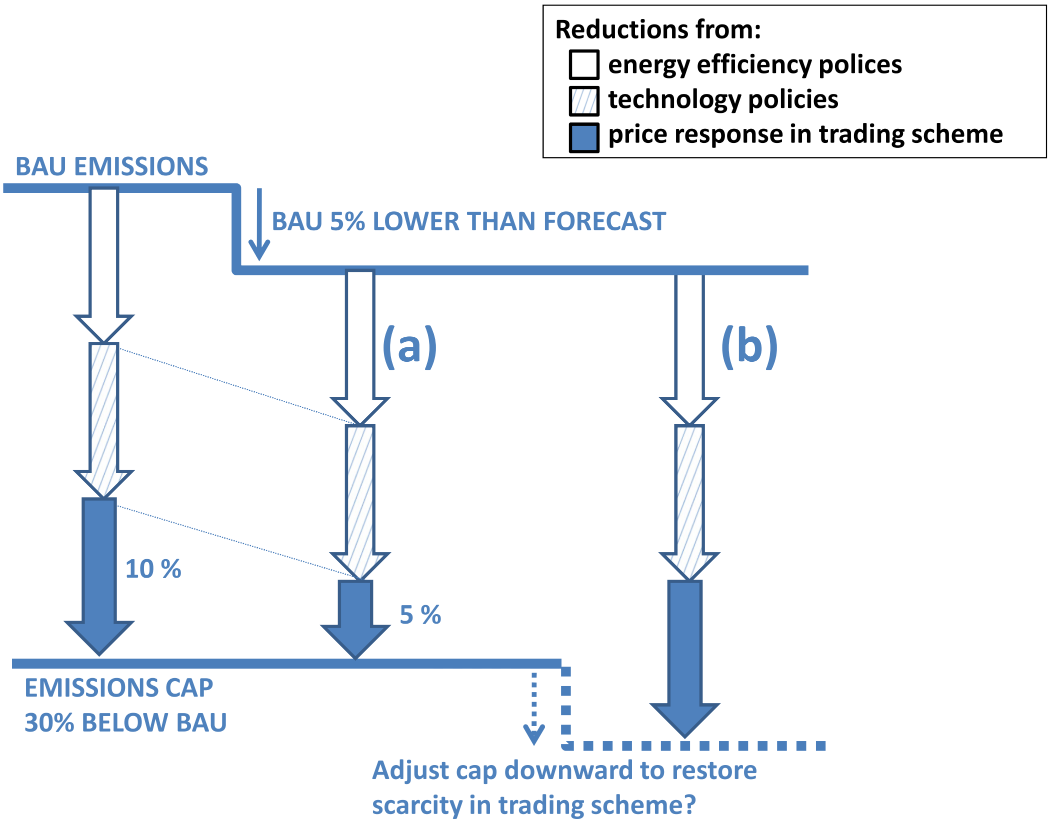
[27] Trading schemes allow for the banking of units for use in future periods, so oversupply of allowances will not necessarily lead to a complete collapse in carbon prices. However, banking these surplus allowances forward risks locking in future emissions, so may make it more difficult to meet long-term targets (Hood, 2010).

The magnitude of carbon price risk arising from such policy interactions is explored in detail by Blyth and Bunn (2011), who use stochastic simulations to explore a range of policy, market and technical risks in the EU ETS. They conclude that policy risk is a particularly strong when carbon prices are low, while market drivers such as fuel prices tend to dominate as risk factors when carbon prices are high. This is consistent with the qualitative picture presented in Figure 4.1, with carbon prices being more susceptible to policy uncertainty if the supplementary policies provide a high proportion of abatement (that is, when carbon prices are lower).

The delivery of some abatement by supplementary policies also makes the emissions price more sensitive to variations in (or miscalculations of) business-as-usual (BAU) emissions. If BAU emissions are lower than forecast, this reduces the pressure for reductions to reach the cap, and hence allowance prices. The variation of allowance prices with normal economic cycles is expected, and is something market participants are expected to manage. However, if supplementary policies deliver a significant proportion of reductions towards the cap, relatively small changes in economic conditions can have a large impact on the level of abatement that must be delivered by the trading scheme (Figure 4.2).

Figure 4.2 Impact of change in BAU emissions on emissions trading system



Note: If supplementary policies deliver a large proportion of emissions reductions under a cap, a relatively small change in economic conditions (BAU emissions) can significantly change the abatement required via the price mechanism.

In the example shown in Figure 4.2, an overall cap is set 30% below an assumed BAU level, and energy efficiency and technology deployment policies are each expected to deliver one-third of this reduction. If BAU emissions are actually 5% lower than anticipated and the reductions delivered by supplementary policies remain the same, the pressure on the trading scheme could be halved, a much greater variation than would have been the case without the supplementary policies.

Again, this risks undermining allowance prices, leading to an inefficient division of effort between the different policies and risking the locking in of higher-emissions investments for the long term. To restore balance, the overall cap could be tightened.

Equally, if a substantial quantity of international offsets is allowed as part of an emissions trading system, changing economic conditions could significantly alter the abatement required domestically, and thereby upset the desired balance between domestic and international action. Offset provisions therefore also need to be considered alongside supplementary policies and the emissions cap to ensure a robust outcome.

Renewable energy support and emissions caps

Combining renewable energy obligations with emissions caps has come under particular scrutiny and criticism. Because the additional renewables policy does not reduce emissions, but merely shifts abatement to the more expensive supported technologies, it is argued that the renewables policy adds cost without adding climate benefits (Sijm, 2005; Commonwealth of Australia, 2008). Taking this argument further, Böhringer and Rosendahl (2009) note that adding renewable-energy targets on top of an emissions trading scheme lowers the permit price, and that this gives a (relative) advantage to more emissions-intensive thermal generators (that is, providing some advantage to coal over gas compared to the case without renewables support). Charles River Associates (2007) finds that in the presence of an ETS, introducing a 20% renewables target in Australia would increase the costs of abatement, as the electricity sector would take on a higher-than-efficient share of abatement, and electricity prices would be higher.

However, as noted in Chapter 3, the justification for renewable energy support is primarily dynamic efficiency, so the fact that emissions are not reduced further in the short term is not the key issue. Philibert (2011) outlines these arguments in greater detail and also addresses the argument of Böhringer and Rosendahl (2009), noting that any such minor price effect “advantaging” coal is unlikely to lock in more polluting technologies on the supply side, given the small relative price change that it generates.[28] He concludes that to resolve the issue of renewables policies suppressing carbon prices, trading schemes need to take renewable-energy policies into account, either by tightening targets or setting a price floor.

Energy-efficiency policies and emissions caps

If additional energy-efficiency policies are cost effective, their implementation will both lower the permit price in the trading scheme and lower overall costs (because the cost of energy-efficiency measures is lower than the alternative abatement that would have been required). However, emissions will not be reduced unless the trading scheme cap is tightened correspondingly. As noted above, if the initial setting of caps did not take these energy-efficiency reductions into account, incentives for abatement within the capped sector could be undermined.

It is also important to note that any uncertainty in the level of abatement to be delivered by energy-efficiency policies will also create uncertainty in the emissions trading scheme. Ideally, energy-efficiency targets and supporting policies would be developed alongside the trading scheme, with policy designed to provide as much certainty as possible to the carbon market.

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[28] He does, however, note the potential for lock-in of inefficient energy end-use (such as poorly performing buildings) if renewables support programmes come at the expense of investment in energy efficiency.

One illustration of this interplay between energy-efficiency policy and an emissions cap is provided by Sorrel *et al.* (2009), who note that emissions allowance prices can be increased or decreased by the interaction with a white certificate scheme,[29] depending on scheme design. They find that design details matter: there is no automatic link between white certificate prices and marginal abatement costs, as prices depend on baselines and additionality criteria. Overall, emissions are not reduced by the added energy-efficiency policy unless the ETS cap is tightened.

Interactions with further supplementary policies

Moving beyond interactions within the core policy package, there are some examples of negative policy interactions that should be highlighted. One clearly redundant (and hence costly) policy combination is the introduction of a tax on emissions already covered by a trading scheme. Here, the additional emissions reductions prompted by the tax simply enable equivalent emissions to be made elsewhere, and the permit price drops so that the total (tax + permit) price is unchanged (Duval, 2008). A second generally counterproductive combination is the addition of a technology standard to activities covered by an emissions cap (Oikonomou, Flamos and Grafakos, 2010), as this restricts flexibility in finding the least-cost means of compliance, raising costs.

Increasing the number of instruments will also make interaction effects more difficult to predict, and specific design details can have a significant impact. An example is given by Palmer, Paul and Woerman (2011), who assess overlaps between cap and trade, renewable portfolio standards and tax credit policies in a United States context. Their study finds that the addition of tax credits will lower the prices for renewables certificates and hence electricity prices, which will tend to induce additional electricity demand and hence emissions.

The potential for unintended side effects does not necessarily mean, however, that overlapping policies should be avoided. Cowart (2010) notes that while supplementary policies won't reduce emissions under a cap, they do increase the likelihood of meeting the target: they can lower costs (and hence the likelihood of future tightening of emissions caps), and the positive spill-over of reduced electricity and carbon costs will in turn reduce the need for competitiveness policies. The key is to understand interactions so that caps and supplementary policies can be designed in harmony.

Supplementary policy interactions with carbon taxes

Some of the issues raised above are less problematic if a carbon tax is in place instead of an emissions trading scheme. Because additional emissions reductions arising from supplementary policies do not change the carbon price, the abatement incentive seen by entities covered by the tax is unchanged when supplementary policies are introduced.

For a given level of total abatement, supplementary policies can still raise or lower the total cost of meeting targets in the short term. The inclusion of low-cost energy-efficiency policies to unlock low-cost abatement will allow a lower tax level to be set than would otherwise be the case to achieve a given level of abatement, or alternatively achieves greater abatement for a given tax level. Renewable energy policies still result in higher abatement costs in the short term, as less expensive options could have been found by increasing the carbon tax instead. However, as in a trading scheme, the primary justification for renewables support is long-term cost reductions, so these additional short-term costs can be rationalised as part of a least-cost mix overall.

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[29] A tradable permit scheme for energy efficiency.

If a quantity-based scheme (such as a renewable energy standard (RES)) is used as a supplementary policy, the permit price in this scheme will be influenced by the amount of activity driven by the carbon tax. The quantity cap must therefore take the carbon tax level into account. Similarly, where subsidy-based support is used as a supplementary measure (for example with feed-in tariffs), the level of support should be designed to be reduced as the carbon tax increases. Once again, policies need to be developed alongside one another to ensure coherence.

Policy interactions not involving a carbon price

Even where a carbon price is not used, policy interactions can be important. Where quantity-based policies are used (such as a renewable energy or clean energy standard), interacting policies that deliver part of the quantity obligation can affect permit prices. For example, adding production tax credits for particular types of renewable electricity would lower the demand for allowances in a tradable renewable energy certificate scheme, undermining prices and potentially changing the relative attractiveness of investment in different technologies.

In one analysis of combining energy efficiency and renewable energy policies without a carbon price, Del Rio (2010) assesses interactions based on effectiveness, cost-effectiveness, and dynamic efficiency for a number of different policies (such as different types of feed-in tariffs and quota schemes). The conclusion is that energy-efficiency policies generally have more effect on renewables obligations than vice versa, as they affect overall energy demand. However, design details are found to be very important. For example, while a tradable white certificate scheme could undermine a renewable energy target by reducing overall demand, this could be circumvented by having an absolute rather than relative renewable energy target, a minimum white certificate price, or replacing the tradable energy efficiency scheme with a fixed feed-in tariff approach. The overall conclusion is that interactions can be managed as long as the focus is on functionality of the whole mix: coordination of the various targets, and the detailed design of instruments taking account of interactions.

Policy interactions between jurisdictions

Interactions between policies set at different levels of government also need to be taken into account. Goulder and Stavins (2010) find that interactions between potential federal and state policies in the United States can be either beneficial or problematic. If there is a federal emissions cap, state action beyond these requirements can simply cause emissions leakage to other states, at an overall loss of efficiency. In general, Goulder and Stavins class interactions as problematic if state rules result in over-compliance with a federal emissions cap, and federal rules allow trading/offsetting in other states.

A similar interaction occurs between national and state vehicle fuel economy standards. Goulder, Jacobsen and van Benthem (2009) calculated that from 2009 to 2020, about 65% of the increased emissions reductions from enhanced fuel economy standards introduced by California would be offset by increased emissions in other states, as auto makers would sell higher-emissions vehicles elsewhere while still meeting the less ambitious national standards.[30]

Another example in the US context would be federal regulation of power plant emissions, where these plants are also covered by CO_2 emissions trading schemes (either in California, or under the

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[30] The federal standard has since been aligned with the California standard, showing that policy leadership may be an important argument for pursuing more ambitious sub-national standards.

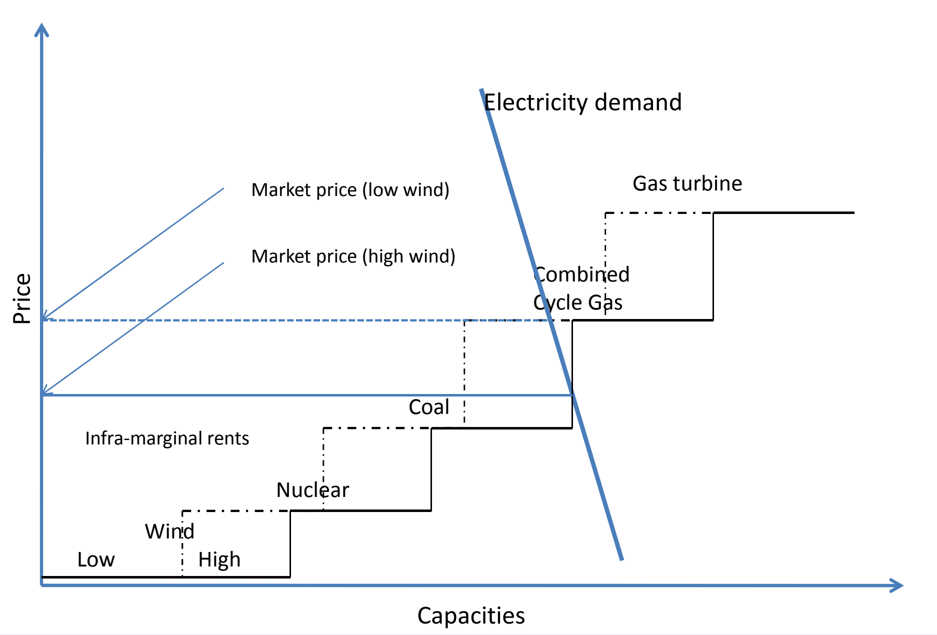
Regional Greenhouse Gas Initiative in the north-eastern states). Here emissions would not be reduced in the short term unless this cap is tightened, as total emissions are determined by the trading scheme cap.

Interactions with electricity markets

The marginal cost structure of competitive electricity market pricing means that the interaction between climate policies and electricity markets is complex. Fischer (2006) points out that wholesale electricity prices can be lowered by renewable portfolio standards, depending on the nature of the supply curves for non-renewable generation.

The deployment of significant levels of renewable generation through supplementary policies can suppress electricity market prices in the short term by displacing the most expensive generation (usually a thermal plant). This so-called "merit order effect" is reviewed in Philibert (2011) and is illustrated in Figure 4.3 below. Here, the quantity of wind generation affects overall market prices by displacing the marginal unit of thermal generation. In the long term, this suppression of prices may not be sustainable, as generators need to be able to recover their costs to justify investment. This has led many to conclude that current wholesale electricity market designs need to be re-evaluated with the goal of supporting a least-cost decarbonisation of the power sector.[31]

Figure 4.3 An increase in wind generation can lower wholesale electricity prices by shifting the merit order of generating plants



Source: Philibert, 2011.

Significant energy-efficiency investment could also lower market prices – this time by shifting the demand curve to the left rather than moving the supply curve to the right. To the extent that

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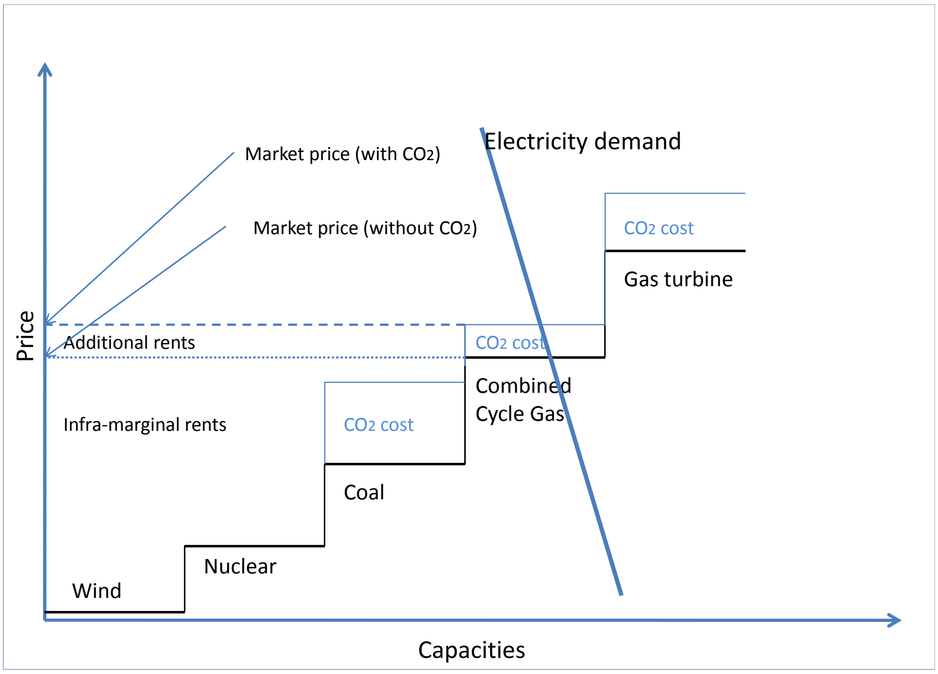
[31] These discussions are reviewed in Hood (2011).

future electricity generation options are more expensive, the avoided need for new generation, and the avoided resulting price rises, is of wider economic benefit.

Carbon pricing policies interact with the marginal electricity price in the opposite direction to the merit order effect, causing prices to rise. This is because the market clearing price is generally determined by a thermal plant, which can pass through a carbon cost into the electricity price received by all generators (Figure 4.4). This can result in consumer payments for electricity increasing by substantially more than the actual cost of emissions allowances (Cowart, 2010). Where electricity price rises are a major issue of political acceptability, or where the price rise greatly exceeds the actual underlying cost of emissions, this interaction could influence policy design.

Figure 4.4 In a wholesale market CO_2 costs are passed through onto all electricity sold



Source: Philibert, 2011.

A final interaction between climate policies and electricity markets relates to their effect on electricity demand. Uncertainty around the setting or delivery of energy-efficiency targets will raise uncertainty around the total level of investment in new generation needed. Similarly, uncertainty in the level of renewable electricity capacity that will be installed raises uncertainty about requirements for thermal capacity – either to meet demand growth or for balancing intermittent renewables. Because of the primary importance of security of supply in energy policy-making, climate policies that provide greater certainty of targets and delivery are desirable.

Chapter summary: policy interactions

Policies can be mutually reinforcing, can work against one another, or can be redundant depending on how they are designed and implemented.

There are particular issues with emissions trading systems:

- Because supplementary policies deliver some of the required abatement under the cap, they reduce the abatement needed in response to the price signal, reducing allowance prices. Particularly where current caps are known to be inadequate in terms of the long-term 2°C target, further undermining price signals for clean investment is likely to be detrimental. However, these policies can improve the cost-effectiveness of the policy response: in the short term for energy efficiency, and in the long term for technology policies.
- Uncertainty in the delivery of emissions reductions by supplementary policies creates uncertainty in the capped system, giving uncertain demand for allowances and hence carbon prices (Figure 4.1).
- If supplementary policies deliver a significant proportion of the abatement required under the cap, fluctuations in BAU emissions can lead to significant uncertainty in the abatement required, and hence carbon prices (Figure 4.2)

With a carbon tax, additional emissions reductions arising from supplementary policies do not change the price level of the tax. Therefore, the abatement incentive seen by entities covered by the tax is unchanged when supplementary policies are introduced. The inclusion of energy-efficiency policies would allow a lower tax level to be set to achieve a given level of abatement, or alternatively there will be greater abatement for a given tax level. Renewable energy policies still result in higher abatement costs in the short term; however, the primary justification for renewables support is long-term cost reductions, so this additional short-term investment can be justified.

Policy interactions can still occur without a carbon price, particularly where quantity-based instruments (such as a renewable or clean energy quota obligation) are used. Interactions between jurisdictions (for example state and federal climate policies) can also be problematic, but may have other justifications.

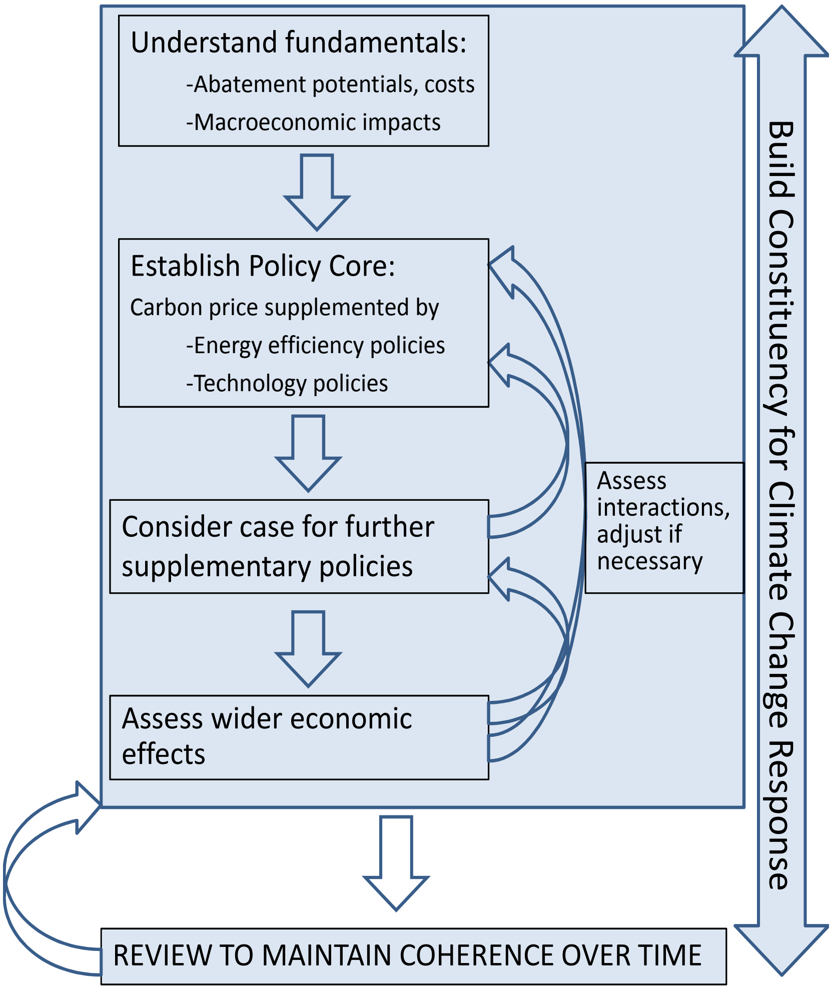
There are competing influences in the interaction between climate policies and competitive electricity markets. Introducing low-cost renewable energy into the market reduces market electricity prices via the "merit order effect", while the pass-through of carbon prices raises electricity prices, as long as fossil-fuelled plants are setting the price. In the longer term, electricity market structure may need to be reassessed to better match the characteristics of low-carbon generation.

5. Designing climate policy for least-cost mitigation: the policy process

As has already been seen, the policy core of a least-cost climate response will ideally be composed of a carbon price, either a tax or the price emerging from an emissions trading system, supplemented by energy efficiency and technology policies which improve the efficiency of the price mechanism by overcoming market failures and barriers. These supplementary policies should result in an enhanced efficiency in the allocation of mitigation efforts and in lower costs over the long term, as long as they are implemented carefully and cost-effectively. Further supplementary policies could be considered to manage such real-world policy implementation issues as incomplete scheme coverage or political acceptability. Here, compared to implementation in a perfect theoretical scheme, supplementary policies have the potential to raise costs, so care is needed to ensure that their benefits outweigh their costs.

When combining policies, the goal should be to design supplementary measures to improve the effectiveness of the CO_2 price where possible, and to minimise damage to it where compromise is unavoidable. Very broadly, one suggested policy process is outlined in Figure 5.1. The individual steps are considered in turn below.

Figure 5.1 Aligning interacting policies to form coherent packages



Throughout the policy process, a critical element is to build a constituency of support for the significant economic transition that is required. A current review by the OECD concludes that political acceptability may be a primary concern: "successfully identifying, quantifying and addressing these concerns is arguably the most crucial element for policymakers to get right" (de Serres and Llewellyn, 2011). This means establishing clear and realistic targets, effectively addressing key concerns (such as competitiveness and distributional effects), and building in public information and engagement throughout the policy process to garner support for the need for action, develop an understanding of least-cost action, and explain how concerns will be addressed.

There is a growing literature exploring the sociological aspects of climate policy, which may be useful in building constituencies for change. For example Cai, Cameron and Geddes (2010) find that people's "willingness to pay" depends not only on their own circumstances, but on their perceptions of the distribution of costs within and across countries. Kollman and Schneider (2010) use Public Choice theory to analyse why price-based mechanisms may be difficult to implement compared to command-and-control policies, despite their economic advantage, due to the varying incentives of players (voters, politicians, producers, traditional and green-interest groups, bureaucracies).

Step 1: Understanding the fundamentals

There are a number of pieces of background information that are very valuable in climate policy design, particularly where there are complex policy interactions. Before considering the particular policy package, it would therefore be useful to have an understanding of:

- The abatement pathway that needs to be followed. There will be a trade-off between ideal policies (which may take some time to implement) and early action. This doesn't mean that early action is always good, however – particularly if it severely undermines the implementation of better policies in the medium to long term. Locking in technologies that may be sub-optimal in the face of the longer-term mitigation goal is another risk of hasty early action.
- The impact of the carbon price on energy prices, and of regulatory measures on other prices in the economy – and how these costs flow into the wider economy and are distributed across society. This understanding is useful not only to aid political acceptability by dispelling any unwarranted fears, but also for design reasons: it will help answer the question of when supplementary policies for cost containment may be justified, even though they undermine the core price measure. As it potentially raises revenue for the government, carbon pricing design also often involves striking a balance between using this revenue to minimise macro-economic impacts and addressing distributional issues, so having a clear understanding of these effects is important.
- Potentials for cost-effective energy-efficiency improvements, and the likely cost and effectiveness of policy tools available to unlock these. As discussed in Chapter 4, having confidence in the delivery of energy-efficiency targets is important for the core package of interacting policies to operate as expected.
- The new technologies that are likely to be important in the local context in the medium to long term, and therefore what role the government will take in reducing the cost of these technologies. Equally, governments will want to assess the green growth opportunities arising from taking an active role in technology development.

- In the local context, other existing barriers to the potential implementation of a comprehensive carbon pricing policy, or areas where a carbon price is not expected to act effectively. In such cases, an assessment of possible supplementary policies might be useful.

Step 2: Aligning interactions within the policy core

The first consideration in aligning the core package (of carbon pricing, energy efficiency and technology policies) is how to balance effort between these policies. Grouping these policies as a core set does not necessarily mean that separate explicit policy targets are necessary for energy efficiency and technology deployment; some governments may choose to focus on a single overall emission reduction target. In this case, for investment certainty it is still important to understand the cost-effective contribution that supplementary policies are likely to deliver toward the overall target, and their interactions with the price mechanism.

For technology policies, analysis is needed on the appropriate level of technology investment compared to its benefits over the long term, including reductions in CO_2 abatement costs and any green growth opportunities. There will also need to be a decision on how much energy efficiency improvement to target, and a need to separate energy savings that overlap with pricing policies from those that do not. For strict cost-effectiveness, energy-efficiency policies would be undertaken where their expected cost per unit of emission reduction is less than or equal to the expected market CO_2 price (and forward expectations for this).[32] If the policy core does not have an explicit carbon price, the same process can use a common shadow price to balance policies.

However, if the initial emissions target is weak and there is no clarity on future carbon prices, there is a case for implementing energy efficiency at a higher standard (particularly for very long-lived assets such as buildings), as long as there is a clear understanding of how the CO_2 price will "catch up" over time. Any measures that second-guess the carbon price run some risk of undermining the success of pricing in the longer term, as there may be temptation at a later stage to continue tightening supplementary policies rather than allowing the carbon price to rise. As such, measures that go beyond the carbon price should be the exception rather than the rule.

The next consideration is to ensure that the design of supplementary policies factors in the carbon price, and the expectation of further reductions in emissions and rising carbon prices. For example, renewable energy support payments can be structured so that direct payments decrease as carbon prices (and hence electricity prices) rise, to avoid unnecessary subsidies. Similarly, if a quantity-based renewable energy target is used, the effect of the carbon price on renewable investment needs to be taken into account in setting the renewables scheme cap: if, for example, the carbon price is sufficiently high to deliver all of the required renewables investment, the renewable support scheme will be redundant at best, and could be counterproductive if it is perceived as overly generous and creates a popular backlash against climate policy. For energy-efficiency policies, the carbon price will have a positive impact in reducing rebound in energy efficiency, enhancing the effectiveness of these policies.

Policy core with emissions trading

Particular issues of interaction arise when there is an emissions cap as part of the policy core. Energy efficiency and technology policies will deliver some of the emissions reductions required by the cap, with the remainder (by definition) delivered by capped entities in response to the

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[32] The market CO_2 price will itself depend on the level of supplementary energy-efficiency investment, so a self-consistent package should be determined.

price signal. A further complication arises from the use of international offset credits in emissions trading systems. The quantity of offsets allowed will determine the balance between domestic decarbonisation and paying for emissions reductions elsewhere. If there is an over-supply of credits internationally due to incomplete global markets, this could lead to low carbon prices and inefficiently low levels of domestic abatement.

To operate well, emissions trading schemes need a reasonably predictable degree of scarcity, so that participants can manage their investments efficiently. As illustrated in Figures 4.1 and 4.2, having a high proportion of the total abatement delivered by supplementary policies leaves the scheme vulnerable to significant uncertainty in this level of scarcity and hence in CO_2 price levels. This leads to the following design considerations:

- Choose a combination of emissions cap, offset entitlements and supplementary policies that is expected to maintain at least a minimum amount of scarcity under a reasonable range of circumstances. BAU emissions may have been over- or under-estimated, and supplementary policies may over- or under-deliver. Testing emissions trading system settings over a reasonable range of varying circumstances is therefore important.
- Design supplementary policies to provide as much certainty as possible on their delivery of emission reductions, taking the carbon price into account. Supplementary support may be able to be phased out in line with a rising carbon price.

Box 5.1 Energy and climate change policy governance: another challenge for policy integration

The IEA has recently published the Energy Efficiency Governance study and related Energy Efficiency Governance Handbook, which highlight the role of governance structures in good policy design, including for the coordination between energy efficiency and climate policies (IEA, 2010c; 2010d).

These studies highlight that the desired alignment of energy efficiency, technology and climate policies could be more difficult to achieve in practice if these policy areas are the responsibility of dispersed ministries or uncoordinated policy processes. For example, in many countries, climate change policy is the purview of the environment ministry, while energy-efficiency policy is the responsibility of an energy or natural resources ministry. These two policy areas often overlap, creating greater need for inter-governmental coordination. Coordination among policies at the international level can be even more challenging: for example, in the European Union, energy and climate policy are not only the responsibility of different agencies, they are subject to different decision-making processes.

The Energy Efficiency Governance studies note that not only is coordination among overlapping policy areas critical, but so is planning for coordination at early stages in the policy process, and building the capacity to coordinate within the relevant government bodies. The studies also discuss the importance of avoiding overlapping and competing policy targets. Targets should be well coordinated to avoid the risk of conflicts among individual targets or duplication of effort. This applies especially when targets are being used in policies which are closely linked, such as energy-efficiency policy and climate change policy.

Policy core with a carbon tax

As noted in Chapter 4, many interactions are less problematic with a carbon tax than with emissions trading, because the introduction of supplementary policies won't reduce the carbon price. However, there can still be misalignment of policies, leading to unequal levels of effort in different parts of the economy. The political difficulty of setting carbon taxes at appropriate levels, and of demonstrating an ongoing credible commitment to price rises, may lead to a temptation to use supplementary policies (rather than a rising carbon price) to deliver emissions reductions. The level of emissions reduction resulting from a carbon tax is also uncertain, so robust review and updating processes are needed.

The carbon tax level should be set taking into account the likely emissions reductions from cost-effective energy efficiency and technology policies. For a given emissions goal, the inclusion of these supplementary policies will allow a lower carbon tax level than would otherwise have been the case. Again, energy efficiency-policies would be undertaken where their expected cost per unit of emission reduction is less than or equal to the carbon tax level, or higher in the case of a weak carbon price. Technology support policies should be designed to phase out in line with a rising carbon price. Here, the under- or over-delivery of these supplementary policies does not cause any carbon price uncertainty, as the tax level is fixed.

Policy core without a carbon price

As noted in Chapter 3, policies can attempt to mirror what would have been achieved by price measures via consideration of a common shadow price. This is obviously a higher-cost approach than simply applying carbon pricing, as knowledge of the cost and availability of abatement opportunities is not perfect, and not all options that would have been triggered by a carbon tax will be reached by targeted policies. But attempting to equalise efforts as widely as possible across the economy, based on a common shadow price of carbon, is a good start.

For example, a clean-energy portfolio standard (CES) is a market-based policy that can be applied broadly and, depending on design, could be a reasonable proxy for a carbon price.[33] This policy would miss some of the abatement opportunities created by a carbon price, but has the political advantage of having less impact on energy prices. If a narrower policy, such as a renewable energy standard, were used instead, to access the same range of abatement as delivered by the CES would require additional policies to provide incentives for natural gas generation, carbon capture and storage, and nuclear, further complicating the policy mix.

Note that the absence of an explicit carbon price could also change the nature of policy design: for example, renewable energy support policy now targets both immediate emissions reductions and technology development, so the optimal policy may be some combination of technology-neutral renewables support (mirroring the carbon price), and targeted support.

Many energy-efficiency policies make sense with or without a carbon price. But again, it would also be appropriate to consider a common long-term shadow price when determining criteria for funding energy-efficiency schemes: particularly where long-lived assets, such as buildings or public infrastructure, are involved. Also, without an accompanying carbon price, the rebound effect in energy efficiency policies will be larger, reducing the effectiveness of these policies somewhat.

There will still be policy interactions to manage even in the absence of a carbon price, particularly where broad quantity-based policies are used (RES, CES or white certificate schemes for energy efficiency) (Del Rio, 2010). Design details, such as alternative minimum payments in an RPS scheme, can affect both cost effectiveness and the nature of policy interactions (Palmer, Paul and Woerman, 2011). As such, the same general design criteria apply: policies should be considered as a package, and tested for robustness under a range of reasonable economic and policy scenarios.

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[33] Because the CES is a requirement for a certain percentage or quantity of generation to come from clean sources, (renewable, nuclear, or fossil fuel with carbon capture and storage, with partial credit for gas-fired generation), it could be a reasonable proxy for an emissions price if applied broadly to new and existing generation, and if crediting levels were linked to emissions.

Box 5.2 Example: Managing cross-jurisdictional interactions

Policy interactions can arise from jurisdictional overlaps, between sub-national and national policies, or between national and international schemes.

Where a jurisdiction is covered as part of a broader scheme (such as a state within a federal scheme, or a country within a regional trading bloc), the relative stringency of the two schemes will determine the effect of the interaction. Where the local scheme is less stringent, its targets will be delivered by the higher-level scheme and the local policy will therefore be redundant. If the local policy is more stringent, it could have an undermining effect on the larger scheme (Goulder and Stavins, 2010; Goulder, Jacobsen and van Bentham, 2009).

For local regions or governments wishing to take more ambitious action than that prescribed by a collective emissions trading scheme, a number of issues need to be weighed. Adding supplementary policies will not reduce total emissions in the short term, as these are set by the overall cap. Rather, they result in emissions occurring elsewhere (or being banked for later use) and will suppress allowance prices. Taking unilateral action could also be seen as undermining support for the collective scheme, and hence the likelihood of its long-term success. On the other hand, there are potential benefits of more ambitious local action: a more rapid local transition to low-carbon infrastructure could better position the economy for higher expected prices in the future; over-achievement (with banking forward of allowances) could increase the likelihood of future tightening of targets; local schemes may be in a position to address some market barriers that cannot be reached at a higher level; and front-runners could set the pace of technology development (such as Californian vehicle fuel economy standards influencing the national fleet).

In some cases, the solution may be for the high-level scheme to override or subsume local policies. For example, proposals to implement a national US emissions trading scheme generally "pre-empt" state renewable energy targets, to ensure consistency. It would also be possible in theory to "carve out" (remove from the trading scheme) sectors covered by the overlapping policies – though the trading scheme cap would need to be adjusted accordingly (Goulder and Stavins, 2010).

Where overlap exists, it will be a judgement call for policy makers as to whether the benefits of supplementary overlapping polices outweigh the costs and risks of undermining of the collective scheme. If it is decided to continue, it is important to set local parameters in light of the higher-level scheme, and vice versa if possible, adjusting the high-level cap to account for local interacting policies.

Step 3: Assessing the case for further supplementary policies

As noted in Chapter 4, there are numerous other potential justifications for supplementary policies. When considering this long list of potential market failures and imperfections, it is important to address the question of whether the solution is better than just allowing the failure. Not every market failure is worth fixing, as externalities are, after all, pervasive.

A first set of issues – market barriers – will in general be desirable to overcome, as these block the cost-effectiveness of the price instrument. Possible options for overcoming these barriers include:

- Policies and financing to support alternative infrastructure development, as the lock-in of existing infrastructure and resulting economic path dependence impair the ability of pricing to drive change.[34]

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[34] For example, existing transport infrastructure is in place for liquid fuels, so the penetration of electric vehicles will depend on the development of charging infrastructure as well as the direct cost of the vehicles.

- Mechanisms to increase access to finance for low-carbon investment, to assist in mobilising the higher levels of capital investment needed in low-carbon scenarios, and addressing higher-risk premiums that lenders can attach to technologies that are perceived as immature.
- Policies to reduce emissions in sectors of the economy that are not covered by the price instrument, and/or to address the competitiveness of sectors facing a carbon price against those that do not.

In the design of these supplementary policies, it is still critical to assess the costs and benefits of each proposed policy. For example, measures to address industry competitiveness may be very expensive, on the basis of cost per tonne of CO_2 saved, compared to the level of emissions leakage prevented (OECD, 2010a). Interactions with the core package must also be considered, and adjustments made if necessary. For example, introducing concessionary financing or government contracts to reduce investment risk could lower the costs and increase the level of investment in low-carbon technology. Depending on the structure of the pricing and renewables support policies, this could mean that ETS caps, renewables targets or renewables support levels should be adjusted to reflect the presence of the additional policy.

A second set of issues relates to the price signal being weaker than optimal in the short term, and not visible in the longer term, due to issues of implementation in the real world. For example,

- Incomplete global coverage (and insufficient global action) means that international offset credits (such as those from the Clean Development Mechanism) are currently undervalued, so carbon prices in trading schemes are likely to be lower than would be the case in a world acting comprehensively.
- Political acceptability issues (particularly the reluctance to raise energy prices) can lead to slow starts in price mechanisms, again giving lower prices than would have been the case in a more optimal trajectory and encouraging too much high-emissions activity.
- Lack of international agreement on targets and burden-sharing means there is no visible forward price path to indicate to investors the decarbonisation transition needed.
- Political unacceptability of some specific actions or technologies could lead either to weakening of the price measure altogether, or to effort being shifted to other sectors of the economy.
- Political uncertainty (election cycles, history of government backtracking) leads investors to doubt the certainty of future climate policy settings, giving a less than efficient response to the price signal or high-risk premiums.

Whether there is a case for addressing sub-optimal carbon prices is more difficult to assess. Ideally, the “first best” solution would be to raise the ambition and certainty of the price mechanism to the highest extent possible. Particularly where political acceptability is the constraint, every effort should be made to build a constituency for change that allows the best possible implementation of pricing (de Serres and Llewellyn, 2011). However, given the urgency of making emissions reductions if the 2°C target is to remain in reach, if the pricing scheme remains inadequate one may legitimately ask whether the best strategy is to

i) Supplement the scheme with additional policies to keep abatement on target in the short to medium term until the price mechanism takes over, or

ii) Accept less than optimal action in the short term (and associated increased costs in the longer term), so as not to undermine the price policy.

Each potential supplementary policy will therefore need to be assessed not only for its costs, benefits and interactions with core policy, but for whether it *helps* or *hinders* implementation of more comprehensive policy in the long term, balanced against the urgency of emissions reductions in the short term. Each time the carbon price is side-stepped could set a precedent for doing so again in future, undermining the future use of a rising carbon-price to drive change, so these decisions will need to be weighed carefully.

If a carbon tax (rather than emissions trading system) is used, the precedent issues arising from introducing further supplementary policies may be even more problematic. Political acceptability considerations mean that it may be more difficult to raise carbon tax levels than to make equivalent quantity reductions in an emissions trading scheme. As such, initially using alternative policies to bolster the carbon price could in practice lead to these alternatives being used *instead* of increasing the carbon tax in the future – at higher overall cost. The temporary phase-in measures risk becoming permanent policy. This risk of undermining the core price mechanism (and hence the core driver of least-cost outcomes) should be carefully considered.

Supplementary policies for long-lived assets

Where there are very long-lived assets, it is easier to make the case for using a higher (shadow) carbon price than that seen in current or forward markets. For example, building standards and transport infrastructure need to be based on a life-cycle assessment of costs, so current CO_2 market prices will be a poor guide to ambition.

Another example would be a regulatory backstop such as an emissions performance standard for new thermal electricity generation, to guard against lock-in of high-emissions investment in the presence of a low carbon price (as proposed by the UK government (see box) and Cowart (2010)). Such regulation may well prevent inefficient investment, and hence lower costs. However, the issue of precedent again needs to be considered: whether reliance on regulation will tend to lead to more regulation rather than to the more efficient pricing instrument, increasing costs in the longer term.

Supplementary policies for "cost minimisation"

There is a particularly difficult question for policymakers on the merits of cost minimisation interventions. Carbon prices (and hence direct costs to consumers) can be kept lower by using alternative policies, such as regulation or subsidies. However, the goal should be to keep prices from being *unnecessarily* high (that is, above efficient levels), rather than simply keeping them low. Particularly if the carbon price mechanism is already weak, undermining prices further would not be helpful to a least-cost response.

One example worth considering is cost impacts in the electricity sector, where the pass-through of carbon prices via electricity markets that use marginal pricing can result in high cost increases to electricity consumers (see Figure 4.4). It may be worth considering whether more subtle ways of passing the price signal to investors are needed, so that the electricity sector can be decarbonised while minimising negative macro-economic or distributional impact from price rises.

Impact of further supplementary policies on the core package

In terms of the impact of further supplementary policies on the core package, these policies (if effective) may well deliver additional emissions reductions that should lead to consistency adjustments of the core package of carbon pricing, technology support and energy-efficiency policies.

Box 5.3 Example: Proposals for reform of the United Kingdom electricity market

The government of the United Kingdom is currently developing options for reform of its electricity market to better facilitate the decarbonisation of the power sector (DECC, 2010; HM Treasury, 2010). The package of measures proposed consists of:

- Carbon price support. The carbon price from the EU emissions trading system would be supplemented by a carbon tax on fuels (the climate-change levy) to guarantee a minimum carbon price for electricity generation.
- Long-term contracts for all low-carbon generators, structured as contracts-for-difference against the market electricity price. This guarantees returns for low-carbon investors, while maintaining market incentives for efficient operation. As the carbon price (and hence electricity price) rises, payments to low-carbon generators will decrease.
- Targeted capacity payments for flexible plants needed for system balancing and meeting peak demand.
- Emissions performance standards for new fossil-fuelled plants, as a backstop minimum emissions requirement.

The current renewables obligation is to be replaced. The United Kingdom also has an additional new carbon tax for small business, aimed at raising awareness in this group.

In terms of the framework outlined in this paper, the carbon price support and the emissions performance standard aim to supplement what is perceived as a weak EU ETS carbon price. Depending on the payment levels set for contracts with low-carbon generators, these could act primarily as a technology development policy ("core" policy in this framework), or could act as a further policy to supplement a weak carbon price. As identified in this paper, the potential for such supplementary policies to undermine the carbon price mechanism over the long term should be assessed.

Step 4: Assessing wider impacts and interactions

In Chapter 2 it was noted that a policy package would likely bring forward the lowest-cost mitigation measures if it is broad-based, encourages innovation, and deals well with uncertainties (Duval, 2008), and the wider economic implications of revenue use were pointed out.

A final assessment of the policy package therefore needs to return to these core criteria, to macro-economic impacts, and to a check that policy criteria are being met in a more general sense (as depicted in Figure 2.3). At this stage, a final balancing may be necessary between the macro and micro levels: it is possible that some policies, though efficient, could have negative wider macro-economic or social implications and therefore need adjustment. Any policy elements that are dropped obviously must be compensated for by greater reductions in other areas, including the core package, to deliver the same level of emissions reductions.

In one example of macro-economic analysis, EPA (2010) find that recycling revenue from an emissions trading system through labour tax cuts, rather than lump sum payments to households, has a dramatic impact on household consumption: with recycling through labour taxes, household welfare is actually improved compared to the baseline in the short term, and the longer-term negative GDP impacts to 2050 are roughly halved.

Box 5.4 Example: Combining multiple policies

Boot and van Bree (2010) analysed policies as part of the European "Roadmap 2050" exercise. They suggest that in addition to the current EU ETS, a package is needed of: greater energy efficiency gains (building standards, financing, white certificates); vehicle standards; support for electric vehicle demonstrations; technology support for renewables, CCS and smart grids; a stronger ETS (studying caps/floors); attention to demand response and electricity market structure; and updated electricity transmission planning processes. This reflects a core package of carbon pricing, energy efficiency and technology support, with added policies to focus on infrastructure.

Step 5: Reviews to maintain coherence of interacting policies

Even if it were politically feasible to leave policy settings untouched for a decade or more for the purpose of providing investment certainty (IEA, 2007b), it is not clear that it would always be desirable to do so. If, as is argued here is necessary, there are interacting supplementary policies, they will drift out of alignment over time. Regular reviews of both emissions trading scheme parameters and supplementary policies may therefore be needed to restore balance, particularly where carbon price signals are being undermined (Blyth *et al.*, 2009). There may also be exceptional circumstances that require policy settings to be reset more immediately. Reviews are particularly important where emissions trading schemes have already been introduced without a full consideration of policies already in place (Matthes, 2010).

If carefully undertaken, with clearly signalled policy intent, such reviews can provide a different type of certainty for emissions trading schemes: they can maintain the expectation of a consistent level of abatement from the capped entities, correcting for volatility caused by supplementary policy interactions or unanticipated external shocks. However, if these reviews are undertaken on an ad-hoc basis, they could cause significant uncertainty and undermine investor confidence in the climate policies, having a chilling effect on investment.

Such a debate is currently taking place in relation to the EU ETS cap. Since the cap was set in 2008, the economic recession has led to drops in GDP and emissions well outside the range anticipated when the scheme was designed, and has led to a significant excess of allowances and offset entitlements being banked for use in Phase III of the scheme. The result is now that if 2020 targets for renewable energy and energy efficiency are met in full, virtually no abatement would need to be delivered by the price mechanism (European Commission, 2011). In addition, due to the reduced level of abatement required overall, the fixed offset entitlement will contribute a greater proportion of abatement than was originally envisioned. To restore balance in the system, the Commission is proposing to set aside a quantity of allowances, so that further energy-efficiency gains do not undermine the price signal of the trading scheme. These set-aside allowances would enable the cap to be tightened more easily if European governments choose to do so in future, or could be released back into the market.

It is an issue of judgement as to when imbalances between emissions trends, trading system parameters and supplementary policies are so serious that they warrant intervention (at the risk of undermining the price signal). Various options could be considered to allow for reviews, while maintaining confidence in the overall policy settings.

Trading scheme reviews could be restricted to set intervals (for example, three or five yearly), with a clear understanding of the process, criteria and rationale for the review, to coincide with any changes in levels of free allocation. In general, it should be made clear that the purpose of the reviews is to maintain balance between the various policies and the required long-term emissions trajectory. If supplementary policies are introduced between reviews, it should be possible to avoid adjustments to the trading scheme until the next scheduled review. If long-term trading scheme caps have been set on an appropriate declining path, it may well not be necessary to adjust the cap.

In the event of a significant imbalance that would justify an adjustment to the trading scheme cap, such adjustments should be left until the next scheduled review where possible. Changing allowance supply mid-course could cause significant uncertainty and make immediate obligations difficult to manage, undermining confidence in the trading scheme (Matthes, 2010). If there is a high level of free allocation of allowances, it would not be possible to adjust the cap between scheduled reviews without cancelling allowances that have already been allocated (or promised) to scheme participants, a move that would seriously undermine investor confidence.

An explicit signal of the likelihood of future tightening could be given to provide clarity to the market and give participants an incentive to bank any immediate excess of allowances to manage the signalled future withdrawal of supply. Even without explicit signalling of next-period tightening, however, there is the probability that significant carry-forward of allowances and low system prices will increase the likelihood of caps tightening when the next review is conducted. These extreme events are somewhat self-correcting as long as there is scope built into the scheme for adjusting the cap over time. For example, the United States SO_2 market cap was adjusted after lower than expected allowances prices (Ellerman, 2002).

However, it should also be acknowledged that there may be misalignments that are so serious that they would be damaging to the long-term emissions abatement effort.[35] In this case, it may be judged that the uncertainty caused by intervention is outweighed by the benefits of realigning the scheme parameters. Although raising the prospect of revision causes uncertainty, the commitment to correcting imbalances will equally provide some reassurance to low-carbon investors who may be concerned about the stability of allowance prices. Criteria could be set for such “force-majeure” conditions, to provide reassurance to trading scheme participants that such reviews would only be taken under truly exceptional circumstances.

Another approach that has been proposed is to build in cap and floor prices into trading schemes, as a mechanism to provide some automatic correction for unanticipated circumstances and give investors greater confidence in the policy’s capacity to deliver a carbon price in any circumstances. The proposed use of these mechanisms in recent emissions trading designs is reviewed in Hood (2010). These schemes typically involve a floor price for allowance auctions, so that allowances are withheld from the market if there is insufficient demand. This can be coupled with a price cap (which effectively acts as a fixed-price carbon tax when prices are high), or a reserve of allowances that can be released when prices reach a trigger level (Philibert, 2009). In theory, such measures would help avoid the need for “force-majeure” interventions, as the carbon price would be more stable under extreme conditions. However, as with carbon taxes, there may be political difficulty in setting caps and floor prices sufficiently high, and if the allowance price were consistently at the cap or floor level, it seems inevitable that the emissions cap and/or cap and floor prices would be updated at the next review. As such, there will still be uncertainty for investors even with the inclusion of price caps and floors.

Rather than the hard-wired corrections in a price cap and floor approach, there have been proposals for an independent “central banker” to manage allowance supply and offset

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[35] For example, the banking forward of an extreme surplus of allowances could mean that little abatement is needed in future periods (Hood, 2010). This runs the risk of locking in high-emissions infrastructure.

entitlement against clear preset policy targets[36] which could be a price band,[37] volatility thresholds, or other parameters. The central bank could either control the quantity of allowances made available for auction (which may be resisted by governments, as it would affect their revenue stream), or could purchase allowances from the market at times of oversupply and bank them for resale in conditions of shortage. While this is an interesting idea, it is not being contemplated in any current existing or proposed trading scheme.

An approach to managing policy reviews could therefore be to:

- Set emissions scheme parameters (caps, offset entitlements), technology targets, and energy efficiency-targets as a package. Avoid making changes to these headline settings except through regular, scheduled review processes. However, these reviews still need to bear in mind issues of certainty for investors in these supplementary mechanisms. For example, if the desire is to accelerate the deployment of new technologies, stability in support scheme parameters is important (IEA, 2008c). The intention to tighten targets at upcoming reviews could be signalled to the market.
- More regularly review supplementary policies, making adjustments if necessary to improve the likelihood of their delivering the target levels of cost-effective emissions reductions.
- Establish criteria to distinguish between normal variations in economic conditions and policy delivery, which emissions trading scheme participants should be expected to manage, and "force-majeure" conditions, under which a mid-term review of the cap would be contemplated. In the case where a miscalibration is so severe that waiting until the next scheduled review risks undermining the longer-term future of the scheme, there will have to be a judgement made weighing the uncertainty created by intervention against the benefits of restoring the scheme's integrity. Having pre-established "force-majeure" conditions could be helpful in limiting the potential for such interventions to truly exceptional circumstances. The presence of price caps and floors could limit the need for mid-term reviews by restricting the impact of unforeseen shocks on trading scheme participants.
- Seek to phase out any redundant or only marginally useful supplementary policies during the review process, as it is likely to be more difficult to maintain policy alignment the larger the number of interacting policies. Many policies should explicitly be time-bound and transitional (OECD, 2009), and referenced to progress in phasing in the price mechanism.

Given three- to four-year political cycles, it is a reality that policies will be adjusted frequently. The more clearly the rationale for various components of the policy mix is articulated, and the complex interactions between policies understood, the greater the likelihood that these reviews will serve to strengthen and streamline policy over time.

Chapter summary: the policy process

The "core" policy set consists of a carbon price, supplemented by energy efficiency and technology support policies. These policies interact, so need to be aligned with one another.

Where an emissions trading scheme is the pricing policy, the trading scheme parameters (cap, offset entitlements) should be set to ensure a reasonable degree of scarcity in the trading scheme after emissions reductions from the supplementary policies are taken into account. Testing cap settings over a reasonable range of varying circumstances (delivery of supplementary

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[36] This suggestion has been put forward in both United States and European policy debates; for example, Bell (2008).

[37] Analogous to the inflation targets set for many reserve banks. These are not hard trigger points for intervention, rather they guide the actions of the central bank on an ongoing basis.

policies, BAU emissions) is important. Supplementary policies also need to be set taking the carbon price into account, allowing for a phase-out as the carbon price increases, and being designed to maximise certainty of delivery in order to provide more certainty to the trading scheme.

Policy alignment is simpler with a carbon tax, as the price level does not change in the presence of supplementary policies. However, for cost effectiveness, the tax level should still be set taking the emissions reductions from supplementary policies into account, and supplementary policies designed to phase out as the tax increases. In the absence of a carbon price, policies can be designed to attempt to mimic the effect a carbon price by deploying abatement options as broadly as possible up to a given “shadow” price level. If broad-based, policies such as clean energy standards could provide a reasonably effective (though higher-cost) response.

Beyond this core set of policies, further measures to address infrastructure lock-in and investment capital may be useful. However, the case for further supplementary policies to bolster a weak carbon price signal – which could be caused by a number of factors from lack of international coverage to political unacceptability – is more complex. In general, because of their potential to undermine long-term cost-effective action, policies that second-guess the carbon price should be avoided. There is, however, a conflicting necessity for short-term emissions reductions if the 2°C global target is to remain achievable. If short-term measures to supplement a weak carbon price are introduced, it should be made clear that any such policies are transitional, and their phase-out could be linked to progress in implementing the trading scheme. The number of supplementary policies should be minimised if possible, as it becomes more difficult to maintain policy coherence the greater the number of policies.

Impacts on the wider economy, and wider policy priorities, also need to be considered: it is possible that some policies, though efficient, could have negative macro-economic or social implications that mean adjustments to the policy package are needed. In this case, the “core” settings may need to be tightened to deliver the same level of emissions reductions.

Finally, given the strong interactions within the policy package, any initial calibration is likely to drift out of alignment over time, or become significantly misaligned by unforeseen shocks. In general, for investment certainty, reviews to reset emissions trading scheme caps and allocations should only occur at scheduled review times, and be subject to well understood criteria. Supplementary policies can be tracked and updated more frequently to maximise their delivery. However, it is also possible that a misalignment could be so severe that the benefits of re-establishing policy balance outweigh the damage to investment certainty caused by intervening in the market. In this case, having pre-established criteria for when such interventions would be contemplated could help with investor confidence.

6. Conclusions

Carbon pricing is a cornerstone policy in climate change mitigation, but it is not a complete solution on its own. There are barriers to the effective response to a price signal that justify additional measures to overcome these barriers and deliver a least-cost policy response. The short- and long-term efficiency of carbon pricing can be enhanced by overcoming barriers to energy-efficiency deployment, and accelerating the development of new technologies that can allow lower carbon costs in the future. Even where it is not feasible to implement carbon pricing at this time, following the same principle of design – using a common shadow carbon price to align policies – can result in policies that, although more costly, can still be effective.

In addition, in real-world implementations of carbon pricing, there will always be incomplete coverage or design compromises that may warrant further supplementary policies. Two common areas of focus are infrastructure funding, and supporting financing arrangements for low-carbon investment. Policies may also need to be "second-best" from a pure economic perspective in order to be robust in the long term. For example, dealing with distributional issues relating to where costs fall within society is important both for initial acceptance of climate policy and for its ongoing strengthening. This could include the need for further supplementary policies.

A further set of supplementary policies such as backstop regulatory emissions control or supplementary taxes could be considered to bolster a weak carbon price, but these should be approached with caution: policies that second-guess the carbon price risk undermining its use in the longer term, which could reduce the efficiency and effectiveness of the long-term decarbonisation transition. However, there is also a short-term imperative for global emissions reductions to peak before 2020 if the 2°C temperature target is to stay within reach, so some temporary supplementation could be justified while price mechanisms are phased in. In this case, policies should be explicitly transitional and time-bound (OECD, 2009). Maintaining coherence of a complex interacting policy package over time will be difficult, so additional policies should be avoided unless clearly beneficial.

The need for a policy mix has been recognised by many governments, but experience to date has been that the interactions among multiple policies are often not well understood nor well coordinated, which can lead to policy redundancy or policies undermining one another, reducing the effectiveness and efficiency of the overall package.

The analysis in this paper has found that these interactions are particularly acute in the presence of quantity-based policies, particularly emissions trading systems. Here, care needs to be taken that the package of trading scheme (cap, offset entitlements) and supplementary policies are aligned to enable a positive permit price under varying economic conditions. This is a particular issue at present in the European Union, where the overlap of renewable energy and energy efficiency policies with the EU ETS is being debated. One element of such policy alignment is to ensure that supplementary policies do not deliver so much of the targeted emissions reduction that the price mechanism has little room to function. It is also helpful to design supplementary policies to provide as much certainty as possible over their delivery of emissions reductions, which in turn helps carbon price certainty and provides greater stability for investors.

For certainty, carbon pricing policies should only be reviewed through regular, well-understood processes. Most variations in economic conditions or policy delivery will not require adjustments to emissions trading scheme caps: these are normal fluctuations that market participants should be able to manage. Where there is significant misalignment, caps can be tightened at the regular reviews (and the likelihood of this could be signalled in advance).

There is also the potential for "force-majeure" events for which the scheme parameters were not designed, and which could risk undermining the scheme's integrity (for example, collapsing prices completely) and therefore the decarbonisation transition. Here, mid-course adjustments could be considered, but this will entail carefully balancing the uncertainty caused by unscheduled intervention and the benefits of recalibrating the scheme. Setting criteria for the truly exceptional circumstances under which such reviews would be considered would be helpful in reassuring market participants. Although these exceptional reviews would raise uncertainty, the commitment to maintaining scheme integrity could provide assurance to low-carbon investors.

As global emissions continue to rise, the window for taking action that will allow temperatures to stay within the 2°C target is rapidly closing. The time for action is now, but concerns about costs are often seen as a barrier. Combining policies to give least-cost, realistic policy responses can assist governments in implementing the actions that are necessary.

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