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15

National and Sub-national Policies and Institutions

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Contents

Executive Summary

Since the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4), there has been a marked increase in national policies and legislation on climate change, however, these policies, taken together, have not yet achieved a substantial deviation in emissions from the past trend. Many baseline scenarios (those without additional policies to reduce emissions) show GHG concentrations that exceed 1000 ppm CO_2eq by 2100, which is far from a concentration with a likely probability of maintaining temperature increases below 2 °C this century. Mitigation scenarios suggest that a wide range of environmentally effective policies could be enacted that would be consistent with such goals. This chapter assesses national and sub-national policies and institutions to mitigate climate change in this context. It assesses the strengths and weaknesses of various mitigation policy instruments and policy packages and how they may interact either positively or negatively. Sector-specific policies are assessed in greater detail in the individual sector chapters (7–12). Major findings are summarized as follows. [Section 15.1]

The design of institutions affects the choice and feasibility of policy options as well as the sustainable financing of climate change mitigation measures (*limited evidence, medium agreement*). By shaping appropriate incentives, creating space for new stakeholders in decision making, and by transforming the understanding of policy choices, institutions designed to encourage participation by representatives of new industries and technologies can facilitate transitions to low-emission pathways, while institutions inherited unchanged from the past can perpetuate lock-in to high-carbon development paths. [15.2, 15.6]

There has been a considerable increase in national and sub-national mitigation plans and strategies since AR4 (*medium evidence, high agreement*). These plans and strategies are in their early stages of development and implementation in many countries, making it difficult to assess whether and how they will result in appropriate institutional and policy change, and thus, their impact on future emissions. However, to date these policies, taken together, have not yet achieved a substantial deviation in emissions from the past trend. Theories of institutional change suggest they might play a role in shaping incentives, political contexts, and policy paradigms in a way that encourages emissions reductions in the future. [15.1, 15.2]

Sector-specific policies have been more widely used than economy-wide, market-based policies (*medium evidence, high agreement*). Although economic theory suggests that economy-wide market-based policies for the singular objective of mitigation would generally be more cost-effective than sector-specific policies, political economy considerations often make economy-wide policies harder to design and implement than sector-specific policies. Sector-specific policies may also be needed to overcome sectoral market failures that price policies do not address. For example, building codes can require publicly funded energy efficient investments where private investments would otherwise not exist. Sector approaches also allow for packages of complementary policies, as, for example, in transport, where pricing policies that raise the cost of carbon-intensive forms of private transport are more effective when backed by public investment in viable alternatives. [15.1, 15.2, 15.5, 15.8, 15.9]

Direct regulatory approaches and information measures are widely used, and are often environmentally effective, though debate remains on the extent of their environmental impacts and cost effectiveness (*medium evidence, medium agreement*). Examples of regulatory approaches include energy efficiency standards; examples of information programmes include labelling programmes that can help consumers make better-informed decisions. While such approaches often work at a net social benefit, the scientific literature is divided on whether such policies are implemented with negative private costs to firms and individuals. Since AR4 there has been continued investigation into 'rebound' effects that arise when higher efficiency leads to lower energy prices and greater consumption. There is general agreement that such rebound effects exist, but there is low agreement in the literature on the magnitude. [3.9.5, 8.3, 9.7.2.4, 15.5.4, 15.5.5]

Fuel taxes are an example of a sector-specific policy and are often originally put in place for objectives such as revenue—they are not necessarily designed for the purpose of climate change mitigation (*high confidence*). In Europe, where fuel taxes are highest, they have contributed to reductions in carbon emissions from the transport sector of roughly 50 % for this group of countries. The short-run response to higher fuel prices is often small, but long-run price elasticities are quite high, or roughly −0.6 to −0.8. This means that in the long run, 10 % higher fuel prices correlate with 7 % reduction in fuel use and emissions. In the transport sector, taxes have the advantage of being progressive or neutral in most countries and strongly progressive in low-income countries. [15.5.2]

Reduction of subsidies to fossil energy can result in significant emission reductions at negative social cost (*high confidence*). [15.5.2] Although political economy barriers are substantial, many countries have reformed their tax and budget systems to reduce fuel subsidies that actually accrue to the relatively wealthy, and utilized lump-sum cash transfers or other mechanisms that are more targeted to the poor. [15.5.3]

Cap and trade systems for greenhouse gases are being established in a growing number of countries and regions (*limited evidence, medium agreement*). Their environmental effect has so far been limited because caps have either been loose or have not yet been binding. There appears to have been a tradeoff between the political feasibility and environmental effectiveness of these programmes, as well as between political feasibility and distributional equity in the allocation of permits. Greater environmental effectiveness through a tighter cap may be combined with a price ceiling that makes for political feasibility. [15.5.3]

Carbon taxes have been implemented in some countries and—alongside technology and other policies—have contributed to decoupling of emissions from gross domestic product (GDP) (*high confidence*). Differentiation by sector, which is quite common, reduces cost-effectiveness that arises from the changes in production methods, consumption patterns, lifestyle shifts, and technology development, but it may increase political feasibility, or be preferred for reasons of competitiveness or distributional equity. In some countries, high carbon and fuel taxes have been made politically feasible by refunding revenues or by lowering other taxes in an environmental fiscal reform. [15.2, 15.5.2, 15.5.3]

Adding a mitigation policy to another may not necessarily enhance mitigation (*high confidence*). For instance, if a cap and trade system has a sufficiently stringent cap, then other policies such as renewable subsidies have no further impact on total emissions (although they may affect costs and possibly the viability of more stringent future targets). If the cap is loose relative to other policies, it becomes ineffective. This is an example of a negative interaction between policy instruments. Since other policies cannot be 'added on' to a cap-and-trade system, if it is to meet any particular target, a sufficiently low cap is necessary. A carbon tax, on the other hand, can have an additive environmental effect to policies such as subsidies to renewables. [15.7]

There is a distinct role for technology policy as a complement to other mitigation policies (*high confidence*). Properly implemented technology policies reduce the cost of achieving a given environmental target. Technology policy will be most effective when technology-push policies (e.g., publicly funded research and development (R&D)) and demand-pull policies (e.g., governmental procurement programmes or performance regulations) are used in a complementary fashion (*robust evidence, high agreement*). [15.6] While technology-push and demand-pull policies are necessary, they are unlikely to be sufficient without complementary framework conditions. Managing social challenges of technology policy change may require innovations in policy and institutional design, including building integrated policies that make complementary use of market incentives, authority and norms (*medium evidence, medium agreement*). [15.6.5].

Since AR4, a large number of countries and sub-national jurisdictions have introduced support policies for renewable energy such as feed-in tariffs (FIT) and renewable portfolio standards (RPS). These have promoted substantial diffusion and innovation of new energy technologies such as wind turbines and photovoltaic (PV) panels, but have raised questions about their economic efficiency, and introduced challenges for grid and market integration (7.12, 15.6).

Worldwide investment in research in support of climate change mitigation is small relative to overall public research spending (*medium evidence, medium agreement*). The effectiveness of research support will be greatest if it is increased slowly and steadily rather than dramatically or erratically. It is important that data collection for programme evaluation be built into technology policy programmes, because there is very little empirical evidence on the relative effectiveness of different mechanisms for supporting the creation and diffusion of new technologies. [15.6.2, 15.6.5]

Public finance mechanisms reduce risks that deter climate investments (*high confidence*). The future value of carbon permits created by an economic instrument such as cap and trade may, for example, not be accepted as sufficiently secure by banks. Government public finance mechanisms to reduce risks include debt and equity mechanisms, carbon finance, and innovative grants. [15.12]

Government planning and provision can facilitate shifts to less energy and GHG-intensive infrastructure and lifestyles (*high confidence*). This applies particularly when there are indivisibilities in the provision of infrastructure as in the energy sector (e.g., for electricity transmission and distribution or district heating networks); in the transport sector (e.g., for non-motorized or public transport), and in urban planning. The provision of adequate infrastructure is important for behavioural change (*medium evidence, high agreement*) [15.5.6].

Successful voluntary agreements on mitigation between governments and industries are characterized by a strong institutional framework with capable industrial associations (*medium evidence, medium agreement*). The strengths of voluntary agreements are speed and flexibility in phasing measures, and facilitation of barrier removal activities for energy efficiency and low emission technologies. Regulatory threats, even though the threats are not always explicit, are also an important factor for firms to be motivated. There are few environmental impacts without a proper institutional framework *(medium evidence, medium agreement).* [15.5.5]

Synergies and tradeoffs between mitigation and adaptation policies may exist in the land-use sector (*medium evidence, medium agreement*). For other sectors such as industry and power, the connections are not obvious. [15.11]

The ability to undertake policy action requires information, knowledge, tools, and skills, and therefore capacity building is central both for mitigation and to the sustainable development agenda (*medium evidence, high agreement*). The needs for capacity building include capacity to analyze the implications of climate change; capacity to formulate, implement, and evaluate policies; capacity to take advantage of external funding and flexible mechanisms; and capacity to make informed choices of the various capacity building modalities. [15.10]

Mainstreaming climate change into development planning has helped yield financing for various climate policy initiatives (*medium evidence, medium agreement*). Among developing and some least developed countries, an emerging trend is the establishment of national funding entities dedicated to climate change. While diverse in design and objectives, they tap and blend international and national sources of finance, thereby helping to improve policy coherence and address aid fragmentation. Financing adaptation and mitigation in developing countries is crucial from the viewpoint of welfare and equity (*medium evidence, high agreement*). [15.12]

Gaps in knowledge: The fact that various jurisdictions produce various policy instruments influenced by co-benefits and political economy and that they interact in complex manners makes it difficult to evaluate the economic and environmental effectiveness of individual policy instrument as well as policy package of a nation. Most importantly, it is not known with certainty how much an emission reduction target may cost to the economy in the real world in comparison to the 'first best' optimal solution estimated by economic models in other chapters in this report. Costs may be under-stated or over-stated.

15.1 Introduction

This chapter assesses national and sub-national mitigation policies and their institutional settings. There has been a marked increase in national policies and legislation on climate change since the AR4 with a diversity of approaches and a multiplicity of objectives (see Section 15.2). However, Figure 1.9 of Chapter 1 suggests that these policies, taken together, have not yet achieved a substantial deviation in emissions from the past trend. Limiting concentrations to levels that would be consistent with a likely probability of maintaining temperature increases below 2 °C this century (scenarios generally in the range of 430–480 ppmv CO_2eq) would require that emissions break from these trends and be decreased substantially. In contrast, concentrations exceed 1000 ppmv CO_2eq by 2100 in many baseline scenarios (that is, scenarios without additional efforts to reduce emissions).

The literature on mitigation scenarios provides a wide range of CO_2 shadow price levels consistent with these goals, with estimates of less than USD 50/tCO_2 in 2020 in many studies and exceeding USD 100/tCO_2 in others, assuming a globally-efficient and immediate effort to reduce emissions. These shadow prices exhibit a strongly increasing trend thereafter. Policies and instruments are assessed in this light.

Section 15.2 assesses the role of institutions and governance. Section 15.3 lays out the classification of policy instruments and packages, while 15.4 discusses the methodologies used to evaluate policies and institutions. The performance of various policy instruments and measures are individually assessed in Sections 15.5 and 15.6.

The two main types of economic instruments are price instruments, that is, taxes and subsidies (including removal of subsidies on fossil fuels), and quantity instruments—emission-trading systems. These are assessed in Sections 15.5.2 and 15.5.3 respectively. An important feature of both these instruments is that they can be applied at a very broad, economy-wide scale. This is in contrast to the regulation and information policies and voluntary agreements which are usually sector-specific. These policies are assessed in Sections 15.5.4, 15.5.5, and 15.5.7. Government provision and planning is discussed in 15.5.6. The next section, 15.6, provides a focused discussion on technology policy including research and development and the deployment and diffusion of clean energy technologies. In addition to technology policy, longer-term effects of the policies assessed in Section 15.5 are addressed in Section 15.6.

Both these sections, 15.5 and 15.6, bring together lessons from policies and policy packages used at the sectoral level from Chapters 7 (Energy), 8 (Transport), 9 (Buildings), 10 (Industry), 11 (Agriculture, Forestry and Land Use) and Chapter 12 (Human Settlements, Infrastructure, and Spatial Planning).

The following sections further assess the interaction among policy instruments, as they are not usually used in isolation, and the impacts of particular instruments depend on the entire package of policies and the institutional context. Section 15.7 reviews interactions, both beneficial and harmful, that may not have been planned. The presence of such interactions is in part a consequence of the multi-jurisdictional nature of climate governance as well as the use of multiple policy instruments within a jurisdiction. Section 15.8 examines the deliberate linkage of policies across national and sub-national jurisdictions.

Other key issues are further discussed in dedicated sections. They are: the role of stakeholders including non-governmental organizations (NGOs) (15.9), capacity building (15.10), links between adaptation and mitigation policies (15.11), and investment and finance (15.12). Gaps in knowledge are collected in 15.13.

15.2 Institutions and governance

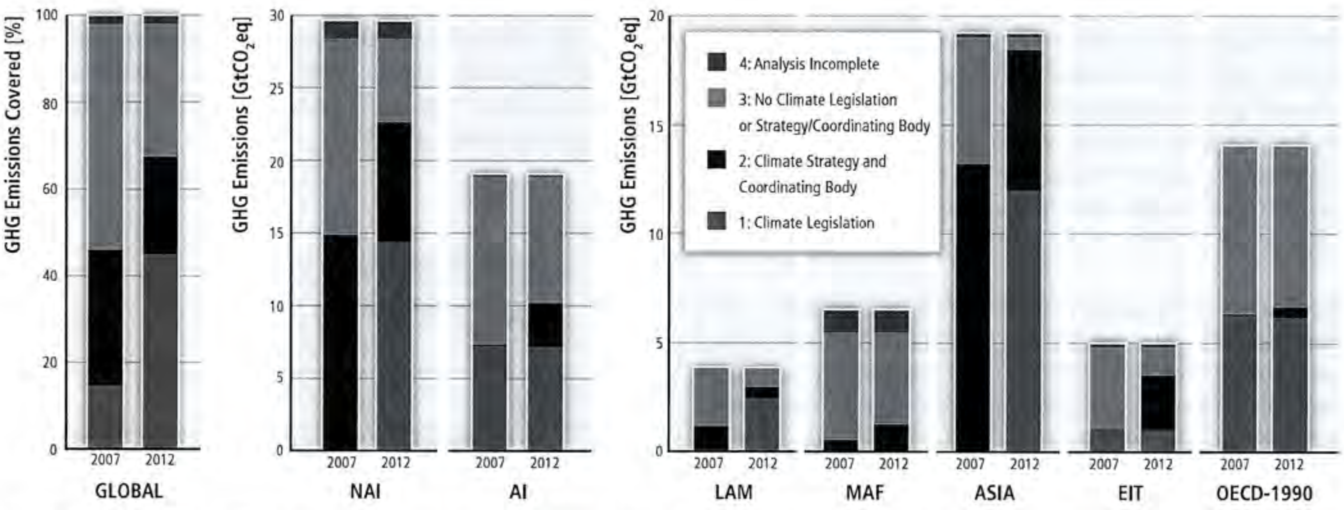
15.2.1 Why institutions and governance matter

Institutions and processes of governance (see Annex 1: Glossary for definitions) shape and constrain policy-making and policy implementation in multiple ways relevant for a shift to a low carbon economy. First, institutions—understood as formal rules and informal norms—set the incentive structure for economic decision making (North, 1991), influencing, for example, decisions about transportation investments, and behavioural decisions relevant to efficient energy use. Second, institutions shape the political context for decision making, empowering some interests and reducing the influence of others (Steinmo et al., 1992; Hall, 1993). Harrison (2012) illustrates this with respect to environmental tax reform in Canada. Third, institutions can also shape patterns of thinking and understanding of policy choices—through both normative and cognitive effects (Powell and DiMaggio, 1991). These effects can result in dominant policy paradigms—ideas, policy goals, and instruments—that favour some actions and exclude others from consideration (Radaelli and Schmidt, 2004). For example, existing energy systems are likely to remain in place without appropriate institutional change (Hughes, 1987) and changes in discourse, which would perpetuate existing technologies and policies and lock out new ones (Unruh, 2000; Walker, 2000). More generally, a mismatch between social-ecological context and institutional arrangements can lead to a lack of fit and exert a drag on policy and technological response (Young, 2002).

15.2.2 Increase in government institutionalization of climate mitigation actions

There has been a definite increase since AR4 in formal governmental efforts to promote climate change mitigation. These efforts are diverse in their approach, scale, and emphasis, and take the form of legislation, strategies, policies, and coordination mechanisms. Many of these are relatively recent, and often in the design or early implementation stage. As a result, it is premature to evaluate their effectiveness and there is insufficient literature as yet that attempts to do so. Since global greenhouse gas emissions have continued to increase in recent years (Chapter 5 and Section 15.1), it will be important to closely monitor this trend to evaluate if policies and institutions created are sufficiently strong and effective to lead to the reductions required to stabilize global temperature, for instance, at the 2 °C target. This section reviews national centralized governmental actions, while 15.2.3 discusses sectoral actions and 15.2.5 examines the roles of other stakeholders including non-state actors.

A review of climate legislation and strategy in almost all United Nation (UN) Member States shows that there has been a substantial increase in these categories between 2007 and 2012 (Dubash et al., 2013) (See Figure 15.1). Dubash et al. (2013) define climate legislation as mitigation-focused legislation that goes beyond sectoral action alone, while climate strategy is defined as a non-legislative plan or framework aimed at mitigation that encompasses more than a small number of sectors, and that includes a coordinating body charged with implementation. International pledges are not included. By these definitions, 39 % of countries, accounting for 73 % of population and 67 % of greenhouse gas emissions, were covered by climate law or strategies in 2012, an increase from 23 % of countries, 36 % of population, and 45 % of emissions in 2007. There are also strong regional differences,



1	7 (15%)	22 (44%)
2	15 (30%)	11 (23%)
3	25 (52%)	15 (30%)
4	1 (3%)	1 (3%)

1	0 (0%)	14 (49%)	7 (38%)	7 (38%)
2	15 (50%)	8 (28%)	0 (0%)	3 (16%)
3	14 (46%)	6 (19%)	12 (61%)	9 (46%)
4	1 (4%)	1 (4%)	0 (1%)	0 (1%)

1	0 (2%)	2 (63%)	0 (0%)	0 (0%)	0 (0%)	12 (62%)	1 (20%)	1 (20%)	6 (44%)	6 (44%)
2	1 (28%)	1 (13%)	1 (8%)	1 (19%)	13 (69%)	6 (34%)	0 (0%)	3 (50%)	0 (0%)	0 (3%)
3	3 (70%)	1 (23%)	5 (76%)	4 (65%)	6 (30%)	1 (3%)	4 (76%)	1 (26%)	8 (55%)	7 (53%)
4	0 (0%)	0 (0%)	1 (16%)	1 (16%)	0 (1%)	0 (1%)	0 (3%)	0 (3%)	0 (0%)	0 (0%)

Figure 15.1 | National climate legislation and strategies in 2007 and 2012.* Reproduced from Dubash et al., (2013). In this figure, climate legislation is defined as mitigation-focused legislation that goes beyond sectoral action alone. Climate strategy is defined as a non-legislative plan or framework aimed at mitigation that encompasses more than a small number of sectors, and that includes a coordinating body charged with implementation. International pledges are not included, nor are sub-national plans and strategies. The panel shows proportion of GHG emissions covered.

* Number of countries and GHG emissions covered (NAI: Non Annex I countries (developing countries), AI: Annex I countries (developed countries), LAM: Latin America, MAF: Middle East and Africa, ASIA: Asia, EIT: Economies in Transition, OECD-1990: OECD of 1990)

with Asia and Latin America recording the fastest rate of increase. Taken as a block, in 2012, 49 % of current emissions from the developing world regions of Asia, Africa, and Latin America were under climate law and 77 % of emissions were under either law or strategy, while for the developed world regions of Organisation for Economic Co-operation and Development 1990 Countries OECD-1990 and Economies in Transition (EIT) the equivalent numbers are 38 % and 56 %. Finally, while the number of countries with climate legislation increased marginally from 18 % to 22 % over this period, the number of countries with climate strategies increased from 5 % to 18 %, suggesting many more countries are adopting a strategy-led approach. (For regional aggregations see Annex II.2)

Climate legislation and strategies follow a wide diversity of approaches to operationalization and implementation. The imposition of carbon prices is one approach widely discussed in the literature (See Section 15.5) but less frequently implemented in practice. Examples include the European Union's Emissions Trading Scheme (ETS) (See Section 14.4.2) or setting of carbon taxes (see Section 15.5.2). One study of the 19 highest emitting countries finds that six have put in place some form of carbon price, while 14 have put in place both regulation and other economic incentives for greenhouse gas mitigation (Lachapelle and Paterson, 2013). Common explanations for this variation are in terms of the novelty of emissions trading (although emissions trading has been in practice implemented much more widely than carbon taxation), the legitimacy problems faced by emissions trading (Paterson, 2010), or political contestation over increased taxation (see for example Laurent (2010), on the French case, Jotzo (2012) for Australia or Jagers and Hammar (2009), for evidence that popular support for carbon taxes in Sweden depend on how it is framed in popular debate), and lobbying by fossil-fuel or energy-intense industry lobbies (Bailey et al., 2012; Sarasini, 2013).

More generally speaking, policy instruments have often been sector-specific. Economy-wide instruments, even when implemented, have had exemptions for some sectors, most commonly those most exposed to international trade. The exemptions have arisen because national policies have been developed under the strong influence of sectoral policy networks (Compston, 2009) and many stakeholders therein—including firms and NGOs—influence the policy to promote their interests (Helm, 2010). This phenomenon undermines the overall cost-effectiveness of climate policy (Anthoff and Hahn, 2010) although it may help further other objectives such as equity and energy security (see Section 15.7).

Another approach follows a model of national-level target backed by explicit creation of institutions to manage performance to that target. In China, for example, a 'National Leading Group on Climate Change' in June 2007, housed in the apex National Development and Reform Commission and chaired by the premier (Tsang and Kolk, 2010a) coordinates the achievement of targets set in the subsequent National Climate Change Programme. The Chinese examples illustrate a broader point emerging from a cross-country study that implementation of climate legislation and plans are, in at least some cases, drawing powerful finance and planning departments into engagement with climate change (Held et al., 2013).

Another approach is to establish dedicated new climate change bodies that are substantially independent of the executive and that seek to coordinate existing government agencies through a variety of levers. The leading example of this approach is in the UK, where a dedicated Climate Change Committee analyzes departmental plans and monitors compliance with five-year carbon budgets (U.K., 2008; Stallworthy, 2009). Instead of direct executive action, as in the Chinese case, this approach relies on analysis, public reporting, and advice to government. Following the UK example, Australia has established an independent Climate Change Authority to advise the government on emission targets and review effectiveness of its Carbon Pricing Mechanism (Keenan et al., 2012).

15.2.3 Climate change mitigation through sectoral action

While there is no systematic study of implementation of climate plans, case study evidence suggests that these plans are frequently operationalized through sectoral actions. There are a variety of ways through which national plans interface with sectoral approaches to mainstream climate change. In some cases, there is a formal allocation of emissions across sectors. For example, in Germany, mitigation efforts were broken down by sectors for the period between 2008 and 2012, with the national 'Allocation Act 2012' specifying emissions budgets for sectors participating in the EU ETS as well as the remaining sectors (Dienes, 2007; Frenz, 2007). More typically, climate mainstreaming occurs through a sector by sector process led by relevant government departments, as in France (Mathy, 2007), India (Dubash, 2011; Atteridge et al., 2012), and Brazil (da Motta, 2011a; La Rovere et al., 2011).

In some cases, the sectoral process involves a role for stakeholders in engagement with government departments. In France, sectoral approaches are devised at the central level through negotiation and consultation between multiple ministries, experts, business, and NGOs. According to at least one analysis, this approach risks a dilution of measures through the influence of lobbies that may lose from mitigation actions (Mathy, 2007). In Brazil, sector specific approaches are developed by sectoral ministries complemented by a multi-stakeholder forum to solicit views and forge consensus (Hochstetler and Viola, 2012; Viola and Franchini, 2012; Held et al., 2013a).

In some cases, climate change considerations bring about changes in long-standing patterns of sector governance. In South Africa, for example, the Copenhagen pledge led to a process of reconsidering South Africa's integrated resource plan for electricity to include carbon reduction as one among multiple criteria (Republic of South Africa, 2011). In India, the establishment of national sectoral 'missions' had the effect of creating new institutional mechanisms in the case of the National

Solar Mission, or of raising the profile and importance of particular ministries or departments as in the example of the Bureau of Energy Efficiency (Dubash, 2011). In other cases, climate mainstreaming was facilitated by prior political shifts in governance of a sector. Brazil's climate approach particularly emphasizes the forest sector (da Motta, 2011b; La Rovere, 2011). Progress on the Brazilian plan was enabled by prior domestic political consensus around a far-reaching Forest Code (Hochstetler and Viola, 2012).

15.2.4 Co-Benefits as a driver of mitigation action

The importance of co-benefits—both development gains from climate policy and climate gains from development policy—emerge as a particularly strong rationale and basis for sectoral action. As Table 6.7 shows, an inventory of sectoral action on climate change (drawn from Chapter 7–12) is linked to a wide range of co-benefits and adverse side-effects, encompassing economic, social, and environmental effects. Table 15.1 provides a roadmap for the co-benefits and adverse side-effects from sectoral mitigation measures most prominently discussed across Chapters 7 to 12. They are listed in three columns: economic, social, and environmental. Each column shows the range of effects on objectives or concerns beyond mitigation discussed in Chapters 7.12 for that category. For example, energy security is categorized in the column of 'economic' and addressed in Section 7.9, 8.7, 9.7, 10.8, 11.13.6, and 12.8.

This perception is reinforced by comparative case studies and specific country studies. A comparative study finds that co-benefits is an important driving force for mitigation policies across large, rapidly industrializing countries (Bailey and Compston, 2012a), a finding that is supported by country level studies. India's National Action Plan on Climate Change (NAPCC), for example, is explicitly oriented to pursuit of co-benefits, with mitigation understood to be the secondary benefit emerging from development policies. The linkage between energy security and mitigation is particularly important to winning broader political support for action on mitigation (Dubash, 2011; Fisher, 2012). A similar trend is apparent in China (Oberheitmann, 2008), where provincial implementation of targets is enabled by linking action to local motivations, notably for energy efficiency (Teng and Gu, 2007; Richerzhagen and Scholz, 2008a; Qi et al., 2008; Tsang and Kolk, 2010b; Kostka and Hobbs, 2012). Tsang and Kolk (2010a) go so far as to say that Chinese leaders essentially equate climate policy with energy conservation. Kostka and Hobbs (2012) identify three ways in which this alignment of global and local objectives happens: interest bundling, through which objectives of political institutions are tied to local economic interests; policy bundling, to link climate change with issues of local political concern; and framing in ways that play to local constituencies.

The concept of 'nationally appropriate mitigation actions' (NAMAs) has a conceptual connection to the idea of co-benefits. Nationally appropriate mitigation actions are intended to be mitigation actions that are 'nationally appropriate' in the sense that they contribute to development outcomes. Therefore, NAMAs provide a possible mechanism for connection of national policies and projects to the global climate regime, although the mechanisms through which this will be accomplished are yet to be fully articulated (see Box 15.1). Another, related mechanism is the explicit formulation in many countries of 'low emissions development strategies' that seek to integrate climate and development strategies (Clapp et al., 2010).

15.2.5 Sub-national climate action and interaction across levels of governance

In many countries, the formulation and implementation of national mitigation approaches are further delegated to sub-national levels, with differing levels of central coordination, depending on national contexts and institutions. Comparative analysis of cross-country climate action is insufficiently developed to allow generalization and explanation of different approaches to climate policy.

Table 15.1 | Roadmap for the assessment of potential co-benefits and adverse side-effects from mitigation measures for additional objectives in the sector chapters (7–12). For overview purposes, only those objectives and concerns are shown that are assessed in at least two sectors. For a broader synthesis of the literature assessed in this report, see Section 6.6.

Effect of mitigation measures on additional objectives or concerns		
Economic	**Social**	**Environmental**
Energy security (7.9, 8.7, 9.7, 10.8, 11.13.6, 12.8)	Health impact (e.g., via air quality and noise) (5.7, 7.9, 8.7, 9.7, 10.8, 11.7, 11.13.6, 12.8)	Ecosystem impact (e.g., via air pollution) (7.9, 8.7, 9.7, 10.8, 11.7, 11.13.6/7, 12.8)
Employment impact (7.9, 8.7, 9.7, 10.8, 11.7, 11.13.6)	Energy/mobility access (7.9, 8.7, 9.7, 11.13.6, 12.4)	Land-use competition (7.9, 8.7, 10.8, 11.7, 11.13.6/7)
New business opportunity/economic activity (7.9, 11.7, 11.13.6)	(Fuel) Poverty alleviation (7.9, 8.7, 9.7, 11.7, 11.13.6)	Water use/quality (7.9, 9.7, 10.8, 11.7, 11.13.6)
Productivity/competitiveness (8.7, 9.7, 10.9, 11.13.6)	Food security (7.9, 11.7, 11.13.6/7)	Biodiversity conservation (7.9, 9.7, 11.7, 11.13.6)
Technological spillover/innovation (7.9, 8.7, 10.8, 11.3, 11.13.6)	Impact on local conflicts (7.9, 10.8, 11.7, 11.13.6)	Urban heat island effect (9.7, 12.8)
	Safety/disaster resilience (7.9, 8.7, 9.7, 10.8, 12.8)	Resource/material use impact (7.9, 8.7, 9.7, 10.8, 12.8)
	Gender impact (7.9, 9.7, 11.7, 11.13.6)	

Box 15.1 | Nationally Appropriate Mitigation Actions (NAMAs)

The Bali Action Plan (BAP), (1/CP.13; UNFCCC, 2007) states that developing countries are called on to take NAMAs supported and enabled by technology and finance. For example, NAMAs could be articulated in terms of national emissions intensity or trajectories, sectoral emissions, or specific actions at sectoral or sub-sectoral levels. As of June 2013, 57 parties had submitted NAMAs to the United Nations Framework Convention on Climate Change (UNFCCC) secretariat.

The design of mechanisms to link NAMAs to global support lead to some complex tradeoffs. For example, large scale sectoral NAMAs provide the least scope for leakage (decreased emissions in one sector is undermined by increased emissions in another part of the economy) and the lowest measurement costs (Jung et al., 2010). However, designing NAMAs around transaction costs might run counter to designing them for targeted focus on national development priorities. Exploring the extent of this tradeoff and managing it carefully will be an important part of implementing NAMAs.

Much of the writing on NAMAs is focused on the challenges of linking national actions to the international climate framework. Conceptual challenges involved in linking NAMAs to the UNFCCC process include the legal nature of NAMAs (van Asselt et al., 2010), financing of NAMAs, and associated concerns of avoiding double counting (Cheng, 2010; Jung et al., 2010; van Asselt et al., 2010; Sovacool, 2011a) and measurement, reporting, and verification of NAMAs (Jung et al., 2010; Sterk, 2010; van Asselt et al., 2010).

While NAMAs pertain particularly to the developing world, co-benefits based arguments are also used in developed countries. In the United States, Gore and Robinson (2009) argue that expansion of municipal scale action is articulated in the form of co-benefits, and is driven by network-based communication and citizen initiative. In Germany, several benefits in addition to climate change have been attributed to the policy for energy transition or 'Energiewende,' including security of energy supply and industrial policy (Lehmann and Gawel, 2013).

In some federal systems, national target setting by the central government is followed by further allocation of targets to provinces, often through nationally specific formulae or processes. For example, in the case of Belgium, Kyoto targets were re-allocated to the regional level through a process of negotiation, followed by the preparation of regional climate plans to implement regional targets (Happaerts et al., 2011). Ultimately, since agreement could not be reached on regional targets to meet the national Kyoto targets, the approach relied on offsets were explicitly internalized as part of the national approach to meeting Kyoto targets. In China, national action is defined and monitored by the central government in consultation with provinces, and implementation is delegated to provinces. Targets set in the subsequent National Climate Change Programme as part of the 11th Five Year Plan were implemented through a mechanism of provincial communiqués to track compliance with the target, and provincial leading groups to implement the target (Teng and Gu, 2007; Qi et al., 2008; Tsang and Kolk, 2010b; Held et al., 2011a; Kostka and Hobbs, 2012). A range of policy mechanisms were used to implement this target, such as differential energy prices based on energy efficiency performance, promotion of energy audits, and financial incentives for performance (Held et al., 2011b). Subsequent revised targets have been set for the 12th Five Year Plan.

Other countries represent intermediate cases between central control and decentralization. India has developed a mix of national policies through its National Action Plan on Climate Change, responsibility for which rests with central government ministries, and State Action Plans on Climate Change to be developed and implemented by states (Dubash et al., 2013). While they are predominantly focused on implementing national level directives, there is also sufficient flexibility to pursue state-level concerns, and some states have created new mechanisms, such as the establishment of a Climate Change department in the state of Gujarat, and the establishment of a green fund in Kerala (Atteridge et al., 2012). In France, the EU objectives were adopted as national goals, and through national legislation, all urban agglomerations over 50,000 are required to prepare 'Climate and Energy Territorial Plans' to meet these goals and, additionally, to address adaptation needs (Assemblée Nationale, 2010). Since all other planning processes related to issues such as transport, building, urban planning, and energy have to conform to and support these objectives, this approach provides a powerful mechanism to mainstream climate change into local public planning. These plans also form a framework around which private voluntary action can be organized. In Germany, while the federal government initiates and leads climate action, the states or 'Länder' have a veto power against central initiatives through representation in the upper house of parliament (Weidner and Mez, 2008). In addition, however, the Länder may also take additional action in areas such as energy efficiency measures, renewable energy development on state property and even through state-wide targets (Biedermann, 2011).

In some cases, sub-national jurisdictions seem to be attempting to compensate for the lack of political momentum at the national level (Schreurs, 2008; Dubash, 2011). In the United States, for example, although progress at the federal level has been slow and halting, there have been multiple efforts at sub-national scales, through unilateral and coordinated action by states, judicial intervention, and municipal-scale action (Carlarne, 2008; Rabe, 2009, 2010; Posner, 2010). There are examples of states joining together in creating new institutional mechanisms, such as the Regional Greenhouse Gas Initiative (RGGI) among Northeastern states in the United States to institute an emissions trading programme, and the Western Climate Initiative (WCI) between California and several Canadian provinces, although both these initiatives have also failed to live up to their original promise (Mehling and Frenkil, 2013). Climate policy in the state of California, with its new cap and trade programme, is particularly worth noting both because of the size of its economy and because California has a history as a pioneer of environmental innovation (Mazmanian et al., 2008; Farrell and Hanemann, 2009).

As detailed further in Section 15.8, cities are particularly vibrant sites of sub-national action in some countries, often operating in networks and involving a range of actors at multiple scales (Betsill and Bulkeley, 2006; Gore and Robinson, 2009). For example, in the Netherlands, the central government has established a programme that provides subsidies to municipalities to undertake various measures such as improvements in municipal buildings and housing, improved traffic flow, sustainable energy, and so on (Gupta et al., 2007). In Brazil, important cities such as Rio de Janeiro and São Paulo have taken specific measures that go beyond national policies. For example, a 2009 São Paulo law (No. 13.798) commits the state to undertake mandatory economy-wide GHG emission reduction targets of 20 % by 2020 from 2005 levels (Lucon and Goldemberg, 2010). In the United States, over 1000 cities and municipalities have committed to reaching what would have been the US Kyoto target as part of the Conference of Mayors' Climate Protection Agreement (Mehling and Frenkil, 2013).

Sub-national action on climate change is a mix of bottom-up experimentation and the interaction of top-down guidance with local implementation action. In some cases, countries have set in place explicit mechanisms for coordination of national and sub-national action, such as in China and India, but there is insufficient evidence to assess the effectiveness of these mechanisms. More typical is relatively uncoordinated action and experimentation at sub-national level, particularly focused on cities. These issues are discussed further in Section 15.8.

15.2.6 Drivers of national and sub-national climate action

National and sub-national actions are related to domestic political institutions, domestic politics, international influences, and ideational factors. Based on data from industrialized countries, a comparative political analysis suggests that proportional representation systems such as those in many EU nations are more likely than first past the post systems to give importance to minority interests on environmental outcomes; systems with multiple veto points, such as the US system, afford more opportunities for opponents to block political action; and in federal systems powerful provinces with high compliance costs can block action, as seems to have occurred in Canada (Harrison and Sundstrom, 2010). Lachapelle and Paterson (2013) use quantitative analysis to substantiate the argument about proportional representation and systems with multiple veto points. They also show that presidential-congressional systems find it systematically more difficult to develop climate policy than parliamentary systems.

These are, however, only general tendencies: the specific details of country cases, as well as the possibility of multiple and interacting causal factors, suggests the need for caution in predicting outcomes based on these factors.

In particular, national domestic political factors are also salient. Electoral politics, operating through pressure for action from domestic constituents, is a determinant of action as is the cost of compliance (Harrison and Sundstrom, 2010). The role of climate change in electoral strategies developed by political parties may also play a role in climate governance, although evidence for this effect is available only for developed countries (Carter, 2008; Fielding et al., 2012; Bailey and Compston, 2012a). For example, the compliance costs of carbon pricing were the subject of direct electoral competition between Australia's major political parties in the 2007 and 2010 general elections (Rootes, 2011; Bailey et al., 2012). The presence of substantial co-benefits opportunities and re-framing policy around these opportunities can also influence domestic politics in favour of climate action (Held et al., 2013b); (Bailey and Compston, 2012a). Finally, the 'type' of state—liberal market, corporatist or developmental—can shape outcomes (Lachapelle and Paterson, 2013). For example, somewhat counter-intuitively corporatist states (e. g., Germany, South Korea) are more likely to have introduced carbon pricing than states with liberal market policy traditions (e. g., the United States, Canada). Conversely, liberal market economies are more likely, as are developmental states (e. g., China), to focus on R&D as a principal policy tool (on the United States, see notably Macneil (2012). These patterns reflect powerful institutional path dependencies and incentives facing actors promoting climate policy in particular countries (Macneil, 2012).

International pressures are also important in explaining state action. Diplomatic pressure, changes in public and private finance that emphasize mainstreaming climate change, and a general trend toward higher fossil-fuel energy prices all are associated with increasing climate action (Held et al., 2013b).

Finally, based on comparative case studies, various ideational factors such as national norms around multilateralism, perceptions of equity in the global climate regime (Harrison and Sundstrom, 2010), and ideas put forward by scientists, international organizations and other voices of authority can also shift domestic politics (Held et al., 2013b).

15.2.7 Summary of institutions and governance

The evidence on institutional change and new patterns of climate governance is limited, as many countries are in the process of establishing new institutions and systems of governance. However, several trends are visible. First, there is a considerable increase in government led institutionalization of climate action through both legislation and policy since AR4. The factors driving these changes include international pressures, scope for co-benefits, and changing norms and ideas. The specifics of national political systems also affect country actions. Second, evidence from national cases illustrates considerable diversity in the forms of action. While there are only a few cases of nationally led economy wide carbon price setting efforts, more common are sectoral approaches to climate change mitigation or delegated action to sub-national levels, often embedded within national climate policy frameworks. Third, the promise of 'co-benefits' is often an important stated reason for climate policies and their framing. Fourth, there is a profusion of activity at sub-national levels, particularly urban areas, much of which is only loosely coordinated with national actions. Finally, the diversity of approaches appears to be strongly driven by local institutional and political context, with legislative and policy measures tailored to operate within the constraints of national political and institutional systems.

15.3 Characteristics and classification of policy instruments and packages

This section presents a brief and non-exhaustive description of the main policy instruments and packages, using the common classification set by Chapter 3.8. Most of these instruments will be assessed with the common evaluation criteria set by Chapter 3 (see Section 15.5) in most of the remaining parts of this chapter. As indicated in Section 15.2, these instruments are introduced within an institutional context that obviously influences their design and implementation.

15.3.1 Economic instruments

Economic instruments are sometimes termed 'market-based' approaches because prices are employed in environmental and climate policies. Economic instruments for climate change mitigation include taxes (including charges and border adjustments), subsidies and subsidy removal, and emissions trading schemes. Taxes and subsidies are known as price instruments since they do not directly target quantities, while emissions trading schemes, especially cap-and-trade schemes (see below), are known as quantity instruments. This distinction can be important, as seen in Sections 15.5.3.8, 15.7.3.2, and 15.7.3.4.

Taxes and charges are ideally defined as a payment for each unit of GHG released into the atmosphere. In the climate context, they are usually unrelated to the provision of a service and are thus known as taxes rather than charges. They can be levied on different tax bases, whereas tax rates, given the global and uniform characteristics of the taxed emissions, usually do not show spatial variation (OECD, 2001). In the last years, many taxes on GHG or energy have devoted part of their revenues to the reduction of other distortionary taxes (green tax reforms), although other revenue uses are now playing an increasing role (Ekins and Speck, 2011).

Border tax adjustments are related instruments that intend to solve the dysfunctions of variable climate change regulations across the world. Although some authors highlight that they could alleviate the problem of leakage and a contribute to a wider application of mitigation policies (Ismer and Neuhoff, 2007), others emphasize that they do not constitute optimal policy instruments and could even increase leakage (Jakob et al., 2013) or cause potential threats to fairness and to the functioning of the global trade system (e.g., Bhagwati and Mavroidis, 2007).

Subsidies to low GHG products or technologies have been applied by a number of countries but, contrary to the previous revenue-raising/neutral economic instruments, they demand public funds. In some countries there are 'perverse' subsidies lowering the prices of fossil fuels or road transport, which bring about a higher use of energy and an increase of GHG emissions. Therefore, *subsidy reduction or removal* would have positive effects in climate change and public-revenue terms and is therefore treated as an instrument in its own right (OECD, 2008).

In 'cap-and-trade' *emissions trading systems* regulators establish an overall target of emissions and issue an equivalent number of emissions permits. Permits are subsequently allocated among polluters and trade leads to a market price. The allocation of emission permits can be done through free distribution (e.g., grandfathering) or through auctioning. In 'baseline and credit' emissions trading systems, polluters may create emission reduction credits (often project-based) by emitting below a baseline level of emissions (Stavins, 2003).

15.3.2 Regulatory approaches

Regulations and standards were the core of the first environmental policies and are still very important in environmental and climate policies all around the world. They are conventional regulatory approaches that establish a rule and/or objective that must be fulfilled by the polluters who would face a penalty in case of non-compliance with the norm. There are several categories of standards that are applicable to climate policies, mainly:

- *Emission standards*, which are the maximum allowable discharges of pollutants into the environment, and which can also be termed as performance standards;
- *Technology standards* that mandate specific pollution abatement technologies or production methods (IPCC, 2007); and
- *Product standards* that define the characteristics of potentially polluting products (Gabel, 2000).

15.3.3 Information policies

A typical market failure in the environmental domain is the lack, or at least asymmetric nature, of relevant information among some firms and consumers. Good quality information is essential for raising public awareness and concern about climate change, identifying environmental challenges, better designing and monitoring the impacts of environmental policies, and providing relevant information to inform consumption and production decisions. Examples of information instruments include eco-labelling or certification schemes for products or technologies and collection and disclosure of data on GHG emissions by significant polluters (Krarup and Russell, 2005).

15.3.4 Government provision of public goods and services and procurement

A changing climate will typically be a 'public bad' and actions and programmes by governments to counteract or prevent climate change can thus be seen as 'public goods'. There are many examples where public good provision may be an appropriate form of mitigation or adaptation. Examples include physical and infrastructure planning, provision of district heating or public transportation services (Grazi and van den Bergh, 2008), and funding and provision of research activities (Metz, 2010). Moreover, the removal of institutional and legal barriers that promote GHG emissions (or preclude mitigation) should be included in this policy type. Afforestation programmes and conservation of state-owned forests are an important example.

15.3.5 Voluntary actions

Voluntary actions refer to actions taken by firms, NGOs, and other actors beyond regulatory requirement. Voluntary agreements represent an evolution from traditional mandatory approaches based on conventional or economic regulations and intend to provide further flexibility to polluters. They are based on the idea that, under certain conditions, polluters can decide collectively to commit themselves to abatement instead of, or beyond the requirements of regulation. Voluntary agreements, sometimes known as long-term agreements, can be developed in different ways; in most cases the voluntary commitment is assumed as a consequence of an explicit negotiation process between the regulator and the pollutant. In other cases a spontaneous commitment may be viewed as a way to avoid future mandatory alternatives from the regulator (Metz, 2010). Finally, there are cases where the regulator promotes standard environmental agreements on the basis of estimation of costs and benefits to firms (Croci, 2005).

15.4 Approaches and tools used to evaluate policies and institutions

15.4.1 Evaluation criteria

Several criteria have been usually employed to assess the effects of climate change policies and these have been laid out in Section 3.7. The criteria that have been used are environmental effectiveness, economic effectiveness (cost-effectiveness and economic efficiency), distributional equity and broader social impacts, and institutional, political, and administrative feasibility and flexibility. Political and institutional feasibility are not only a separate criterion, but also need to be taken into account when judging other criteria such as economic effectiveness. It would be misleading to show that a tax would have been more cost-effective than, for example, a regulation if it would never have been feasible to implement the tax at a sufficiently high level to have the same effect as that regulation.

15.4.2 Approaches to evaluation

One can evaluate the effect of policy instrument x on a set of variables y that matter for the evaluation criteria either through modelling or through ex-post empirical measurement. For any evaluation based solely on modelling, it will never be possible to know whether all important aspects of the relationship between x and the y's are captured appropriately by the model. For this reason, it is highly desirable to have ex-post empirical analysis to evaluate a policy instrument. In order to measure the effect of a policy instrument, one must compare the observed y's in the presence of x with the 'but-for' or 'counterfactual' value of the y's defined as their estimated likely value but for the implementation of x.

Statistical methods can be used to attempt to control for the evolution of the world in the absence of the policy. The most reliable basis for estimating counterfactual developments is to build programme evaluation into the design of programmes from their inception (Jaffe, 2002). If the planning of such evaluation is undertaken at the beginning of a programme, then data can be developed and maintained that greatly increase the power of statistical methods to quantify the true impact of a programme by controlling for but-for developments.

Statistical analyses capture only those policy effects that can be and have been measured quantitatively. Qualitative analyses and case studies complement statistical analyses by capturing the effects of policies and institutions on other aspects of the system, and the effect of institutional, social and political factors on policy success (e.g., Bailey et al., 2012).

Of course, data for ex-post evaluation is not always available, and even where it is, it is very challenging to capture all aspects of the situation empirically. Therefore, there will always be a role for models to elucidate the structure of policy effects, and to estimate or put bounds on the magnitude of effects. Such models can be purely analytical/theoretical, or they can combine empirical estimates of certain parameters with a model structure, as in 'bottom-up' models where many small effects are estimated and cumulated, or in simulation models, which combine an analytical/theoretical structure with numerical estimates of parameters of the model. Many such models are 'partial equilibrium,' meaning they capture the particular context of interest but ignore impacts on and feedback from the larger system. There are also computable 'general equilibrium' (CGE) models that allow for interactions between the context of the policy focus and the larger system, including overall macroeconomic impacts and feedbacks see for example, Bohringer et al., (2006).

'Experimental economics' uses a laboratory setting as a 'model' of a real-world process, and uses 'experimental subjects' responses in that setting as an indicator of likely real-world behaviour (Kotani et al., 2011). With any model, results are truly predictive of real-world results only to the extent that the model—be it theoretical, simulation or experimental—captures adequately the key aspects of the real world in the experiment.

15.5 Assessment of the performance of policies and measures, including their policy design, in developed and developing countries taking into account development level and capacity

15.5.1 Overview of policy implementation

In this section we assess the performance of a series of policy instruments and measures, starting with economic instruments (taxes in 15.5.2, emissions trading in 15.5.3), regulatory approaches (15.5.4), information programmes (15.5.5), government provision of public goods (15.5.6) and voluntary agreements (15.5.7). We assess aspects of these and other policies in Section 15.6 on technology and R&D policy, and in Section 15.7 that deals with interactions between policies.

Many policy instruments are in principle capable of covering the entire economy. However, as mentioned in Section 15.2, in practice the instruments are often targeted to particular sectors or industries. This partly reflects the fact that certain barriers or market failures are specific to or more pronounced in certain sectors or industries. Furthermore, some policies may cover only part of the economy as a result of the ability of special interests to exempt some sectors or industries (Compston, 2009), (Helm, 2010).

Broader coverage tends to promote greater cost-effectiveness. However, on fairness grounds there is an argument for partly or fully exempting certain industries in order to maintain international competitiveness, particularly when the threat to competitiveness comes from other nations that have not introduced climate policy and would gain competitive advantage as a result.

Table 15.2 brings together policy instruments discussed in sector chapters (Chapters 7 to 12). Two broad themes emerge from this survey. First, while policies that target broad energy prices—taxes or tradable allowances are clearly applicable across all sectors—a wide range of other policy approaches are also prevalent, which enable policy design that addresses sector specific attributes. For example, in the buildings sector regulatory instruments are an important tool. In the absence of a building code enforcing enhanced efficiency, an energy price signal alone might be insufficient to induce a builder to invest in an energy efficient building that they plan to sell or rent. Building and product standards also increase investor certainty thereby reducing costs. Similarly, the transport sector relies not only on pricing policies but also on government provision of infrastructure and regulation that guides urban development and modal choices. The industry sector faces information and other barriers to investment in efficiency, which can be overcome by audits and other information based programmes. In Agriculture, Forestry, and Other Land Use (AFOLU), government regulation to protect forests and set the conditions for REDD+ (Reducing Emissions From Deforestation and Forest Degradation) plays a substantial role, as do certification programmes for sustainable forestry.

Sector-specific policies often exist alongside broader ones. In energy supply, broad-based GHG emissions pricing has often been supplemented by specific price- and quantity-based mechanisms (such as feed-in-tariffs (FITs) and portfolio standards) and underpinned by sufficient regulatory stability (including non-discriminatory access to electricity and gas networks). In industry, relatively broad tax exemptions may be combined with mandatory audits, with the former helping 'level the playing field' and providing the impetus for action, and the latter addressing an information barrier; thus each instrument addresses a separate market failure or barrier. The implementation of multiple policy instruments within a single sector can promote cost-effectiveness when the two instruments address distinct market failures. On the other hand, multiple instruments can work against cost-effectiveness when the two instruments fail to address different market failures and thus are simply redundant. This issue is discussed further in Section 15.7 below.

Table 15.2 | Sector Policy Instruments.

Policy Instruments	Energy (See 7.12)	Transport (See 8.10)	Buildings (See 9.10)	Industry (See 10.11)	AFOLU (See 11.10)	Human Settlements and Infrastructure (See 12.5)
Economic Instruments—Taxes (Carbon taxes may be economy-wide)	• Carbon taxes	• Fuel taxes • Congestion charges, vehicle registration fees, road tolls • Vehicle taxes	• Carbon and/or energy taxes (either sectoral or economy wide)	• Carbon tax or energy tax • Waste disposal taxes or charges	• Fertilizer or Nitrogen taxes to reduce nitrous oxide	• Sprawl taxes, impact fees, exactions, split-rate property taxes, tax increment finance, betterment taxes, congestion charges
Economic Instruments—Tradable Allowances (May be economy-wide)	• Emissions trading (e.g., EU ETS) • Emission credits under the Kyoto Protocol's Clean Development Mechanism (CDM) • Tradable Green Certificates	• Fuel and vehicle standards	• Tradable certificates for energy efficiency improvements (white certificates)	• Emissions trading • Emission credits under CDM • Tradable Green Certificates	• Emission credits under CDM • Compliance schemes outside Kyoto protocol (national schemes) • Voluntary carbon markets	• Urban-scale Cap and Trade
Economic Instruments—Subsidies	• Fossil fuel subsidy removal • Feed-in-tariffs for renewable energy • Capital subsidies and insurance for 1st generation Carbon Dioxide Capture and Storage (CCS)	• Biofuel subsidies • Vehicle purchase subsidies • Feebates	• Subsidies or tax exemptions for investment in efficient buildings, retrofits and products • Subsidized loans	• Subsidies (e.g., for energy audits) • Fiscal incentives (e.g., for fuel switching)	• Credit lines for low carbon agriculture, sustainable forestry.	• Special Improvement or Redevelopment Districts
Regulatory Approaches	• Efficiency or environmental performance standards • Renewable Portfolio Standards for renewable energy • Equitable access to electricity grid • Legal status of long-term CO_2 storage	• Fuel economy performance standards • Fuel quality standards • GHG emission performance standards • Regulatory restrictions to encourage modal shifts (road to rail) • Restriction on use of vehicles in certain areas • Environmental capacity constraints on airports • Urban planning and zoning restrictions	• Building codes and standards • Equipment and appliance standards • Mandates for energy retailers to assist customers invest in energy efficiency	• Energy efficiency standards for equipment • Energy management systems (also voluntary) • Voluntary agreements (where bound by regulation) • Labelling and public procurement regulations	• National policies to support REDD+ including monitoring, reporting and verification • Forest law to reduce deforestation • Air and water pollution control GHG precursors • Land-use planning and governance	• Mixed use zoning • Development restrictions • Affordable housing mandates • Site access controls • Transfer development rights • Design codes • Building codes • Street codes • Design standards
Information Programmes		• Fuel labelling • Vehicle efficiency labelling	• Energy audits • Labelling programmes • Energy advice programmes	• Energy audits • Benchmarking • Brokerage for industrial cooperation	• Certification schemes for sustainable forest practices • Information policies to support REDD+ including monitoring, reporting and verification	

Policy Instruments	Energy (See 7.12)	Transport (See 8.10)	Buildings (See 9.10)	Industry (See 10.11)	AFOLU (See 11.10)	Human Settlements and Infrastructure (See 12.5)
Government Provision of Public Goods or Services	• Research and development • Infrastructure expansion (district heating/cooling or common carrier)	• Investment in transit and human powered transport • Investment in alternative fuel infrastructure • Low emission vehicle procurement	• Public procurement of efficient buildings and appliances	• Training and education • Brokerage for industrial cooperation	• Protection of national, state, and local forests. • Investment in improvement and diffusion of innovative technologies in agriculture and forestry	• Provision of utility infrastructure such as electricity distribution, district heating/cooling and wastewater connections, etc. • Park improvements • Trail improvements • Urban rail
Voluntary Actions			• Labelling programmes for efficient buildings • Product eco-labelling	• Voluntary agreements on energy targets or adoption of energy management systems, or resource efficiency	• Promotion of sustainability by developing standards and educational campaigns	

15.5.2 Taxes, charges, and subsidy removal

15.5.2.1 Overview

Taxes on carbon (together with emissions trading systems) are economic instruments. In the presence of rational consumers, firms, and complete markets, they achieve any given level of emissions reduction in the least costly way possible. Economic instruments like carbon taxes are attractive because of their simplicity and broad scope covering all technologies and fuels (Section 3.8) and thus evoking the cost-minimizing combination of changes to inputs in production and technologies to changing behaviour as manifested in consumption choices and lifestyles. This is the reason they have the potential to be more efficient than directly regulating technology, products, or behaviour.[1] To minimize administrative costs, a carbon tax can be levied 'upstream' (at the points of production or entry into the country). Finally, unlike an emissions trading system that requires new administrative machinery, a tax can piggyback off existing revenue collection systems.

Despite these attractive properties, carbon taxes are not nearly as prevalent a policy instrument as one might expect. As yet, the Scandinavian countries, the Netherlands, the UK, and the Canadian province of British Columbia are the only large jurisdictions with significant and fairly general carbon taxes of at least USD 10/tCO_2.[2] The reasons for this are not entirely clear. It may be that a carbon tax, unlike a narrower sectoral regulation, attracts more hostile lobbying from fossil fuel interests[3] for whom the stakes it creates are high (Hunter and Nelson, 1989; Potters and Sloof, 1996; Goel and Nelson, 1999; Godal and Holtsmark, 2001; Skjærseth and Skodvin, 2001; Kolk and Levy, 2002; van den Hove et al., 2002b; McCright and Dunlap, 2003; Markussen and Svendsen, 2005; Pearce, 2006; Beuermann and Santarius, 2006; Deroubaix and Lévèque, 2006; Pinkse and Kolk, 2007; Bridgman et al., 2007; Bjertnæs and Fæhn, 2008; Blackman et al., 2010; Sterner and Coria, 2012). Secondly, the payments required by a tax are transparent, unlike the less visible costs of regulations. The general public, not being aware of the above-mentioned efficiency properties of a tax, may be less likely to accept such an instrument (Brännlund and Persson, 2010). Third, policy may be driven by perceived risks to competitiveness and employment as well as the distribution of costs rather than on considerations of pure efficiency (Decker and Wohar, 2007). Finally, a set of institutional path dependencies may have led to a favouring of emissions trading systems over taxes, including a post-Kyoto preference for emissions trading in key bureaucracies, supported by creation of supportive industry and other associations (Skjærseth and Wettestad, 2008; Paterson, 2012).

Countries that have sizeable general carbon taxes are fewer still—mainly a few Northern European countries. The carbon tax in Sweden is 1100 SEK or USD165/tCO_2, which is an order of magnitude higher than the price of permits on the EU emissions trading scheme (ETS) market or than the carbon taxes discussed in many other countries. Such high taxes typically have some exemptions motivated by the fact that other (competing) countries have no (or low) taxes. Sweden, for example, exempted the large energy users who participate in the EU ETS from also paying the carbon tax on the grounds that there would otherwise be a form of 'double' taxation (See 15.5.2.4 for a more thorough discussion).

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[1] If psychological or institutional barriers to adoption or other market failures are the main factor impeding choice then regulations or other instruments may be an efficient complement or stand-alone instrument to deal with this (see Section 15.4).

[2] Australia has a fixed fee hybrid system sometimes described as a tax that will be converted into an ETS.

[3] These can be either producers (for instance of fossil fuels) or users of energy, ranging from energy intensive industries to truck drivers.

Although general carbon taxes are so far uncommon, there are many policies that have similar effects but (for political reasons) avoid using the words 'carbon' and/or 'tax', (Rabe and Borick, 2012). Taxes on fuels, especially transport fuels are very common. While narrower in scope, they nevertheless cover a significant fraction of emissions in many countries. They can be interpreted as sectoral carbon taxes; in some countries this is clearly stated as an objective of fuel taxes, in others it is not. Fuel taxes may be politically easier to implement in some countries since (private) transport is hardly subject to international competition and hence leakage rates are low. A large share of all revenues from environmentally related taxes in fact come from fuel taxes, which were introduced in various countries, beginning with Europe and Japan, though they are also common in low income, oil-importing countries. One of their main stated purposes is to finance road building, although additional arguments include reducing expensive imports, government revenue raising, and reducing environmental impacts. Irrespective of the motivation, the effect of carbon taxes on fuel is to raise prices to consumers and restrict demand (see Section 15.5.2.2). Fuel taxes are important for climate change mitigation since the transport sector represents a large and increasing share of carbon emissions (27 % of global energy-related CO_2 emissions in 2010—see Section 8.1). Theory, simulation, and empirical studies all suggest strongly that taxing fuel is a lower cost method of reducing emissions compared to policies such as fuel efficiency mandates, driving restrictions, or subsidies to new technologies[4] (Austin and Dinan, 2005). However, consumers who buy vehicles may be unable to correctly internalize the long-run savings of more fuel-efficient vehicles. This would be considered a 'barrier' and would provide motivation for having fuel efficiency standards in addition to fuel taxes (see Section 15.5.4).

Variation in fuel prices is generated by subsidies as well as taxes. Fossil fuel subsidies are prevalent in many countries, being most common in oil and coal producing countries. According to the International Monetary Fund (IMF) (2013), the Middle East and North Africa region accounts for around 50 % of global energy subsidies. In 2008, fossil fuel subsidies—for transport fuels, electricity, tax breaks for oil and gas production, and for research and development into coal generation, exceeded USD_{2010} 489.1 billion globally (IEA/OECD, 2011). A more recent estimate by the IMF (2013) puts the figure at USD_{2010} 469.5 billion or 0.7 % of global GDP in 2011. This is a pre-tax estimate and includes petroleum products, electricity, natural gas, and coal. A large share is in the fossil fuel exporting countries. After factoring in negative externalities, through corrective taxes, the IMF reports USD_{2010} 1.85 trillion in implicit subsidies. This figure assumes damages corresponding to a USD 25/t social cost on carbon, consistent with United States Interagency Working Group on Social Cost of Carbon (2010). 'Advanced economies' make up 40 % of the global post-tax estimate. Reviewing six major studies that estimate fossil fuel subsidies, Ellis (2010) notes that removal of such subsidies would increase the aggregate GDP in OECD and non-OECD countries in the "range from 0.1 per cent in total by 2010 to 0.7 per cent per year to 2050 (Ellis, 2010)." The studies reviewed include both modelling and empirical exercises.

15.5.2.2 Environmental effectiveness and efficiency

Assessing the environmental effectiveness of carbon taxation is not straightforward because multiple instruments and many other factors co-evolve in each country to produce policy mixes with different outcomes in terms of emissions. For example, energy taxes varying by sector have been prominent in the Nordic countries since the 1970s with carbon taxes being added on in the early 1990s. Ex-post analyses have found varying reductions in CO_2 emission from carbon taxes in Norway, Sweden, Denmark, and Iceland, compared to business-as-usual (see Andersen (2004) for an extensive review of these studies and their estimation techniques).

The UK's Climate Change Levy (CCL), introduced in 2001 on manufacturing plants and non-residential energy users (offices, supermarkets, public buildings, etc.), has had a strong impact on energy intensity (Martin et al., 2011). Electricity use, taxed at a rate of about 10 %, declined by over 22 % at plants subject to the levy as compared to plants that were eligible to opt out by entering into a voluntary agreement to reduce energy use. There was no evidence that the tax had any detrimental effect on economic performance or led plants to exit from the industry (Martin et al., 2011).

From 1990 to 2007, the CO_2 equivalent emissions in Sweden were reduced by 9 % while the country experienced an economic growth of +51 %. In Sweden, with the highest carbon tax (albeit with exemptions for some industrial sectors), there was a very strong decoupling of carbon emissions and growth with reductions in carbon intensity of GDP of 40 % (Johansson, 2000; Hammar et al., 2013). Per capita emissions in Denmark were reduced by 15 % from 1990 to 2005; the experience in Scandinavia, the UK, and the Netherlands was similar (Enevoldsen, 2005; Enevoldsen et al., 2007), (Bruvoll and Larsen, 2004), (Cambridge Econometrics, 2005), (Berkhout et al., 2004; Sumner et al., 2011; Lin and Li, 2011). Of course, many factors may be at play, and these differences cannot be attributed solely to differences in taxation. Overall, the evidence does suggest that carbon taxes, as part of an environmental tax reform, lead to abatement of GHG emissions, generate revenue for the government, and allow reductions in income tax threatening employment. Theory strongly suggests that if a tax is implemented then it would also be cost effective, but it is for natural reasons hard to demonstrate this empirically at the macro level.

There is much more evidence available on the environmental efficacy of fuel as compared to carbon taxation. In the short run, consumers may be locked into patterns of use by habit, culture, vehicle characteristics, urban infrastructure, and architecture. The short-run response to higher fuel prices is indeed often small—price elasticity estimates range between −0.1 to −0.25 for the first year. However long-run price elasticities are quite high: approximately −0.7 or a range of −0.6 to

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[4] See also Section 15.12 on climate finance.

−0.8. This range is the average found by surveys of hundreds of studies that use both market based variations in fuel price as well as policy induced variations and exploit both temporal and cross-sectional variations in the data; the individual study estimates range substantially more depending on countries or regions covered, time period, method and other factors (Oum, 1989; Goodwin, 1992; Graham and Glaister, 2002; Goodwin et al., 2004). In the long run, therefore, 10 % higher fuel prices will ultimately lead to roughly a 7 % reduction in fuel use and emissions. Income elasticities are about 1, which means that 5 % growth in income gives 5 % growth in emissions. If instead a 2 % reduction is desired there is a 7 % gap between the 5 % increase and the −2 % desired and a 10 % increase in fuel price every year would be needed to achieve such a reduction in emissions with a 5 % growth in income.

The long-run effects of transport fuel taxation have been large. Sterner (2007) shows that in Europe, where fuel taxes have been the highest, they have contributed to reductions in CO_2 emissions from transport by 50 % for this group of countries. The whole Organisation for Economic Co-operation and Development (OECD) would have had 30 % higher fuel use had not the European Union and some other members imposed high fuel taxes (i.e., if all the OECD countries had instead chosen as low fuel taxes as in the United States). Similarly, the OECD could have decreased fuel use by more than 35 % if all member countries would have chosen as high taxes as the United Kingdom. The accumulated difference in emissions over the years leads to a difference in several ppm in CO_2 concentration, presumably making fuel taxes the policy that has had the largest actual impact on the climate up till now (Sterner, 2007).

The environmental effect of a fuel tax is illustrated in Figure 15.2, where the fitted curve is from a log-linear regression of the emission intensity of liquid fuels on the price of diesel. The cross-country variation in diesel prices is mostly due to variation in taxes (and in some cases, subsidies). Figure 15.2 suggests that the effect of a change in the price of a fuel on emissions is greater at low prices. This is intuitive, since fuel will be consumed wastefully when it is cheap, allowing for greater demand reductions when the price rises.

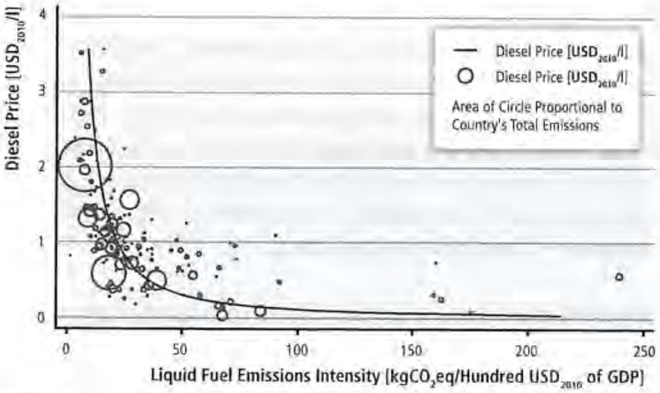

Figure 15.2 | The impact of average diesel prices across the world on the emissions intensity of liquid fuels.

Though there are few clean experiments, the market continuously creates 'quasi-experiments' which are analogous to the introduction of policies. Increased fuel prices in the USA in 2008, for instance, led to a shift in the composition of vehicles sold, increasing fuel-efficiency, while also reducing miles travelled (Ramey and Vine, 2010; Aldy and Stavins, 2012).

Other price instruments that have been used in the transport sector are congestion charges, area pricing, parking fees, and tolls on roads or in cities. These have been used to reduce congestion; emission reduction is a co-benefit. The USD_{2010} 15.4 congestion fee in London led to reductions in incoming private cars by 34 % when introduced. Overall congestion was also estimated to have been reduced by 30 %, and emissions fell (Leape, 2006). The smaller (USD_{2010} 2.6) congestion fee in Stockholm reduced total road usage by 15 % (Johansson et al., 2009).

Reducing subsidies to fossil energy will have a significant impact on emissions. Removing them could reduce world GHG emissions by 10 % at negative social cost by 2050 (Burniaux and Chateau, 2011).The IMF calculates that the removal of these subsidies induce a 15 % reduction in global energy related carbon emissions or 5 billion tCO_2 in absolute terms and concludes that the post-tax estimate of USD_{2010} 1.85 trillion in subsidies is 'likely to underestimate' energy subsidies due to the assumptions made, hence the impact on carbon emissions is likely to be higher. Ellis (2010) reports a range of effects from just a few percent to 18 % by 2050 depending on the size of the subsidy reduction.

Recognizing the potential impact of a reduction in subsidies to fossil fuels, the G20 and APEC blocks agreed in 2009 to phase out inefficient fossil fuel subsidies in all countries (G20 Leaders, 2009).

In China, the energy saving policies adopted in 1991, the 1998 Law on Energy Conservation, and the 2004 Medium and Long Term Specific Schema on Energy Saving, led to higher energy prices and explain half the decline in energy intensity of Chinese industries between 1997 and 1999, while R&D accounted for only 17 % of the decline (Fisher-Vanden et al., 2006; Yuan et al., 2009).

15.5.2.3 Distributional incidence and feasibility

Although fuel taxes have often been criticized for being regressive (that is, for imposing a proportionally higher burden on the poor), this is not always the case. There are large variations in distributional impacts both within and between social groups the effects range from regressive or progressive (Rausch et al., 2010, 2011); see also 6.3.5.2.

Studies of the distributional incidence of fuel taxes show that they may be neutral or weakly regressive (before revenue recycling) in rich countries, but they are generally progressive in poor countries. In many least developed and developing countries such as India, Indonesia, China, and many African countries, the progressivity of fuel taxes is in fact quite strong. In Europe they are approximately neutral (Sterner, 2012). Carbon taxation can sometimes have regressive effects prior to recycling revenue, but recycling can make the poorest households better off. Generally, the degree of progressivity can be selected depending on the method of recycling revenues. The environmental taxation gives rise to government income that can be allocated in ways that either benefit the poor or any other group giving a considerable range of options for how progressive or regressive the politicians want to make the overall package (Bureau, 2011).

The distributional effects of other taxes vary significantly. Kerosene taxes in developing countries are regressive since kerosene is used predominantly by the poor (Younger et al., 1999; Gangopadhyay et al., 2005; Datta, 2010). This regressivity may also apply to taxes on electricity or coal. The distributional effects of a more general carbon tax will depend on the mode of implementation with respect to different fuels and sectors and typically be more complex than for a single fuel, since the potential substitution possibilities are many. Results vary, but for instance, Hassett et al. (2009) finds a carbon tax to be regressive in the USA, showing that the cost is about 3.74 % for the poorest decile four times the effect on the highest decile. In India, on the other hand, a carbon tax would be progressive (Datta, 2010). The pro- or regressivity of carbon taxes will vary between countries but can also be affected by design, as shown for instance by Fullerton et al., (2012) or Sterner and Coria (2012).

The assertion that fuel taxes are regressive is often used as an argument and can make fuel taxes politically difficult to implement even if not true. Feasibility is however not tied in any simple way to income distribution effects. If a tax is progressive, this does not necessarily increase feasibility since this means that the interests of influential groups are affected, which may be a much bigger impediment to feasibility (Datta, 2010). Fear of social unrest may hold up subsidy removal. Protests over reduced petrol subsidies are common; for example, recently riots erupted in Nigeria when President Jonathan Goodluck tried to eliminate very costly petrol subsidies with only partial success. Some countries such as Iran and Indonesia have recognized that fuel subsidies actually accrue to the relatively wealthy and managed to successfully reduce the subsidies without much unrest, by making sure that revenues saved are spent fairly—for instance through general lump-sum cash transfers (Coady et al., 2010; Atashbar, 2012; Sterner, 2012; Aldy and Stavins, 2012).

15.5.2.4 Design issues: exemptions, revenue recycling, border adjustments

As mentioned above in 15.5.2.1, despite the attractive efficiency properties of a broad carbon tax, and even its progressivity in many circumstances, it may face political resistance. To have a big effect on emissions a tax must be high. Carbon and fuel taxes have often been initially resisted, but once introduced it seems the fee level has often been increased, (Sumner et al., 2011b). Another factor may be a path dependency since the taxes reduce the use of fossil fuel and lower fuel use means less opposition to fuel taxes, (Hammar et al., 2004). This path dependency may be the rationale for raising the fuel or carbon taxes slowly and steadily as done by the Conservative government in the UK with the Fuel Price Escalator starting in 1993, a policy that was continued under the successor Labour government for several years.

An emissions tax involves a transfer from economic agents to the state, namely the tax revenue from the residual emissions that are not abated. Private parties have to make this transfer in addition to bearing the cost of actually reducing emissions. There are a number of approaches to designing a tax (or fee) so that the transfer does not take place and resistance from incumbent polluters is reduced.

One approach is simply to exempt certain carbon-intensive industries—such as heavy industry in Sweden, as mentioned earlier. Such policies with incomplete coverage are less cost efficient than general policies (Montgomery, 1972 and Chapter 6.3.5.1). This lack of efficiency applies not only to carbon emissions—it applies even more broadly to agriculture, forestry and to other climate gases such as methane or nitrous oxide (Bosetti et al., 2011). However, narrow sectoral policies may be politically more feasible due to concerns about international competitiveness, the structure of winners and losers, and consequent lobbying (Holland et al., 2011).

A related approach that tries to avoid the loss of coverage is to exempt some firms from taxes conditional on their undertaking emission reduction commitments. In Denmark, for example, companies signing an energy savings agreement with the government received a 25 % tax reduction (OECD, 2001; Agnolucci, 2009; Sumner et al., 2011; Ekins and Speck, 2011; Aldy and Stavins, 2012). Similarly, in the UK some firms may sign Climate Change Agreements (CCA) to reduce emissions that exempt them from the CCL. This experience offers a cautionary tale: on average the agreements did not require firms to reduce emissions beyond what they would have done anyway (Martin et al., 2011). Conditional exemptions amount to unconditional ones if the conditions are lax.

Yet another approach to avoiding a large transfer to the state is to recycle all or part of the tax revenue. In the Canadian province of British Columbia, revenue from the broad carbon tax of USD_{2010} 29.1/tCO_2 is fully rebated to the general population via income tax cuts and transfers to low-income people who do not pay income tax. British Columbia raised the tax gradually in increments of USD_{2010} 4.8/tCO_2 annually to its current level (Jaccard, 2012).

Sometimes revenues are recycled to firms in emission-intensive industries. Again, this relies on identifying the recipients, so it is usually confined to a few sectors with the attendant disadvantages mentioned above. Refunded emission payments and other combinations of taxes and subsidies may be designed to be neutral so that, for example, the industry pays the cost of abatement but does not pay a tax for the allowed or reference level of pollution (Fischer, 2011). One expression of this is fees, which are collected in environmental funds and subsequently used in ways that benefit the polluters. An example from NO_x emissions in Sweden is that a refunded emission payment may be politically more acceptable and thus environmentally more effective than simply a tax. Since the fee is refunded (in proportion to output), there is considerably less resistance to the fee and it can be set much higher than what would have been acceptable for a pure tax. Norway has pioneered another instrument for NO_x emissions—taxes are refunded to cover abatement expenses. This implies a combination of a tax on emissions with a subsidy on abatement. Experience shows that a lower fee can achieve the same result with this instrument design as a tax (Fischer, 2011). Norway is considering promoting similar solutions for carbon emissions (Hagem et al., 2012). The drawback of such schemes for reducing carbon emissions is that their sectoral nature reduces coverage and raises costs.

Abatement subsidies have also been financed out of general revenues. Abatement subsidies need to be financed through tax revenues. The taxes needed to finance the subsidies in general involve a marginal excess burden. This deadweight loss is an extra cost of subsidies relative to emissions taxes. Furthermore, there is an efficiency penalty due to their sectoral nature. If applied to firms, subsidies may create perverse incentives to enter or to fail to exit from, a polluting industry, and raise costs (Polinsky, 1979). Perhaps for such reasons, they are seen in residential and commercial sectors, for instance, tax breaks are provided for building insulation or refurbishing. There are also white certificates and innovative financing schemes that allow loans to be repaid as part of electricity bills (See Section 9.10 for further discussion).

Another reason for tax exemptions is to avoid a loss of competitiveness in industries exposed to foreign competition that is not subject to taxation or equivalent policies. A pure tax (at a high level) may incentivize industries to move to neighbouring countries. This is known as 'leakage', since emissions 'leak' to jurisdictions not subject to taxation. It is generally hard to find decisive empirical evidence of carbon leakage, though this may be partly because high carbon taxes have not been tried in any significant way for trade-exposed sectors. As discussed in Chapter 5, some simulations suggest that there could be sizeable effects (Elliott et al., 2010). Though the overall effects of border tax adjustment on leakage are subject to debate (see Jakob et al., 2013), a recent model comparison suggests that full border tax adjustments would moderately decrease leakage rates from on average from on average 12 to 8 % (Bohringer et al., 2012). Border tax adjustments are taxes levied on imported goods that impose equivalent taxes on emissions 'embedded' in the goods. Aichele and Felbermayr (2011) find that sectoral carbon imports for a committed (i.e., taxed) country from an uncommitted exporter are approximately 8 % higher than if the country had no commitments and that the carbon intensity of those imports is about 3 % higher. When measurement of embedded emissions is uncertain, border tax adjustments can be criticized for introducing trade barriers in environmental guise (Holmes et al., 2011).

Leakage can also occur intertemporally. As shown by Sinn (2008, 2012), a carbon tax might not only encourage demand in other areas. There may also be a perverse supply side reaction (referred to as the Green Paradox) increasing the current supply of fossil fuels in anticipation of rising carbon taxes. Subsequent research (Gerlagh, 2011; Hoel, 2012) has shown that, strictly speaking, this only applies to very simplified and special models with complete exhaustion of all fossil fuels (which would lead to very drastic climate change) and also only to models in which the carbon tax actually starts low and rises faster than the discount rate. A number of conclusions can be drawn from the debate: (1) generally, the supply side should not be neglected; (2) if a tax is used, there are arguments for making it high rather than low and fast-growing; and most importantly, (3) instruments used need to cover as many countries and sources as possible. It may be difficult to find a single optimal tax, and it may be necessary, rather to formulate a tax rule that will decide how the tax rate is to be updated (Kalkuhl and Edenhofer, 2013).

15.5.3 Emissions trading

15.5.3.1 Overview of emissions trading schemes

Over the past three decades, emissions trading, or cap and trade, has evolved from just a textbook idea (Dales, 1968) to its current role as a major policy instrument for pollution control. Earlier experiences with emissions trading include schemes such as the California RECLAIM Program and the US Acid Rain Program (Tietenberg, 2006; Ellerman et al., 2010).

But since the start of the EU carbon trading system (See Section 14.4.2), several countries and sub-national jurisdictions (e.g., New Zealand, Australia, California, northeastern United States, Quebec, South Korea, Tokyo, and five cities and seven provinces in China) have also put in place or proposed trading schemes to control their carbon emissions. This section provides a brief overview of the literature (see further Perdan and Azapagic, 2011; Aldy and Stavins, 2012) and draws lessons for the design of carbon trading programmes.

15.5.3.2 Has emissions trading worked?

We begin by assessing environmental effectiveness. There were three GHG cap-and-trade programmes that were operational[5] by 2012 (Newell et al. 2013). The EU ETS, reviewed in 14.4.2, is by far the largest. Emissions are estimated to have fallen by 2–5 % relative to business-as-usual in the first pilot phase from 2005–2007 (Ellerman, Convery, De Perthuis, et al., 2010). Similarly, Egenhofer et al., (2011) attribute

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[5] California and Quebec started recently in 2013, as did Australia with its 'fixed-price' or tax period; trading starts 2014 and S Korea starts even later. None of these can be evaluated empirically at present.

reduction of emission intensity by 3.35 % per year in 2008–2009, in contrast to only 1 % in 2006–2007, to the EU ETS. Permit prices have fallen to around USD 10–15 in 2012 (Newell et al., 2013). Section 14.4.2 concludes that environmental effectiveness has been compromised to a large extent by a structurally lenient allocation of permits that was driven by the necessity for institutional and political feasibility.

The Regional Greenhouse Gas Initiative (RGGI), (see 15.5.3.3) has been ineffective since the cap has never been binding and is not expected to become so for several years (Aldy and Stavins, 2012). The third, much smaller, New Zealand ETS, appears to have had a small impact on emissions (Bullock, 2012). The last of the emissions trading schemes in GHGs, the Clean Development Mechanism (CDM), was an offset programme, not a cap-and-trade scheme. Section 13.13.1.2 finds that there are many challenges when it comes to additionality, baseline definition and leakage but possibly some advantages from the viewpoint of generating income in developing countries.

This experience shows that it is has been very difficult to get a cap-and-trade programme for GHGs enacted with a cap tight enough to have a significant environmental effect, at least initially. Other programmes (notably for the whole USA) that have been suggested have not made it through the political process. It is unclear to what extent this issue is peculiar to ETSs but there is a similar if not stronger opposition to the other major economic instrument, carbon taxation. One of the advantages claimed for an ETS is a greater option of allocating rights to appease opponents of a tax scheme. Hence there is a tradeoff between feasibility, distributional effects, and environmental effectiveness at least in the short run. Older non-GHG cap-and-trade programmes such as the SO_2 and leaded petrol phase-out programmes in the United States have been environmentally effective (Tietenberg, 2006; Schmalensee and Stavins, 2013).[6] It may be that any policy instrument stringent enough to have a significant environmental effective programme may have faced opposition in the particular circumstances. One possible lesson for design may be to build a price ceiling into any proposed cap-and-trade programme. In that case, the concern that a tight cap would lead to very high costs, would be alleviated and may make it politically feasible to have a somewhat more ambitious cap (Aldy and Stavins, 2012).

Cost-effectiveness is the main economic rationale for using emissions trading as opposed to simpler regulation. The experience with regard to GHG programmes is too limited to draw any conclusions yet. As in many of the earlier markets, cost savings in the US Acid Rain Program—an allowance trading system established in 1995 to control SO_2 emissions from coal-fired plants in the continental United States—were substantial (Carlson et al., 2000; Ellerman et al., 2000). Cost savings in this programme came not only from equalizing marginal costs across affected electric utility units on a period-by-period basis but also from equalizing (present value) marginal costs intertemporally as firms have saved current permits for future use in what is known as banking of permits. According to (Ellerman and Montero, 2007), the use of banking has been substantial and remarkably close to what would be expected in a well-functioning market. Recently, the price has collapsed to zero also in this market as the Environmental Protection Agency (EPA) has used other instruments to push for further reductions.

Banking has also been responsible for a large part of the significant cost savings in the US Lead Phasedown Program, a trading scheme established in 1982 to provide refineries with flexibility to gradually remove lead from gasoline. In addition to banking, cost savings in this program were driven by dynamic efficiencies, i.e., the faster adoption and/or development of more efficient refining technologies (Kerr and Newell, 2003). In contrast, dynamic efficiency has played a minor role in explaining cost savings in the US SO_2 allowance program (e.g., Ellerman et al., 2000; Fowlie, 2010; Kumar and Managi, 2010).

The introduction of a price on carbon through either a carbon tax or cap-and-trade can have substantial distributional consequences. Extensive analyses of these effects have been conducted in the US context. Burtraw et al. (2009) illustrate in the context of a trading programme that the outcome for the average household will depend much more importantly on the use of the value associated with emissions allowances than with the actual stringency of the regulation. For example, lump sum dividends or some kinds of tax reform can be progressive. Similarly Hassett et al. (2009) find that the degree of regressivity is much reduced when a lifetime measure of income is used. Parry (2004) shows in an analytical framework that emissions trading can be regressive, especially if implemented with free allocation to incumbent emitters (grandfathering). Bovenberg et al. (2005) find that profits can be maintained throughout the economy by freely allocating less (sometimes considerably less) than 25 % of pollution permits, with the rest auctioned. These considerations are very similar for tax or cap-and-trade systems. Granting greater than this quantity for free would lead to windfall profits. In simulation modelling of the US electricity market, Burtraw and Palmer (2008) find that it would be sufficient to allocate just 6 % of the allowances to the electricity industry to offset costs under a CO_2 trading programme because a majority of costs are borne by consumers; greater allocation would again lead to windfall profits. Hassett et al. (2009) examine regional effects and find them not to be very significant. Blonz et al. (2012) show that even if programmes are regressive, social safety nets, which adjust automatically to inflation, generally protect low-income groups in the United States, and middle income groups may be most vulnerable.

It should be noted that the experience with emissions trading, whether for greenhouse gases or other, non-climate-related pollutants, has been wholly in high-income countries. Coria and Sterner (2010) describe some success for air pollution in a middle income country like

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[6] Note that there is literature (e.g., Lohmann, 2008) much less enthusiastic about the concept of emissions trading for reasons of justice and environmental integrity, among others, and more so after the current collapse of carbon prices in the EU-ETS (Lohmann, 2008).

Chile but it is unclear to what extent these can be transferred to developing countries.

15.5.3.3 Sector coverage and scope of the cap

A key component in a trading scheme is establishing the pollutants (e.g., greenhouse gases) and entities that will be regulated. There are several factors that may affect this decision: (1) the quality and cost of emissions measurement and verification, (2) the ability to target sectors with the greatest mitigation potential, (3) the ability to broaden the coverage to unlock low-cost mitigation opportunities, (4) the political and institutional feasibility of including certain sectors, and (5) the interactive effects the cap may have with other policies.

In most trading schemes, the affected sources are relatively large emitting sources whose emissions have been closely monitored (smaller sources are often regulated with alternative instruments). This applies to the earlier programmes (e.g., Acid Rain, RECLAIM, Lead Phasedown)[7] but also in carbon markets. In other words, there are few cases in which the point of obligation has been upstream, i.e., different than the emitting point. The trading scheme in Australia, launched in 2012, covered 373 entities comprising approximately 60 % of Australia's GHG emissions. Electricity generation, industrial processes, fugitive emissions, and non-legacy waste are under permit liability (Clean Energy Regulator, 2012). Small-scale stationary fossil fuel use (especially gas) is covered by upstream permit liability on fuel distributors. Liquid fuels used in aviation/shipping and synthetic GHGs are subject to an equivalent carbon price through changes to existing taxes. Agriculture and forestry can produce offset credits (Macintosh and Waugh, 2012; Caripis et al., 2012).[8]

Coverage in the carbon-trading scheme in New Zealand, is the most comprehensive and covers all GHGs and all sectors. It has expanded in stages from the forestry sector (in January 2008) to fossil fuels and industrial emissions (in July 2010), and will cover the waste sector in May 2014. The agricultural sector must report emissions since January 2012 but a decision on when it will face surrender obligations has not yet been made. This is the only national emissions trading scheme to include forestry, and is intended to shift land-use change decisions towards greater carbon sequestration and less deforestation (Karpas and Kerr, 2011; Adams and Turner, 2012). Coverage is also scheduled to expand in stages in the recently launched carbon market in California (Hanemann, 2009). In the first compliance period, which runs from 2013–2014, electricity generating and industrial facilities that exceed 25,000 tonnes of CO_2eq per year will be obligated to abide by the agreement; the second period (2015–2017) adds distributors of transportation, natural gas, and other fuels; and the third period (2018–2020) adds transportation fuels (CARB, 2011). All major sources will be covered over time, which will represent an equivalent of 85 % of California's GHG emissions (CARB, 2011). Offset projects are foreseen in forestry management, urban forestry, dairy methane digesters, and the destruction of ozone-depleting substances.

There are other carbon markets that are less ambitious in scope. The trading scheme in Tokyo, launched in April 2012, includes 300 industrial facilities—which in total consume at least 1,500 kl of crude oil equivalent per annum—and a combined 1,000 commercial and institutional buildings. In aggregate, this is equivalent to only 20 % of Tokyo's total CO_2 emissions (Partnership for Market Readiness, 2012). Though the programme may be limited in scope, it is one of the first programmes in the world to address emissions from urban buildings, which can be quite significant (Nishida and Hua, 2011). The Regional Greenhouse Gas Initiative (RGGI), a cap-and-trade programme initiated in 2009 and that covers nine Northeast and Mid-Atlantic states in the United States (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont), only regulates CO_2 emissions from power plants.

15.5.3.4 Setting the level of the cap

The cap defines the stringency of the trading scheme. Naturally, the permit prices also depend on many circumstances such as the economic growth. In many of the trading programmes reviewed above, the caps appear however to have been set below what would lead to efficient levels of abatement—since the allowance prices (the marginal abatement costs) have ended up below most estimates of the marginal environmental benefits from abatement. The RECLAIM Program which covers NO_x and SO_2 is an example as are the acid rain and lead phase-out programmes. It should be noted, however, that to varying extents, carbon trading programmes include mechanisms to tighten the cap gradually.

Caps in the carbon markets have slower reductions maybe because of higher short-term mitigation costs. In the Australian scheme, there is no cap on emissions during the initial so-called 'fixed-price phase' (2012–2014) but a price that rises from AUS 23.00 per tonne in 2012/2013 to AUS 25.40 in 2014/2015. The fixed price scheme, has many of the characteristics of a tax and offered advantages in the specific political circumstances that failed to agree on an emissions target but not on a price (Jotzo et al., 2012) hence preferring implicitly uncertainty on emissions rather than on the price (Jotzo and Betz, 2009; Jotzo and Hatfield-Dodds, 2011; Pearce, 2012). The fixed price period naturally established a price signal and provided time for important elements of the flexible price period to be implemented, such as an auction platform. Starting with the first flexible-price phase (2015–2018), the government will set annual caps for five-year peri-

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[7] An exception is the market for particulates established in Santiago-Chile in 1992 for industrial sources (Montero et al., 2002). The trading commodity was not actual emissions, which were difficult to monitor on a daily basis, but a firm's maximum capacity to emit.

[8] For more see Section 7A of the National Greenhouse and Energy Reporting Act 2007 (National Greenhouse and Energy Reporting Act 2007, 2007). The carbon market in South Korea, to start in 2015, will cover around 450 large facilities and about 60 % of the country's GHG emissions (Kim, 2011).

ods, extending the cap by one year every year. A default cap (associated to a GHG emissions reduction of 5 % from 2000 levels by 2020) will apply in the event the parliament cannot agree on a cap (CAUS, 2012).

New Zealand, on the other hand, has operated within the Kyoto cap for 2008–2012 by requiring every unit of emission to be matched by a Kyoto unit at the end of the Protocol's true-up period. For 2012 and forward, the government has proposed legislative amendments to introduce a domestic cap and remove the requirement to back domestic emission with Kyoto units (NZME, 2013).

The cap in the California scheme is set in 2013 at about 2 % deviating under the projected level for 2012, and then drops about 2 % in 2014 and about 3 % from 2015 to 2020 on an annual basis (4 % of allowances will be held in reserve to contain costs). The Regional Greenhouse Gas Initiative has introduced a 'soft' fixed cap from 2009 to 2014 to decline by 2.5 % per year. Economic growth and natural gas prices have been lower than expected, so it is unlikely that the cap becomes binding by 2020 (Aldy and Stavins, 2012).[9]

15.5.3.5 Allocations

Permits have been allocated either by auction, or have been given away for free. In the latter case, allocation has been proportional to past emissions or output (i. e., grandfathered) or proportional to current output. Earlier programmes relied almost exclusively on grandfathering. The SO_2 allowance programme allocated less than 3 % of the total cap, through revenue-neutral auctions; mainly to provide an earlier and more reliable price signal to participants (Ellerman, Convery, De Perthuis, et al., 2010). Some of the recent carbon markets also provide free allocations because of concerns about emissions-intensive trade-exposed industries. In fact, the programme in New Zealand considers a very limited amount of auctioning (although increasing over time) unlike RGGI, which allocates the vast majority of permits through auctions (the softer cap in RGGI may explain the difference). Australia and California are somewhere in the middle in terms of auctioning, roughly 50 % and 80 % respectively.

The Californian and Australian schemes also make explicit output-based (free) allocation rules for energy-intensive, trade-exposed sectors, where recent production determines firm-level allocation. The Australian experience on this matter has also shown the influence that industry lobby groups can have in policy design (Garnaut, 2008; Pezzey et al., 2010) and how politically involved this can become (Macintosh et al., 2010).

15.5.3.6 Linking of schemes

Linking occurs when a trading scheme allows permits from another trading programme to be used to meet domestic targets. Such linkages can be mutually beneficial as they can improve market liquidity and lower costs of compliance. However, these benefits need to be weighed against challenges like losing unilateral control over domestic design and being subject to international price movements. Linking, however, involves certain tradeoffs in terms of exposure to international prices and loss of flexibility to unilaterally change features in the domestic design once links are established. International linkage of trading schemes might be simpler than harmonizing carbon taxes through international agreements (Karpas and Kerr, 2011). There is however, not general agreement on this point; to the contrary, agreements on taxes might avoid the most contentious baseline issues see for instance Nordhaus (2007).

The experience with linking is limited because carbon markets are relatively recent. One example of a linking process is the ongoing collaboration, since 2007, between California and the Canadian province of Quebec, which will both place compliance obligations on large emitters under their trading schemes beginning in January 2013 and continue negotiations for a full linking of the two schemes later on in 2013 (CARB, 2011). Another example is the announcement in 2013 of an Australia-EU ETS link by 2018 preceded by a transition phase in which Australian installations can use EU-Allowances for compliance from 2015 on. Interestingly, Australia is also exploring ways for establishing links with schemes in South Korea and California, which, de facto, would create links between all these trading schemes.[10] We do not yet know if linking schemes without prior commitment on overall caps will facilitate or complicate future negotiations on the caps.

15.5.3.7 Other design issues: banking, offsets, leakage, price volatility and market power

There are additional, important, aspects of policy design on which we can only briefly touch here. Unlike borrowing, banking of permits for future use is a feature used in many trading schemes with good results in terms of cost savings and environmental benefits (i. e., absence of emission spikes and acceleration of emission reductions). A well-documented example is the US SO_2 allowance programme (Ellerman and Montero, 2007). A dramatic example of volatility is given by the RECLAIM programme where in the summer of 2000 permit prices that began under USD 5,000 per ton of NO_x increased abruptly in price to almost USD 45,000, leading to a relaxation of the cap see Metcalf (2009). Offsets, the possibility of using emission credits outside the capped sectors either domestically or internationally (e. g., CDM or REDD), is another design feature common in most trading

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[9] There is a proposal from the RGGI states, however, to reduce the cap in 45 % by 2020 (Regional Greenhouse Gas Initiative, Inc., 2013).

[10] The firm intentions of New Zealand and Australia about linking their systems came to a sudden end after the latter announced it was linking its system to the EU ETS.

schemes but of much concern because of the well-known tension between cost-effectiveness and additionality. One way to somewhat assuage this tension is to move away from a project-based crediting approaches (e.g., CDM) to scaled-up approaches—to the level of the sector, jurisdiction or country. Offset provisions, if well designed, can also help alleviate the 'leakage' problem of moving emissions from capped to uncapped sectors. An alternative design option to address leakage might be to use output-based allocation rules although this will raise concerns related to output subsidy. Another problem is market power specific to permit trading which has been the subject of much research since the work of Hahn (1984). It seems, however, that market power is less of a problem than anticipated (Liski and Montero, 2011), also confirmed by findings from laboratory experiments (Sturm, 2008).

15.5.3.8 Choice between taxes and emissions trading

Regarding the choice between taxes and tradable permits, longstanding economic theory (Weitzman, 1974; Hoel and Karp, 2001, 2002; Newell and Pizer, 2003) suggests that in the presence of uncertainty about the marginal cost of emission reduction, for a stock pollutant like CO_2, a carbon tax is more economically efficient than a tradable permit system. According to the Weitzman intuition, a tax is preferred since the benefits curve is fairly flat for a stock pollutant (this result could be changed in the presence of a major threshold effect). The reason is essentially that when there is a negative shock to the cost of emission reduction, as has been the case in the EU following the economic slowdown that began in 2008, cost efficiency calls for doing more abatement, with less being done at other times when the abatement cost is higher. This is achieved with a tax, but not with a cap that is fixed in each period. The slump in the carbon price in the EU ETS is thus suggestive of a loss of cost-effectiveness.

In the very long run there may be more uncertainty about the level of an optimal tax than about a quantity target and policymakers may then prefer to legislate a long-run abatement target in a cap-and-trade system. As seen above, this can entail short-run efficiency losses and it would be desirable to allow flexibility with regard to annual caps that would add up to the long run target, but concerns about credibility mean that such flexibility must be severely limited. As shown in Chapter 2 (Section 2.6.5), there is a literature on regulatory uncertainty that shows extra costs deriving from the hesitancy by investors in the face of all regulatory uncertainty but in particular perhaps, when it comes to cap-and-trade systems.

To prevent a large loss of efficiency in a cap-and trade-system, and to avoid exceptionally high price volatility that deters investment, price floors and ceilings can be used, although care would be needed in design to avoid breaching the integrity of the cap. Banking and borrowing of permits (see Section 15.5.3) are another means of providing intertemporal flexibility in abatement as are the availability of credit reserves or of offsets.

As explained in Section 15.7, a tax can be used in conjunction with other policy instruments while a cap-and-trade system either renders the other policies environmentally irrelevant or is itself rendered environmentally irrelevant by them. This is a major concern when decision making takes place at several levels.

As discussed in Section 15.5.2.4, the issues of intertemporal (and spatial) leakage discussed in the green paradox literature would appear to give preference to cap and trade over taxes but this is partly a simplification. The green paradox mainly exists in oversimplified models and poorly designed tax schemes. There are however, lessons from this literature concerning design details. For example, one might prefer high taxes that grow slowly to low taxes that rise very fast, and one might be careful with too much flexibility, particularly borrowing in permit systems. Kalkuhl and Edenhofer (2013) compares four policies, (1) a conventional Pigouvian carbon tax, (2) a carbon tax rule (that adjusts the tax level dependent on GHG concentrations), a permit trade (3) with or (4) without banking and borrowing) in the context of a (weak) green paradox setting with respect to three different criteria: the informational burden for the government, the commitment problem of the government, and the robustness of the policy with respect to deviations in behaviour (discount rate) by agents in the economy. They find that a tax and a trading scheme without banking and borrowing have high informational requirements. The ETS with banking and borrowing shifts the timing problem of carbon emissions to the private sector, but does not work well if these have different discount rates from the regulator. The flexible tax rule or an ETS with restricted banking and borrowing can lead to an optimal allocation even in this case, but then again the informational requirements for the regulator are daunting.

One of the attractions of emissions trading schemes appears to have been that they may meet with less opposition from industry, which can be allocated permits for free. Taxation is often resisted by lobbies and sometimes for constitutional reasons. Taxation is also resisted by those who want a smaller government—in which case environmental fiscal reform (raising carbon taxes while lower other taxes) may be more acceptable. Another argument that has been made in favour of an ETS is that it may be easier to link permit schemes across borders than to agree on common taxes. Harmonization is advantageous, since it reduces costs (15.7). There is however, no general agreement on this. Some analysts believe the opposite, that it will be easier to link taxation systems within an international agreement (Helm, 2003; Nordhaus, 2007; Jaffe et al., 2009; Metcalf and Weisbach, 2011) and (15.8.1). Finally, linking cap-and-trade systems would automatically involve financial transfers between countries. These might be a benefit for low-income countries if they can be carbon-efficient and maybe less controversial than negotiated side payments but this hinges on agreement concerning the various country targets.

Finally taxes, unlike an emission-trading scheme, do not require a new institutional infrastructure to keep track of ownership of emissions allowances. This consideration may be especially important in developing countries.

15.5.4 Regulatory approaches

15.5.4.1 Overview of the implementation of regulatory approaches

As discussed in Section 15.2, economy-wide carbon pricing, though widely discussed in the literature, has been rarely implemented. Those policies that have been implemented have often been sector-specific, and have often fallen in the category of a regulatory approach. Regulatory approaches are used across sectors, usually alongside other policies, as can be seen in Table 15.2. For example, Renewable Portfolio Standards (RPS), and energy efficiency standards may be combined with fuel subsidy reduction in the energy sector (Chapter 7). In the transport sector, vehicle efficiency and fuel quality standards are used alongside government provision of mass transit, and fuel taxes (Chapter 8). In the building sector, a number of complementary policies, such as appliance standards, labelling, and building codes are employed, along with tax exemptions for investment in energy-efficient buildings (9.9). In the industrial sector, energy audits for energy-intensive manufacturing firms are also regularly combined with voluntary or negotiated agreements and energy management schemes. Information programmes are the most prevalent approach for energy efficiency, followed by economic instruments, regulatory approaches and voluntary actions (10.11).

Several of these regulatory approaches often contain market-like features so that the distinction between regulatory approaches and economic instruments is not always sharp. Renewable Portfolio Standards programmes often, for example, allow utilities to satisfy their obligations by purchasing renewable energy credits from other producers, while feed-in tariffs involve both regulations and subsidies for renewable energy. Low-carbon fuel standards also sometimes incorporate market-like features including trading among suppliers.

Regulatory approaches play the following roles in mitigation policy. First, they directly limit greenhouse gas emissions by specifying technologies or their performance. Second, in sectors such as AFOLU (see Chapter 11) and urban planning (see Chapters 8 and 12) in which much activity is strongly influenced by government planning and provision, regulations that take climate policy into account are clearly important. These are discussed in further in Section 15.5.6. Third, regulations such as RPS can promote the diffusion and innovation of emerging technologies, a role that is examined in Section 15.6. Fourth, regulations may remove barriers for energy efficiency improvement. These may arise when firms and consumers are hindered by the difficulty of acquiring and processing information about energy efficient investments, or have split incentives as in landlord-tenant relationships.

Regulatory approaches have been criticized, both for being environmentally ineffective, and more strongly, for lack of cost-effectiveness, as the governments have limited information and may make governmental failures in intervention (Helm, 2010; see also Section 3.8.2). Some are opposed to the regulations on libertarian philosophical grounds (Section 3.10.1.1). In what follows, we assess the environmental and cost effectiveness of regulatory approaches, largely focusing on short-run effects of energy efficiency policies that have been extensively studied. Long-run effects acting through technology development are assessed in Section 15.6. There is insufficient literature on distributional incidence and feasibility to underpin an assessment of these dimensions.

15.5.4.2 Environmental effectiveness of energy efficiency regulations

Several prospective studies reviewed by Gillingham, Newell, and Palmer (2006) and one large ex-post study of US energy efficiency standards for appliances (Meyers et al., 2003) found substantial energy savings. Such savings have also been found in the building sector across countries (Section 9.10) in a study of best-practice building codes and other standards. Recently, econometric studies in the United States have also found energy reductions from building codes (Aroonruengsawat, 2012; Jacobsen and Kotchen, 2013). These studies also reported significant energy savings and related CO_2 reduction. Fuel economy standards for vehicles have also been successful in reducing fuel consumption in many countries (Anderson et al., 2011). Generally speaking, energy efficiency policies that address market failure can result in energy savings (7.10, 8.10, 9.10, Table 9.8, 10.10). Some case studies however, identified weak environmental effectiveness due to lack of implementation. Such examples were found for building codes and energy management systems.

Rebound effects need to be taken into account in interpreting these findings of environmental effectiveness of energy efficiency regulations. The rebound effect refers to the increase in energy consumption induced by a fall in the cost of using energy services as a result of increased energy efficiency. For detailed general discussion on rebound effects, see Sections 3.9.5 and 5.6.2. For sector-specific studies of rebound effects, see Section 9.6.2.4 for building sector and Chapter 8 for transport sector. With regard to appliance standards and fuel-economy regulations in the United States, environmental effects remain large even when taking the rebound effect into account (Gillingham et al., 2006; Anderson et al., 2011). More generally, direct rebound effects (within the regulated sector as a result of the fall in the cost of energy services) are commonly found to be in the range of 10%–30% in various sectors in developed countries, and higher in developing countries (Sorrell et al., 2009; Gillingham et al., 2013). Indirect rebound effects, which result from increased economic growth resulting from the fall in the cost of energy services, can be much larger. Reviewing claims of rebound effects in excess of 100%, Dimitropoulos (2007) concluded that although the evidence base and methodologies were weak, the possibility of significant rebound effects could not be dismissed. A recent review suggests that total rebound effects are unlikely to exceed 60% (Gillingham et al., 2013).

While the scale of the rebound effect varies, its presence suggests that complementary policies that include carbon pricing are called for so that mitigation is not compromised. Some countries, such as the UK, have begun to account for a direct rebound effect in energy policies (Maxwell et al., 2011).

Regulations such as emissions standards have also been criticized on the ground that they are less flexible than incentive-based approaches and may even provide perverse incentives and increase emissions under certain conditions like treating new units more stringently than old ones (Burtraw et al., 2010). Yet, recent modelling that incorporates institutional features of various policies in the United States, including the capacity to adjust the stringency of a regulation or a cap/tax, suggests that emissions standards may be more effective than cap and trade in reducing overall emissions (Burtraw and Woerman, 2013).

15.5.4.3 Cost effectiveness of energy efficiency regulations

Regulatory approaches are often implemented in contexts in which market failures or barriers to adoption of energy-efficient technologies exist. There is a considerable sectoral literature showing that energy efficiency regulations have been implemented at negative costs to firms and individuals, meaning that their value to consumers exceeded programme costs on average. In the transport sector, fuel economy standards have been shown to produce net cost savings over the life of the vehicle (Chapter 8.10). In the building sector, a range of energy efficiency policies including appliance standards and building codes have been found to have negative private costs (Table 9.8), (Gillingham et al., 2006, 2009a). In the industrial sector, a number of case studies on energy management systems and energy audit systems show that they have been cost effective (Chapter 10.10).

The cost effectiveness of such regulations has been the subject of heated debate. Economic theory points to the following circumstances in which regulations may be implemented with negative private costs. Buyers may have less information about the efficiency and cost of a device than sellers. They may not be able to assess the energy savings from an appliance even after using it. This can lead to a situation in which low-efficiency devices drive more expensive high-efficiency models out of the market. Efficiency standards in this setting can improve consumer welfare by reducing the informational asymmetry between buyers and sellers (Akerlof, 1970; Leland, 1979; Goulder and Parry, 2008). When competition is imperfect and sellers compete on both quality (efficiency) and price, then a minimum quality standard eliminates low-quality sellers from the market enhancing price competition among high-quality goods. This can make all consumers better off (Ronnen, 1991). Split incentives, as in landlord-tenant relationships, can lead to economically inefficient devices persisting in the market, absent intervention. For more details, see Box 3.10.

Individuals working in small workplaces often find it difficult to acquire and analyze information on energy efficiency (see 2.6.5.3 on human behaviour on energy efficiency). As a consequence, those individuals are prone to rely on intuition to make decisions. In many cases, analyzing the minimum cost actions given the price signal is too challenging, and thus cognitive costs may result in some consumers simply not taking operating (energy) costs into account at all while making their purchase decisions (Section 3.10.1.1). (Allcott, 2011) exhibits this case in a recent survey of US car buyers, 40 % of whom were shown not to consider fuel costs in their purchasing decision. This kind of consumer decision making can lead sellers to offer—and consumers to buy—less energy efficient products than if consumers could more easily compute the operating costs. Section 9.8 indicates that such barriers to energy efficiency are significant in the building sector. Regulation and information measures can help overcome these barriers.

Large firms have more resources than individuals to assess information on energy efficiency, and so may be more sensitive to carbon pricing. However, firms, especially small and medium enterprises, also face the barriers such as split incentive and lack of information. Governments may employ regulations (and information measures) to help correct this by implementing energy efficiency standards for equipment. See 3.10.1.2 for more on behaviour of firms on energy efficiency.

Although both the theory and empirical evidence detailed above show that policy interventions to remove barriers can have negative costs to firms and individuals, it has been argued that unaccounted labour and opportunity costs borne by governments, firms, and individuals involved in policy design and implementation process, as well as loss of amenity (for example, fuel economy standards may undermine other functions of cars, such as speed, safety, quality of air conditioning, and audio sets), result in understatement of regulatory costs. Such unaccounted costs are called 'hidden costs' (Box 3.10).

On the other hand, an ex-post evaluation of expected and realized costs of environmental regulations in the United States found that estimates of the unit cost of regulations by the regulator were overstated just as often as they were understated, while total costs were more frequently overstated (Harrington et al., 2000). Furthermore, Gillingham et al. (2006) note that in the United States, "even if unaccounted-for costs of appliance standards were almost equal to those measured, and actual energy savings only roughly half of those estimated, appliance standards still would yield positive net benefits on average" (Gillingham et al., 2006b). There may also be hidden benefits of regulations, (Sorrell, 2009), such as improved amenities and 'free drivers' (which would occur if nonparticipants were induced to invest in energy efficiency because others in the programme made such investments) induced by regulation (Gillingham et al., 2006). In conclusion, while it is clear that opportunities do exist to improve energy efficiency at negative private cost by regulations, the literature is divided as to what extent such negative private cost opportunities exist.

It is the social rather than the private costs of regulations, however, that are more relevant for public policy. This means that externalities need to be taken into account and co-benefits of policies, such as local air pollution reduction, would ideally be valued and subtracted from costs. Such externalities can be large. Muller, Mendelsohn, and Nordhaus (2011) found that the external costs of coal-fired utilities in the United States exceeded value-added in that sector. These and other costs and benefits have to be taken into account when evaluating policies.

15.5.5 Information measures

Information measures have been widely used in all sectors. To take typical examples, energy efficiency labelling for home electric appliances and thermal insulation of buildings, as well as carbon footprint certificates and public awareness initiatives are implemented in the building sector (9.10). Energy management systems, as well as government-assisted energy audits, either mandatory or voluntary, are used in the building, industry, and energy sectors (7.10, 9.10, 10.10). Mandatory reporting of GHG emissions is common for firms in the power and industrial sectors (7.10, 10.10), while labelling of automobile fuel economy is used in the transport sector (8.10). Sustainability certificate programmes are used in the forestry sector (11.10).

Regarding the environmental and economic effectiveness, a number of case studies in the building sector are shown for the energy efficiency labelling for home electric appliance, building label and certificates, energy audit programmes, and awareness raising campaign to stimulate behavioural change (see 9.10, Table 9.8). For energy efficiency, the role of information measures is the same with regulatory approaches, that is, to address market failure such as lack of information and split incentives. For details of the market failure and role of information measures, see Section 15.5.4.

While some studies mentioned above reported high economic and environmental effectiveness, the results are mixed in general, reflecting the wide diversity of the information measures, and it is not appropriate to draw a general conclusion. Note that some policy instruments, such as energy management systems and energy audit in the industrial sector that may fall either in regulatory approach and information measures, are also covered in the section on regulatory approach above.

Since information programmes typically provide information and leave it to firms or consumers to take appropriate action, those actions will usually only be taken spontaneously, or if they are perceived to have negative private costs economically. The discussion of hidden costs/benefits and rebound effects parallels that of regulatory approach, are covered in Section 15.5.4.

It should be noted that the role of information measure has been mostly supplementary to other policy instruments such as obligatory standards or much wider policy package as detailed in sector specific policy chapter (7.10, 8.10, 9.10, 10.10, 11.10). For example, energy efficiency labelling is often followed by energy efficiency standard as a single policy package. This also makes difficult to estimate the impacts of the information measure alone.

15.5.6 Government provision of public goods or services, and procurement

While formal assessment is difficult, it is clear that public provision and planning can and have played a prominent role in the mitigation of climate change at the national and sub-national levels, and in a wide range of industries including energy, transport, agriculture, forestry, and others. At the national level, government provision or funding is crucial for basic research into low and zero-emission technologies (see Section 15.7).

In the energy sector, the provision and planning of infrastructure, whether for electricity transmission and distribution or district heating networks, interconnectors, storage facilities, etc., is complementary to the development of renewable energy sources such as wind and solar energy (7.6.1.3). A modal shift from air to rail transport also requires public planning or provision by national and local governments as a part of the policy mix and in best-case scenarios could reduce associated emissions by 65–80 % (8.4.2).

Urban planning that incorporates climate change mitigation can have a major impact on emissions (Chapter 12); therefore, municipal governments have a very important role to play. Since mitigation policies have many co-benefits at the local level, including reduced local pollution and congestion, and improved quality of urban space, cities have an interest in mitigation policies in addition to the largely external climate benefits they provide. Land-use and transport policies can considerably influence the share of non-motorized transport, public transport, and associated emissions (8.4.2.3). Buildings and associated energy supply infrastructure are very long-lasting (9.4.5) so public planning to encourage the rapid adoption of new low-carbon technologies and avoid lock-in to high-emission infrastructure assumes importance. Such planning would need to take into account transport pricing relative to land prices, building, parking, and other zoning regulation, city-wide district heating and cooling systems, and green areas (see Section 12.5, and Baeumler et al., 2012). Capacity building at the municipal level may be needed for incorporating climate change mitigation and its co-benefits into the planning process, especially in developing countries (see Section 15.10.3).

Government planning and infrastructure provision can complement a carbon or fuel tax, addressing additional market failures that increase the quantity response to the price instrument by making substitution towards less energy and carbon-intensive lifestyles easier to implement. Conversely, whether or not a public transit system will generate sufficient demand to be economical depends on whether private transit (and its climate externalities) is suitably priced. By contrast, as noted below in Section 15.8, a tradable permit system for emissions would be a substitute, rather than a complement for emission reduction through public provision. In conjunction with a tradable permit system, local actions would affect the cost of reducing emissions, but not overall emissions themselves. This raises the possibility that local governments may be de-motivated to integrate mitigation in their planning if they are located in a national or international jurisdiction with a tradable permit system. In that case, their actions would not be 'additional' in GHG emission reduction, rather they would reduce the cost of meeting the overall cap. Furthermore, the cost reduction would not be captured entirely by the residents of the local jurisdiction in which the actions took place.

Since most of the world's forests are publicly owned, provision of sequestration services as part of forest conservation is largely in the public sector. Forest protected areas make up 13.5 % of the worlds' forests, and 20.8 % for tropical lowland evergreen broadleaf forests (rainforests) (Schmitt et al., 2009). During the period 2000–2005, strictly protected forest areas experienced 70 % less deforestation than all tropical forests (Campbell et al., 2008), but impact studies must also control for 'passive protection' (protected areas being located in remote and inaccessible areas), and 'leakage' (more deforestation outside the protected area). The understanding of how protected areas can contribute to forest conservation, and thereby be a means of climate change mitigation, has advanced much since AR4, due to better spatial data and methods.

Andam et al. (2008) find substantial passive protection for protected areas in Costa Rica. While a simple comparison suggests that protected areas reduce deforestation by 65 %, the impact drops to 10 % after controlling for differences in location and other characteristics. Gaveau et al. (2009) estimate the difference between deforestation rates in protected areas and wider areas in Sumatra, Indonesia during the 1990s to be 58.6 %; this difference falls to 24 % after propensity score matching which accounts for passive protection. In a global study, also using matching techniques, Joppa and Pfaff (2011) finds that for about 75 % of the countries, protected areas reduce forest conversion, but that in 80 % of these controlling for land characteristics reduces the impact by 50 % or more. Thus, an emerging consensus is that protected areas reduce deforestation (Chomitz et al., 2007), even though protection is not perfect, and there is a medium to high degree of passive protection. Estimates of leakage are more challenging, as the channels of leakage are diverse and harder to quantify.

Local governance of forests can be an effective way of reducing emissions from deforestation and forest degradation, as at least some of the public goods provided by forest are included in the decision making process. A meta-analysis of 69 cases of community forest management finds that 58 % of these were successful in meeting ecological sustainability criteria, e.g., 'improved forest condition' (Pagdee et al., 2006). Similarly, using data from 80 different forest management units in 10 countries, a study found positive correlation between greater devolved authority at the local level with higher levels of carbon sequestration (Chhatre and Agrawal, 2009). However, a study analyzing forest cover of central Himalaya in India that controls for confounders reports no statistically significant results (in forest cover) between village and state-managed forests, even though the costs per hectare are seven folds greater for the state-managed forests (Somanathan et al., 2009).

Where property rights are insecure, strengthening land rights is often put forward as a way to contain deforestation, though the effects are ambiguous. It is argued that the lack of tenure rights can discourage investment in land and increase soil exhaustion. This would, in turn, lead to greater incentives to deforest to compensate for the lost productivity due to degradation. Unclear tenure can also lead to unproductive and violent land conflicts (Alston et al., 2000). However, by increasing the value of land clearing, policies that strengthen private property rights over land could increase deforestation (Angelsen, 1999).

15.5.7 Voluntary actions

It has become quite common for major firms, either individually or in alliance with others, to commit to mitigation of climate change as part of their corporate social responsibility through emission cuts at their offices and facilities, technological research, development, and sales of climate friendly equipment (See IPCC, 2007). Non-government organizations also initiate voluntary actions (See Section 15.9).

This section focuses on voluntary agreements that are convened by industries in association with government. Voluntary agreements have been developed in very different ways in different nations, depending on their institutional and corporate culture background. In what follows the literature will be reviewed according to the three categories provided by Pinkse and Kolk (2009).

15.5.7.1 Government-sponsored voluntary programmes for firms

Government-sponsored programmes for firms, where participation is completely voluntary and there are no penalties for not participating in the agreement, have been implemented in several countries, including the United States and Australia. The United States EPA led voluntary programmes foster partnerships with industry and the private sector at large by providing technical support among other means (US EPA, 2013).

Ex-post case studies on the environmental and economic effectiveness have been scarce compared to the wide range of activities. Where available, they have been critical of this type of programme. Several studies say little reduction was achieved (see Brouhle et al. (2009) analyzing a voluntary programme in the US metal-finishing industry) or the impacts were short lived, as was the case for the US Climate Wise Program (Morgenstern et al., 2007). See also Griffiths et al. (2007) and Lyon and Maxwell (2004) who conclude the US Climate Leaders programme had little effect on firm behaviour.

15.5.7.2 Voluntary agreements as a major complement to mandatory regulations

Voluntary agreements (VAs) often form a part of a larger climate policy approach that contains binding policies such as a carbon tax or a cap-and-trade programme. Voluntary agreements conducted jointly with mandatory regulations have been widely implemented in Europe (Rezessy and Bertoldi, 2011).

This approach allows the regulated industries to use the voluntary agreement as a partial fulfilment of the mandatory regulation. For example, through participation in the CCA in the UK, energy intensive industrial sectors established targets to improve energy efficiency and the companies that met such targets received an 80 % discount from the CCL (Price et al., 2008). Likewise, the Dutch government ensured industries participating in Long-Term Agreements (LTA) were not subject to additional government policies regulating CO_2 emission reductions or energy conservation and that the new energy tax would not be levied on the participating industries. In both cases participants established a long term plan to save energy and reduce CO_2, and implemented energy management systems (Price et al., 2008; Stenqvist and Nilsson, 2012).

Some studies found that the voluntary agreements were environmentally and economically effective. Bressers et al. (2009) found positive results in terms of ambition, compliance, goal attainment and behavioural change. They also acknowledged the efficiency advantages of flexibility in phasing technical measures. Ekins and Etheridge (2006) analyzed the UK CCA and found that, while the targets were not very stringent and were generally achieved in advance of the set date, the CCAs appeared to have catalyzed energy savings by increasing awareness. This allowed the net environmental benefits to exceed what would have been achieved by levying a flat tax without rebates and CCAs while also generating economic gains for the companies under the CCAs (Ekins and Etheridge, 2006).

Rezessy and Bertoldi (2011) assessed the effectiveness of voluntary agreements in nine EU member countries. In cases where there is cooperative culture between governmental entities and the private sector, VAs can have some beneficial effects compared to legislation. They include willingness by the industry, sharing of information, flexibility in phasing measures, and fine-tuned solutions to individual industries. They emphasized that by engaging signatories in energy audits, consumption monitoring, energy management systems and energy efficiency project implementation, the voluntary agreements helped overcome the barrier for energy efficiency improvement in a systematic manner. Nevertheless, they also noted that the VAs had been criticized for lenient targets, deficiencies in monitoring, and difficulty in establishing the additionality. There are other critical studies. Bohringer and Frondel (2007) argued that they found little evidence that the commitment of the German cement industry was effective, due to weak monitoring. Martin et al. (2011) concluded that the CCL had strong negative environmental impacts. Voluntary agreement between the European Commission and the car industry which set a mid-term target of 25 % reduction on CO_2 emissions from automobiles by 2008 completely failed (Newell and Paterson, 2010).

15.5.7.3 Voluntary agreements as a policy instrument in governmental mitigation plan

Voluntary agreements may be used as a major policy instrument with wide coverage and political salience in a governmental mitigation plan. This type of voluntary agreement has been implemented in Japan and Taiwan, province of China.

The Japanese Voluntary Action Plan (VAP) by Keidanren (Japan Business Federation) was initiated in 1997. The plan, led by Keidanren and joined by 114 industrial associations, covered about 80 % of GHG emissions from Japan's industrial and energy transformation sectors. The plan is embedded in the regulatory culture in which the government constantly consults with industrial associations. It was reviewed annually in governmental committees, and an independent third party committee was also established to monitor its implementation; the included industries were required to be accountable with their environmental performance constantly. Industrial groups and firms established energy and GHG management systems, exchanged information, being periodically reviewed and acted to improve energy efficiency and cut GHG emissions. Several industry sectors raised the ambition levels with stricter targets during the course of VAP, once they achieved original targets (Tanikawa, 2004; Akimoto, 2012; Uchiyama et al., 2012; Yamaguchi, 2012). An econometric analysis found that voluntary actions by the manufacturing sector led to significant energy efficiency investments (Sugino and Arimura, 2011).

Two successful case studies in VAP have been reported. In cutting stand-by power by electric appliances, three major industrial associations announced 2001 the target to limit stand-by power less than 1 W for all electric appliances to be met by 2003. It was possible for them to commit to the ambitious targets—ambitious in terms of the level of target (1 W), wide coverage of appliances, and early timing of goal—exactly because it was voluntary, not mandatory. In contrast, other countries that took a regulatory approach have implemented much weaker targets at later dates, and the coverage of appliances had been small. By 2003, almost all appliances met the target on time in Japan. Also, semiconductor industrial associations committed to cut

Perfluorocarbons (PFC) emissions in 1998 and succeeded in reduction by 58 % by 2009 (Wakabayashi, 2013).

Chen and Hu (2012) analyzed the voluntary GHG reduction agreements of six different industrial sectors, as well as the fluorinated gases (F-gas) reduction agreement of the semiconductor and liquid crystal display (LCD) industries in Taiwan, province of China. They found that the plan launched in 2005 was largely successful.

15.5.7.4 Synthesis

The voluntary agreements have been successful particularly in countries with traditions of close cooperation between government and industry (IPCC, 2007; Rezessy and Bertoldi, 2011; Akimoto, 2012; Yamaguchi, 2012).

Successful voluntary agreements are characterized by a proper institutional framework. This framework consists of, first, capable and influential industrial associations that serve as an arena for information exchange and development of common expectation among industries. Second, governmental involvement in implementation review is crucial. Third, accompanying measures such as technical assistance and subsidies for energy audits and equipment can also be instrumental. Finally, regulatory threats, even if they are not explicitly articulated, are an important motivating factor for firms to be active in the voluntary agreements.

The key benefits of voluntary agreements are: 1) quick planning and actions when technological solutions are largely known but still face uncertainties; 2) flexibility in phasing technical measures; 3) facilitating coordination and information exchange among key stakeholders that are crucial to removing barriers to energy efficiency and CO_2 reductions; and 4) providing an opportunity for 'learning by doing' and sharing experiences.

However, several voluntary agreements have been criticized for not bringing about significant environmental impacts due to their limited scope or lack of proper institutional framework to ensure the actions to be taken (see Sections 15.5.7.2 and 15.5.7.3).

As cross-national evaluations, Morgenstern and Pizer (2007) reviewed voluntary environmental programmes in the United States, Europe, and Japan and found average reductions in energy use and GHG emissions of approximately 5 % beyond baselines. Borck and Coglianese (2009) argued that, as an alternative to regulatory approaches, voluntary agreements may effectively achieve small environmental goals at comparatively low cost.

The major role of voluntary agreements is to facilitate cooperation among firms, industrial associations, and governments in order to find and implement low cost emissions reduction measures. Such a role is important because large mitigation potential exists, yet it is hampered by formidable barriers such as lack of information and coordination among actors. In such context the voluntary agreements can play an important role as part of a policy package.

15.5.8 Summary

This section has reviewed a range of policy instruments. Among the four policy evaluation criteria, literature is rich for economic and environmental effectiveness. The distributional incidence of taxes has been studied quite extensively, much less is known about other policy instruments. Political and institutional feasibility was also discussed as a design issue of economic instruments. The reasons for which sector specific policy instruments such as regulations and information measures have higher political feasibility than economy-wide economic instruments were briefly discussed in Section 15.2, but there is a dearth of literature really analyzing this issue.

Basic economics suggests that one instrument—e.g., a price on carbon—would be most cost effective in dealing with the market failure associated with the release of greenhouse gases. The presence of other market failures, however, means that one instrument is insufficient for dealing comprehensively with issues related to the climate problem. We have seen in Section 15.5.4 that there are cognitive and institutional factors that imply barriers to market response to carbon prices. Therefore, regulatory approaches, information programmes, voluntary agreements, and government provision may serve as a complement to pricing policy as a way to remove barriers, thereby saving the money of firms and individuals and reducing social costs. There are strong separate arguments for a technology policy to correct for the externality implied by insufficient protection of property rights, as detailed in Section 15.6. Furthermore, because carbon-pricing policy is often lacking or insufficient for political reasons in nations, various policy instruments are playing substitutive role (see Section 8.10 for examples of the transport sector).

In several sectors such as transport, urban planning and buildings, energy, and forestry, government planning and provision of infrastructure is important, even crucial, for achieving emission reductions in a cost-effective manner. Absent the appropriate infrastructure, the costs of achieving significant emission reduction might be prohibitive.

As discussed in Section 15.2 and this section, real-world politics tend to produce various policy instruments and differentiated carbon price across sectors owing to politics. Those policy instruments may positively interact as illustrated above, but may also negatively interact. Such interactions will be further detailed in Sections 15.7 and 15.8. Policymakers face the challenge to understand how the policy package is constructed in their nation and must harmonize various policy instruments so that they interact synergistically.

Box 15.2 | National and sub-national policies specific to least developed countries (LDCs)

A number of developing countries have developed legislative and regulatory frameworks to measure and manage GHG emission (Box 15.1). These frameworks or strategies can be a part of larger development plans that aim to shift the economy to a low carbon and climate resilient trajectory. These plans can serve an important signaling function by aiding coordination of government agencies and stakeholders in addition to providing the government's commitment to a low-carbon policy framework (Clapp et al., 2010).

There are pre-requisites to develop these low carbon development strategies. Achieving this policy 'readiness' entails assembling the technical knowledge and analytical capacity, legal and institutional capacity, and engagement of stakeholders in the process (Aasrud et al., 2010; van Tilburg et al., 2011). Capacity building is also a continuous process that aims to improve strategies over time to enhance low carbon outcomes. Readiness for market-based instruments increases mitigative capacity in general and enables implementation and monitoring of mitigation policies (Partnership for Market Readiness, 2011). Due to tremendous variation in capacity across countries, sufficient flexibility to allow these strategies to evolve over time is needed (Clark et al., 2010; van Tilburg et al., 2011).

Evidence from CDM projects indicates that capacity building is necessary but not sufficient to allow countries to attract CDM projects. Targeted measures like support for Designated National Authorities have shown to be successful (Okubo and Michaelowa, 2010). In addition, CDM projects have been an important mechanism for creating awareness about climate change mitigation, and have served as an indirect link between cap-and-trade systems around the world (Michaelowa, 2013). Some developing country beneficiaries of CDM are also moving towards implementing longer-term national mitigation policies. For an assessment of the Clean Development Mechanism, please refer to Chapter 13 (13.13.1.2) and Chapter 16 (16.8) for the technology component.

Climate change mitigation has also been pursued through a co-benefits approach (See Section 15.2). Increasing access to energy services is an important priority for policymakers in developing countries (Chapter 4). An estimated 1.3 billion of the world's people have no access to electricity and roughly three billion rely on highly polluting and unhealthy traditional solid fuel for household heating and cooking (IEA, 2012; Pachauri et al., 2012, p. 19) (see Section 14.3.2.1). In the short term, policies may address use of climate-friendly technologies like solar lighting alternatives to kerosene lamps (Lam et al., 2012), and gasifier cook stoves (Grieshop et al., 2011), while longer term policies may address more comprehensive approaches such as universal grid connectivity. Chapter 6 (Section 6.6.2.3) and Chapter 16 (Box 16.3 in Section 16.8) use global scenario results to conclude that universal basic energy access can be achieved without significantly increasing GHG emissions.

One option particularly relevant for developing countries is a repeal of regressive subsidies given to fossil fuel based energy carriers, together with suitable compensating income transfers so as not to limit energy access or increase poverty (see Section 15.5.2). In some developing countries, subsidies to fossil fuels are slowing penetration of less expensive renewables. For example subsidies to natural gas result in an incremental levelized cost of wind power in Egypt of an estimated 88 % (Schmidt et al., 2012). Care must also be taken to ensure transparency and to clearly demonstrate that the savings that accrue from the removal of subsidies will be used to benefit the poor.

15.6 Technology policy and R&D policy

15.6.1 Overview of the role of technology policy and R&D policy

As discussed in Chapter 3.11, there are market failures associated with research, technology development, and technology diffusion that are distinct from and interact with the market failures associated with environmental harm of human activities such as anthropogenic climate change. There is therefore a distinct role for technology policy in climate change mitigation, which is complementary to the role of policies aimed directly at reducing current GHG emissions, which are discussed in Section 15.5 above.

Public policies and institutions affect the rate and direction of technological change at all points in the chain from the invention, to innovation, to adoption and diffusion of the technology, and unaddressed market failures or barriers at any stage in the chain can limit policy effectiveness (Nemet, 2013). The innovation systems literature stresses that technology development and deployment are driven by both technology push (forces that drive the development of technologies and innovation such as R&D funding and tax breaks for R&D, patents), and demand pull forces that increase the market demand for technologies such as technology subsidies and standards (Gallagher et al., 2012; Wilson et al., 2012).

Technology systems may create path dependencies in the innovation process. The current dominance of the carbon-based system creates incentives to improve carbon technology rather than non-carbon. This has been observed in private (Aghion et al., 2012) as well as public institutions (Unruh, 2000) exemplified by fossil fuel subsidies (OECD, 2013). Escaping carbon lock-in is essentially a problem of coordination (Rodrik, 2007; Kretschmer, 2008), which can be facilitated by public policy that addresses technology-push, demand-pull, and framework conditions in a complementary fashion (Nemet, 2013).

This section addresses the generic issues that arise in the implementation of policies intended specifically to foster the development and implementation of low-GHG technologies. It begins by discussing technology policy instruments in three overarching categories: 1) the patent system and other forms of intellectual property (IP); 2) public funding of research, tax subsidies for firms engaging in R&D; and 3) various policies designed to foster deployment of new technologies. It then moves on to discuss the impact of environmental policy on technological change in general, technological change in a broader social framework often termed an 'enabling environment' together with interactions across various elements of innovation systems, and finally the importance of incorporating programme evaluation into the design of technology policy.

15.6.2 Experience with technology policy

15.6.2.1 Intellectual property

Public policy towards IP inherently involves a tradeoff between the desire to create incentives for knowledge creators and developers, and the desire to have new knowledge used as widely as possible once it is created (Hall, 2007). It is therefore crucial to analyze the extent to which IP protection such as patents, will foster climate change mitigation, by encouraging the creation and development of new GHG-reducing technologies, versus the extent to which it will hamper mitigation by raising the cost and limiting access to such new technologies as are developed. Intellectual Property policy will affect climate change mitigation both through its effects on the creation of new technology and on the international transfer of mitigation technology. The first of these mechanisms will be considered here; the effect of IP policy on technology transfer is discussed in Chapter 13.9.

In general, the empirical evidence that IP protection stimulates innovation is limited to the chemical and pharmaceutical sectors, and to developed economies (Park and Ginarte, 1997). It is unclear to what extent IP protection is relevant to the development of the kind of technologies that would mitigate climate change in advanced and middle income countries, and it appears unlikely to be relevant to indigenous technology development in the poorest countries (Hall and Helmers, 2010).[11]

The Trade Related Intellectual Property Rights (TRIPS) agreement generally commits all countries to create and enforce standard IP protections, but it does allow for the possibility of exceptions to standard patent regulations for public policy reasons (World Trade Organization, 1994). Hence a major policy issue related to climate change is the extent to which developing countries will be compelled within the TRIPS framework to enforce strong IP protection relative to GHG-reducing technologies, or whether an exception or exceptions will develop for these technologies on public policy grounds (Derclaye, 2008; Rimmer, 2009).

Because the evidence that strong IP protection increases domestic innovation is almost entirely limited to specific sectors in the developed world, it is unclear whether maintenance of strong IP protection in less developed countries will increase those countries' indigenous creation or adaptation of GHG-reducing technologies. As discussed in Chapter 13, however, the evidence does suggest that the presence of an effective IP regime is a factor in fostering technology transfer into a country.

15.6.2.2 Public funding of research and development

Public funding of research and development may address specific market failures related to innovation (as discussed in Chapter 3.11), but may also help to compensate for barriers to private investment that may result from long lifetimes of incumbent technologies leading to lengthy transition times from one system/technology to another (Fouquet and Pearson, 2006; Fouquet, 2010), uncertainty about future levelized costs of capital or discount rates (Nemet, 2013), or the lack of guarantee on the success of an investment (Mazzucato, 2013; Nemet, 2013).

Public research expenditures that have the potential to foster the long-run development of GHG-mitigating technology come under a number of different common public research expenditure categories, including environment, agriculture, materials, and others. There are no widely accepted data that attempt to identify and sum up public expenditures across different categories that potentially relate to mitigation technologies. Much discussion about the potential for technological change to mitigate GHG emissions revolves around reducing and eliminating use of fossil fuels, and the largest single category of public research expenditure related to mitigation is energy research, discussed in Chapter 7.12.2.

Public energy-related research expenditures among the International Energy Agency (IEA) countries currently comprise about 5 % of total public R&D spending in those countries, less than half the share of

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[11] There are however other relevant examples for instance of indigenous knowledge in developing countries being valuable when it comes to biodiversity and pharmaceuticals.

such research in total public research spending in 1980. Gallagher et al. (2012) report an increase in public funding for energy-technologies among IEA member countries in the 2000s but also find a continued prominence of funding for nuclear and fossil fuel technologies. A similar trend has been noted for non-IEA members like Brazil, China India, Mexico, Russia, and South Africa (Gallagher et al., 2012). A gradual but steady increase in this share is a major policy option for fostering the long-run development of GHG-reducing technologies (Jaffe, 2012).

The U.S. National Research Council (NRC) evaluated Federal Energy research, development, and demonstration (RD&D) investments in energy efficiency and fossil energy for the period 1978–2000. The NRC found that these investments "yielded significant benefits (economic, environmental, and national security-related), important technological options for potential application in a different (but possible) economic, political, and/or environmental setting, and important additions to the stock of engineering and scientific knowledge in a number of fields" (U.S. National Research Council, 2001). In terms of overall benefit-cost evaluation, the NRC found that the energy efficiency programmes produced net realized economic benefits that 'substantially exceeded' the investment in the programmes. For the fossil energy programmes, the net realized economic benefits were less than the cost of the programmes for the period 1978–1986, but exceeded the cost of the programmes for 1986–2000 (U.S. National Research Council, 2001). Japanese technology RD&D programmes for renewable energy and energy efficiency, known as Sunshine program and Moonlight program since 1974, were also found to be both economically and environmentally effective (Kimura, 2010).

In the short run, the availability of appropriately trained scientists and engineers is a constraint on a country's ability to increase its research output (Goolsbee, 1998) (See also Jensen and Thomson, 2013). This factor combines with short-run adjustment costs in laboratory facilities to make rapid ramp-up in research in a particular area likely to be cost-ineffective, as found to occur, for example, as a result of the doubling of US health research (Cockburn et al., 2011). Therefore, sustained gradual increases in research are likely to be more effective than short-run rapid increases. In the long run, it is possible to expand the supply of scientific and technical labour available to perform energy-related research. This can occur through training that occurs when publicly funded research is carried out at universities and other combined research and teaching institutions, and/or via direct public funding of training. Success at increasing the technical workforce has been found to be a crucial factor in the long-run benefits of health-related research in the United States (Cockburn et al., 2011).

15.6.2.3 Policies to foster or accelerate deployment and diffusion of new technologies

In addition to fostering technology development through research, many policies seek to foster the deployment of GHG-mitigating technologies in households and firms. Such deployment policies could be thought of as a form of abatement policy, to the extent that they reduce emissions relative to what would occur with the use of previous technologies. But the more fundamental reason for public policy to foster technology deployment is that deployment feeds back and enhances subsequent improvement of the technology over time (Jaffe and Stavins, 1994; Henkel and Hippel, 2005; Jaffe, 2012). For example, publicly funded research certainly played a role in the digital revolution, but active government involvement as an early purchaser was also crucial (Mowery, 2011). Purchases were made of products meeting stated technical specifications, and this approach has helped move products down the learning curve, eventually allowing civilian versions to be sold competitively.

Market failure in the deployment of new technologies is often illustrated via an image of a 'Valley of Death' between small scale or prototype developments and successful commercialization, in which the need for substantial increase in the scale of investment combines with uncertainty about technical reliability, market receptiveness and appropriability to stall or slow deployment (Grubb, 2004; Nemet, 2013, p. 112). A variety of demand-pull public policies can operate to carry technology deployment through the Valley of Death.

As laid out in Table 15.2, economic instruments such as subsidies, regulatory approaches, information programmes, government provision of public goods and services, as well as voluntary actions are common across sectors. The targeted technologies include low-emission vehicles such as hybrid cars in the transport sector (8.10), efficient electric appliances such as light-emitting diodes (LED) in the building sector (9.10), and advanced industrial equipment (11.10). Feed-in-tariffs are used for renewable in the power sector (7.10). Quantity requirement are also common, including RPSs in the power sector (7.10), biofuel mandates in the transport sector (8.10). Information programmes such as labelling of home electric appliance may be used to promote the sales of new, low emission technologies (9.10).

Since AR4, a large number of countries and sub-national jurisdictions have introduced support policies for renewable energy. These have promoted substantial diffusion and innovation of new energy technologies such as wind turbines and photovoltaic panels, though many renewable energy (RE) technologies still need policy support, if their market shares are to be increased (see 7.5.3, 7.6.1, 7.8.2, and Chapter 11 Bioenergy Annex).

Chapter 7 (citing the IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN)) argued that "...some feed in tariffs have been effective and efficient at promoting RE electricity, mainly due to the combination of long-term fixed price or premium payments, network connections, and guaranteed purchase of all RE electricity generated". Feed-in-tariffs have been effective in promoting renewables in Germany and other nations (Couture and Gagnon, 2010; Ragwitz and Steinhilber, 2013). It is also argued that the flexibility of FITs can incorporate economic and technological changes (Klobasa et al., 2013) and encourage dynamic innovation (Mitchell et al., 2006). Proving dynamic efficiency in the narrow economic sense is more complicated, although Jaffe et al., (2005) have explored this in a somewhat positive light.

There are different views on FITs, especially in relation to their cost-effectiveness. Some criticize FIT of having 'failed to harness market incentives' because it is not statically cost effective (i.e., it supports photovoltaics in addition to wind energy, although the former is more expensive than the latter) (Frondel et al., 2008, 2010) . Schmalensee (2012), using a simple model, argues that while FITs shift risk away from investors in renewable energies, they may not reduce the risk to society as a whole. In a paper for the European Union, Canton and Linden (2010) argue that feed-in premiums are preferable to FITs if internal market distortions are to be avoided.

With the increasing market shares of intermittent generation, new challenges have to be addressed in respect to grid and market integration such as capacity constraints, demand spikes, back up capacity, and transmission. A reform of market design, including flexible demand side pricing, is proposed to make the system more flexible so it can react to the new challenges (See 7.10 and SSREN Chapter 8 for details (Sims et al., 2012).

A theme that runs through many of the sectoral deployment policy discussions is the importance of information, and the relationship between incomplete information and risk. Uncertainty about the physical and economic performance of new technologies is a major factor limiting their diffusion, so policies that address information issues may be complementary with economic incentives or regulatory approaches.

Many nations, including Germany, Spain, China, India, among others, have implemented ambitious deployment programmes for renewables consisting of capacity targets, FIT, and so forth (Jänicke, 2012), resulting in rapid capacity expansion and lower costs of technologies. Such progress may result in economic and environmental efficiency in the long run at the global scale (Kalkuhl et al., 2013). Ondraczek (2013) identifies awareness among consumers as a critical element in market development in Kenya and Tanzania and finds evidence for a 'virtuous cycle' between dissemination and awareness. Friebe et al. (2013) emphasize the need for including pre and post-sales services to sustain the uptake of solar home systems. Glemarec (2012) highlights the role for public-private partnerships to deliver energy access but underlines the need for public investment in capacity and market development.

Many developing countries face a somewhat different set of choices in encouraging technology deployment because of the dominance of state-owned or other monopoly enterprises in the energy sector. Liu and Kokko (2010) evaluate the factors related to the significant growth of wind power in China, and conclude that administrative rules stipulating levels of wind usage have been more effective than incentives operating through the pricing system. Pegels (2010) describes the introduction of a renewable FIT guaranteed for 20 years in South Africa, but notes that it is unclear what effect this will have on the investment decisions of the monopolist electricity supplier.

15.6.3 The impact of environmental policy instruments on technological change

There is some empirical literature assessing the impact of generic environmental policy instruments (discussed in the previous section) on technological change. For surveys, see Newell (2010) and Popp et al. (2010b). Jaffe and Palmer (1997), looking across industries in the United States., found that more stringent regulation was associated with higher R&D expenditures (controlling for industry fixed effects), but did not find any impact on industry patents. Lanjouw and Moody (1996) did find that across the United States, Germany, and Japan, patenting rates were correlated at the industry level with pollution control expenditures.

A number of studies have looked at the impact of energy prices on energy-saving technological change. These effects can be seen as indicative of the possible consequences of GHG policies that increase the effective price of emitting GHG. Popp (2002) found that rising energy prices increased the rate of patenting with respect to alternative energy sources and energy efficiency, with more than one-half the effect coming within five years of energy price changes. Newell (1999) found that rising energy prices increased the efficiency of the menu of household appliances available for purchase in the United States. The Norwegian carbon tax appears to have triggered technology innovation in the form of carbon dioxide storage in the Sleipner gas field (Sumner et al., 2011). Fuel taxes moved auto industry innovation towards more efficient technologies (Aghion et al., 2012), and the EU ETS moved the firms most affected by its constraints towards low-carbon innovation (Calel and Dechezleprêtre, 2012).

At a theoretical level, there are arguments why incentive-based policies such as carbon taxes or tradable permits are more conducive to innovation than regulatory approaches (Popp, Newell, et al., 2010b). After the 1990 Clean Air Act Amendments in the United States implemented a tradable permit programme for sulphur dioxide, Popp (2003) found that the rate of patenting on techniques for sulphur removal increased, and Lange and Bellas (2005) found that both capital and operating expenditures for scrubbers were reduced. In a survey of research on the effects of tradable permit systems on technology innovation and diffusion, Bellas (2011) concluded "The general result is that tradable permit programs have improved the pollution control technology compared to the previous regulation used." Sterner and Turnheim (2009) find similarly that the very high fee on NO_x in Sweden has led to a rapid process of both innovation and technology diffusion for abatement technologies.

More recently, a few studies have explored the effect of renewable energy policies on energy innovation. Johnstone et al. (2010) found that policy had a significant impact on patent applications for renewable technologies, with different policy instruments being effective for different technologies. Popp et al. (2010a) found that the link between greater patenting and investment in specific technologies is weak, but there does seem to be an association between policy and investment.

15.6.4 The social context of technological transitions and its interaction with policy

The central insight from the empirical literature is that both technology push and demand pull policies are required to be most effective (Nemet, 2009). A 'virtuous cycle' (IEA, 2003; Edenhofer et al., 2012) can occur, derived from learning from combined technology push and market pull whereby as 'learning' from market demand feeds back in to research and development, the improved product leads to more market demand and reduced costs. This virtuous technology and market cycle has been extended to include a third cycle of policy learning (Jänicke, 2012) whereby as learning from a successful policy occurs across the innovation chain, it can also be fed back into the process.

A technology policy will be more effective if it addresses multiple aspects such as institutions, regulations and standards, political models, laws, social norms and preferences, individual behaviours, skills, and other characteristics. This idea was originally developed and encapsulated in the UNFCCC definition of an 'enabling environment' (UNFCCC, 2001).[12] This general intention to match up specific technology requirements with the system situation in which they develop has been called framework conditions (Grubb, 2004), enabling environment (Edenhofer et al., 2012; Johansson et al., 2012), enabling factors (Nemet, 2013), and complementary innovations (Grubb et al., 2014).

There is a literature base that explores technology transitions and the implications of multilevel interactions across social and technological elements (e.g., Geels, 2011; Meadowcroft, 2011; Foxon, 2011). Three social challenges are raised as especially salient to social management when attempting to alter the technological system: (1) the size and visibility of transfers and assets created; (2) the predictability of pressure to expand the focus of the policies to broaden the social benefits; and (3) the potential for market incentives and framings of environmental issues to undermine normative motivational systems (Parson and Kravitz, 2013). Managing these social challenges may require innovations in policy and institutional design, including building integrated policies that make complementary use of market incentives, authority, and norms (Foxon, 2011; Gallagher et al., 2012; Parson and Kravitz, 2013). Doing so will reduce the risk of market incentives failing to achieve behavioural change and recognizes that incentives and norms have to be integrated to achieve sustainability transitions.

15.6.5 Building programme evaluation into government technology programmes

Evaluation of government programmes to foster new energy technologies has been hampered by a lack of complete and consistent evaluation data at the programme level (U.S. National Research Council, 2001). This problem is common to many government technology programmes. Proper evaluation requires that data on project selection and project performance be collected as programmes commence and maintained after they are completed (Jaffe, 2002). Wider use of such evaluation methods would allow experience with relative effectiveness of different programmes to be used to improve outcomes over time. While the above argument applies to all governmental policy in general, it is particularly important for technology development programmes that may be vulnerable to governmental failure related to the picking and choosing of technologies under high uncertainty (Helm, 2010).

15.6.6 Summary of technology policy and R&D policy

There is a distinct role for technology policy in climate change mitigation. This role is complementary to the role of policies aimed directly at reducing current GHG emissions (15.6.1).

The availability of new technologies is crucial for the ability to realistically implement stringent carbon policies. Technology policy will be most effective when all aspects of the innovation/deployment chain are addressed in a complementary fashion (see Section 15.6.1). Investment depends on the willingness of a variety of actors to manage the balance between the risks and rewards in each step of the chain, and government decisions are crucial to this balance.

Evidence suggests that the presence of an effective IP regime increases domestic innovation. However, as evidence is almost entirely limited to specific sectors in the developed world, it is unclear whether strong IP protection in less developed countries will increase those countries' indigenous creation or adaptation of mitigation technologies (15.6.2.1).

Worldwide investment in research in support of climate change mitigation is small relative to overall public research spending. The effectiveness of research support will be greatest if it is increased steadily rather than dramatically or erratically (15.6.3).

A wide range of policy approaches is prevalent across sectors, which enable policy design that addresses sector- and technology-specific attributes. These policies are often designed as complementary sets of policies, or policy packages (15.5.1 and 15.6.2.3).

Complementary framework conditions, or an enabling environment, may complement a package of technology-push and demand-pull policies (15.6.4). Managing social challenges of technology policy change

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[12] Enabling environment is defined as: "the component of the framework [that] focuses on government actions such as fair trade policies, removal of technical, legal and administrative barriers to technical transfer, sound economic policy, regulatory frameworks and transparency, all of which create an environment conducive to private and public sector technology transfer" (UNFCCC, 2001).

may require innovations in policy and institutional design, including building integrated policies that make complementary use of market incentives, authority and norms (15.6. 4).

It is important that data collection for programme evaluation be built into technology policy programmes (15.6.5), because there is very little empirical evidence on the relative effectiveness of different mechanisms for supporting the creation and diffusion of new technologies.

15.7 Synergies and tradeoffs among policies

This section discusses interactions between policies with different main objectives as well as between differing climate policies with the same objective. Section 15.7.2 discusses relationships between policies with different principal objectives—for example, between climate policy and development policy. The next two sections consider interactions between climate policies. Section 15.7.3 describes interactions between different climate policies at different levels of government, and 15.7.4 takes up interactions between climate policies enacted at the same level of government. The interactions in 15.7.3 and 15.7.4 reflect the absence of policy coordination, and they affect the environmental and economic outcomes. Deliberate linking of policies is discussed in Section 15.8.

15.7.1 Relationship between policies with different objectives

Governments throughout the world have enacted various policies to support the mitigation of climate change, which is the central objective of climate policy. However, the implementation of mitigation policies and measures can have positive or negative effects on additional objectives—and vice versa. To the extent these side-effects are positive, they can be deemed 'co-benefits'; if adverse and uncertain, they imply risks.[13] The co-benefits of climate policy are primary benefits of policies with other main objectives. Social development is a primary benefit of development policy, since such development is the main objective. Similarly, enhanced energy security, technological development, and reduced air pollution are primary benefits of energy security, technological development, and air-pollution policies, respectively. To the extent that these other policies (with other objectives) lead to mitigation, such mitigation is a co-benefit of these other policies.

Although there is growing interest in research on mitigation as a co-benefit (see Sections 1.2.1 and e.g., Kahn Ribeiro and de Abreu, 2008), the great majority of the literature assessed in other chapters focuses on the co-effects of sectoral mitigation measures (Chapters 7.9, 8.7, 9.7, 10.8, 11.7, 11.13.6, and 12.8) or transformation pathways (Section 6.6) on additional objectives. Table 15.1 in Section 15.2.4 provides a roadmap for the assessment of those co-benefits and adverse side-effects on the many objectives examined in various chapters of this report and highlights that the effects on energy security and air pollution as well as the associated reductions in health and ecosystem impacts are discussed in all sector chapters. For example, stringent mitigation results in reduced combustion of fossil fuels with major cuts in air pollutant emissions significantly below baseline scenarios (see 6.6.2.1 and, e.g., ApSimon et al., 2009) for a discussion of policy interaction in Europe); by increasing the diversity of energy sources and reducing energy imports in most countries, mitigation often results in energy systems that are less vulnerable to price volatility and supply disruptions (see 6.6.2.2 and, e.g., Lecuyer and Bibas, 2011) for a discussion of policy interaction in Europe).

According to recent scenario studies assessed in Chapter 6.6.2.7, stringent climate policies would significantly reduce the costs of reaching energy security and/or air pollution objectives globally. Recent literature assessed in Chapters 6.6.2.3, 7.9.1 and 16.8 finds that increasing access to modern energy services may not conflict with mitigation objectives—and vice versa.

There are two important advantages to coordinating separate policies and their various benefits. By coordinating policies, the various benefits and costs can be considered in an integrated fashion, which offers information helpful to determining how to achieve the objectives at low cost (see 6.6.2.7). In addition, coordinating policies can improve political feasibility. The concept of 'mainstreaming' climate policy refers to the linking of climate policy with other policy efforts, particularly policy efforts that have broad recognition. The prospects for successful climate policy can be enhanced through such mainstreaming (Kok and de Coninck, 2007).

Development frameworks at international or national levels, or by sector, may include mainstreaming as a key element. For it to be effective, climate change mitigation needs to be mainstreamed in appropriate national and sector planning processes to widen development goals within national and sectoral contexts. For developing countries, such integration of mitigation into development planning can reduce problems of cooperation and coordination that may arise across different levels of government (Tyler, 2010).

Mitigation plans can be embedded in national policy-making processes to align economic and social development with mitigation actions. For example, in China, the National Leading Group on Climate Change is part of the National Development and Reform Commission, the principal national planning body (see Section 15.2.2.2).

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[13] Co-benefits and adverse side-effects describe effects in non-monetary units without yet evaluating the net effect on overall social welfare. Please refer to the glossary in Annex I for definitions and to Chapters 3.6.3 and 4.8 for a discussion of how the concept of co-benefits relates to welfare and sustainable development, respectively.

Limited institutional capacity in developing countries presents the most significant barrier to mainstreaming of mitigation policies. This includes a lack of knowledge and/or expertise in climate change issues, a lack of (or weak) oversight and/or enforcement. Developing countries aiming to mainstream and implement climate change mitigation policies must; 1) encourage awareness on the topic; 2) establish related training programmes; 3) ensure an adequate level of finance for enforcement; and 4) enhance coordination between ministries (Ellis et al., 2009).

15.7.2 Interactions between climate policies conducted at different jurisdictional levels

Climate policy has been conducted at various jurisdictional levels: international, national, regional (state or provincial), and local (municipal). Important interactions can occur across jurisdictional levels. Some interactions are beneficial, reinforcing the intended effects; others are problematic, interfering with the planned objectives. Sound policymaking requires attention to these interactions.

15.7.2.1 Beneficial interactions

Policies introduced by a local jurisdiction sometimes reinforce the goals of efforts undertaken at a higher jurisdictional level. In particular, a sub-national policy can enhance cost-effectiveness if it addresses market failures that are not confronted by a national climate policy. Thus, for example, as seen in Sections 15.5.4 and 15.5.6, an RPS in the electricity sector and an R&D subsidy could usefully complement a national emissions pricing policy.

The connections between instruments that deal with climate change and those that deal with congestion or local pollution also present an opportunity to policymakers, but they are very different since the latter vary depending on the socioeconomic context, technology, fuel, and vehicle use (Parry et al., 2007; Oikonomou and Jepma, 2008; Vanderschuren et al., 2010; Parry, 2013). For example, urban planning implemented jointly with fuel or carbon taxes can help fast growing developing countries minimize resource waste by avoiding urban sprawl. Policies incentivizing more dense urban architecture combined with the appropriate infrastructure for modern public transport can be an important complement to energy taxation. Such policies can be supported (and possibly financed) by fuel taxes if the policymaker wants to discourage citizens from making private decisions that are incompatible with this broader vision; policy combinations for this sector are discussed in greater detail in Chapter 8. Conversely, subsidizing fuels and taking a hands-off urban planning approach can result in urban sprawl and a growth in private automobile use along with growth in resulting emissions.

Local-level action can also be a good source of information by allowing experimentation. In the United States, environmental policies by the federal government have a history of evolving out of successful policy 'experiments' undertaken by states (Goulder and Stavins, 2011; Shobe and Burtraw, 2012). Thus, an appealing feature of local-level actions are their ability to try out policy options not currently in place at the higher jurisdictional level; the higher jurisdiction may have more confidence in introducing a policy subsequently if it already has a successful track record at the more local level.

Finally, local policies can produce beneficial strategic interactions. If national policy is insufficiently stringent, a stringent state/province or even municipal policy may create pressure on the national government to increase its own policy's stringency. Goulder and Stavins (2011) cite the example of California, which repeatedly increased the stringency of its local air pollution standards and was repeatedly followed by the federal government increasing Clean Air Act regulations' stringency. Similarly, Lucon and Goldemberg (2010) note the importance of São Paulo's GHG-reducing policies in influencing other local and even regional governments in Brazil.

15.7.2.2 Problematic interactions

Policies introduced at different levels sometimes interact in ways that compromise or weaken the intended environmental or economic impacts.

One particular difficulty that may arise is the problem of emissions leakage. This can occur, for example, when a climate policy introduced at a lower jurisdictional level is 'nested' within a cap-and-trade programme implemented at a higher jurisdictional level. Consider the case where a cap-and-trade programme exists at the national level, and where a sub-national authority introduces a new policy intended to reduce its own (sub-national) emissions beyond what would result from the national programme alone. The sub-national jurisdiction's efforts might indeed yield reductions within that jurisdiction, but facilities in other sub-national jurisdictions covered by the cap-and-trade programme will now use these allowances leading to higher emissions in these jurisdictions completely compensating the abatement effort in the more stringent jurisdiction. Since overall emissions at the higher level are determined by the given national-level cap, the effort by the sub-national jurisdiction does not succeed in reducing nationwide: it just causes emissions leakage—offsetting increases in emissions elsewhere in the nation. The national cap effectively prevents sub-national jurisdictions from achieving further emissions reductions (Goulder and Stavins, 2011; Shobe and Burtraw, 2012).

The issue applies to the United Kingdom's efforts to reduce emissions through a carbon tax on the power sector (electricity generators). The generators are required to pay the tax on every unit of carbon emissions while also being subject to the EU ETS cap on overall emissions. While the tax may lead to greater reduction in carbon emissions by the generators in the UK, the impact on overall emissions in the EU might be negligible, since overall European emissions are largely determined by the Europe-wide cap under the EU ETS. On this, see (Böhringer et al., 2008; Sartor and Berghmans, 2011; Goulder, 2013)

This leakage problem can be avoided when the lower-level jurisdiction's programme is nested within a carbon tax programme, rather than emissions cap, at the higher level. In this case, the sub-national policies generally are not environmentally irrelevant. The reduced emissions in the sub-national jurisdiction do not lead to a fall in the emissions price (the carbon tax) at the national level; hence there are no offsetting increases in emissions in jurisdictions outside the jurisdiction introducing the more stringent policy (De Jonghe et al., 2009; Fankhauser et al., 2010; Goulder and Stavins, 2011). This can be an important advantage of a carbon tax over a cap-and-trade system.

15.7.3 Interactions between policies conducted at the same jurisdictional level

Interactions also can arise when different policy instruments are introduced at the same jurisdictional level. These interactions can be beneficial or problematic in terms of the cost-effectiveness of reducing greenhouse gas emissions.

15.7.3.1 Beneficial interactions

The potential for cost-reducing interactions is greatest when the different instruments address different market failures. A fundamental principle of public policy is that the most cost-effective outcome results when there are as many policy instruments as the number of market failures involved, with each instrument focusing mainly on a different market failure (Tinbergen, 1970).

Climate policy is meant to address one market failure in particular—the climate-change-related externalities associated with GHGs. As seen in Section 15.6, another important market failure applies in the market for innovation: because new knowledge can spill over to third parties, innovators often cannot capture all of the social benefits from the new knowledge they create. Introducing two policy instruments, for example, emissions pricing to address the emissions externality, and a subsidy to R&D to address the innovation market failure, can lower the costs of achieving given emissions reductions. In addition to helping reduce emissions by encouraging fuel-switching and a reduction in demand, emissions pricing can help spur innovation. Likewise, the R&D subsidy can promote invention of low-carbon technologies, thereby helping to curb emissions. Hence the interactions of the two policies are beneficial. Although each of the two policies might to some degree affect both of the market failures, emissions pricing is particularly well focused on the first, while the R&D policy sharply addresses the second. Using two instruments helps achieve emissions reductions at the lowest cost. In this connection, Fischer and Newell (2004) and Oikonomou et al. (2010) find that a policy combination including a price on GHG emissions and renewable energy subsidies achieves emissions reductions at significantly lower cost than either of these policies alone. Schneider and Goulder (1997) obtain a similar result for the combination of carbon tax and R&D subsidy.

As noted already in Section 15.5.4.1, several studies (Greene, 1998; Goulder and Parry, 2008; Gillingham et al., 2009b) argue that there is a market failure associated with consumer purchases of durable energy-using equipment (automobiles, refrigerators, etc.), according to which consumers systematically underestimate their own future gains from purchasing more energy efficient durables. To the extent that this market failure is significant, the combination of emissions pricing and a second instrument (for example, an energy-efficiency standard for appliances) to address this additional market failure could lead to beneficial interactions and promote cost-effectiveness.

Some studies suggest a market failure associated with reliance on crude oil, claiming that reliance on oil produces an 'economic vulnerability externality', given the possibility of supply disruptions on the world oil market (Jones et al., 2004). Under these circumstances, the combination of emissions pricing (to address the climate change externality) and a tax on oil consumption (to address the vulnerability externality) can be a cost-effective way of dealing with both climate change and economic vulnerability. Several authors (e.g., Nordhaus, 2009), emphasize that the vulnerability to world oil price changes is largely a function of the share of overall oil consumption in GDP, rather than the share of consumed oil that comes from imports. This suggests that the vulnerability externality is best addressed through a tax on oil consumption rather than a tax on imported oil.

15.7.3.2 Problematic interactions

Multiple policies at the same jurisdictional level also can yield problematic interactions. This can happen when multiple policies only address the same market failure. Consider the situation where a given jurisdiction attempts to reduce greenhouse gases through both emissions pricing and another policy such as a performance standard (a limit on the ratio of emissions per unit of production). Economic theory claims that, absent market failures and other barriers, emissions pricing tends to promote a highly cost-effective outcome by promoting equality in the marginal costs of emissions-abatement across all the facilities that face the given price of emissions (the carbon tax or the price of emissions allowances). If, in addition, facilities face a performance standard, then this added policy approach either is redundant or it compromises cost-effectiveness.

It is redundant if meeting the performance standard would involve marginal abatement costs lower than the emissions price. In this event, cost-minimizing firms would be induced to meet or exceed this standard by the emissions price alone: there is no need for the standard. On the other hand, if the performance standard entails a cost per unit of abatement that is significantly higher than the emissions price, then this requirement sacrifices cost-effectiveness. Relying on emissions pricing alone would have promoted emissions reductions by the facilities that can achieve those reductions at the least cost. Thus it would likely have led to a situation where the more expensive technology approach was not employed. Hence in this case the combination of emissions pricing and the performance standard does not promote cost-effectiveness.

Emissions price policies interact with other policies differently depending on whether the emissions price policy involves a quantity limit (as is the case under cap and trade) or a stipulated emissions price (as is the case under an emissions tax). In the presence of a cap-and-trade programme, introducing an additional instrument such as a performance standard might yield no further reductions in overall emissions (Burtraw and Shobe, 2009; Fankhauser et al., 2010). The reason is that overall emissions are determined by the overall cap or number of allowances in circulation. The problem is formally very similar to the difficulty described in Section 15.7.3 above, where in the presence of a national cap-and-trade programme an effort by a sub-national jurisdiction to achieve further emissions reductions is likely to have difficulty achieving that goal. In contrast, introducing a performance standard in the presence of an emissions tax can in fact lead to a reduction in overall emissions. The price of emissions—the emissions tax—does not change when the performance standard causes a reduction in emissions. For this reason the reduction caused by the performance standard does not lead to a compensating increase in emissions elsewhere. Overall emissions fall.

For similar reasons, the same difficulty arises when a carbon tax is introduced in the presence of a cap-and-trade programme at the same jurisdictional level (Fischer and Preonas, 2010).

Nevertheless, as suggested above, the combination of emissions pricing and some other policy could be justified in terms of cost-effectiveness to the extent that the latter policy directly addresses a second market failure that emissions pricing does not directly confront.

It is important to recognize that the notion of a 'market failure' pertains only to the criterion of economic efficiency. Another important public policy consideration is distributional equity. Concerns about distributional equity can justify supplementing a given policy instrument with another in order to bring about a more equitable outcome. This may be desirable even if the multiplicity of instruments reduces cost-effectiveness.

15.8 National, state and local linkages

15.8.1 Overview of linkages across jurisdictions

In the last few years, an increasing number of sub-national administrations across the world have been active in the design and application of climate policies. Section 15.2 has reported some of these experiences, whereas Section 15.7 has dealt with some of the interactions that may arise with the simultaneous use of climate policy instruments by several jurisdictions. This section goes back a little and is basically interested in the allocation of climate policy responsibilities across the different levels of government that usually exist in most countries (central, provincial, and local administrations). Although such allocation involves the use the policy types described in Section 15.4, the emphasis here will not be on instrument use in itself, as this was already covered in Sections 15.5 to 15.7. The objective of this section is to examine the theoretical backing for such practical applications and to extract lessons that may be useful for future sub-national applications and even for the design and implementation of national and supra-national mitigation policies. When dealing with the reasons for and guidelines for the 'vertical' allocation of responsibilities among jurisdictions that co-exist in a country, the theory of fiscal federalism (economic federalism) offers valuable insights. In short, that the responsibility for public decision making over a particular issue (e.g., allocation of public goods, economic stabilization, or distribution) should be given to the jurisdictional level that could better manage it. In this sense, fiscal federalism contends that the central government should have the basic responsibility for functions whose national extension would render ineffective and inefficient a sub-national approximation, including 'national' public goods (Oates, 1999).

15.8.2 Collective action problem of sub-national actions

Given the global and public good nature of climate change, its jurisdictional allocation should actually be at the highest possible level. A sub-global allocation, as observed in Chapter 13, would lead other jurisdictions that are not active in climate change mitigation to benefit without paying the costs, i.e., in a free-riding fashion (Kousky and Schneider, 2003). Empirically, case studies found that climate policies tended to be less intrusive at sub-national level. While co-benefits with local development were pursued, policies that might incur costs to local economy were avoided in prefectures in Japan (Aoki, 2010). The costs for a sub-national administration may be actually beyond those of pure mitigation, as climate policies implemented by a jurisdiction might bring about leakage, (see the glossary in Annex I for a definition) (Kruger, 2007; Engel, 2009). Moreover, the 'reshuffling' that may be associated to sub-national policies may reduce their environmental effectiveness (Bushnell et al., 2008). As a consequence, climate change mitigation would be provided in a sub-optimal level with sub-national allocation of responsibilities.

15.8.3 Benefits of sub-national actions

Yet, even if the central government has a major responsibility in this area, this does not preclude the allocation of mitigation responsibilities within a federation, as observed in citizen's attitudes on this matter (Lachapelle et al., 2012). But even within the theory of fiscal federalism there are other reasons that may justify sub-national action in this field. First, as noted by Edenhofer et al. (2013), the exploitation of heterogeneous sub-national preferences for mitigation would lead to efficiency gains. This is actually one of the reasons for the decentralization theorem, a centrepiece of fiscal federalism, which in fact justifies sub-national allocation of certain public goods.

Moreover, decentralization can contribute to policy innovation by providing an opportunity to experiment with different approximations. Indeed, there might be potential gains from learning by doing in policy terms without imposing large costs on an entire country or the world with untried options (Oates, 2002). Sub-national governments could also choose to be leaders in the development of climate policies to obtain potential economic gains that are associated to 'first movers' (Jänicke and Jacob, 2004) and may provide guidance and incentives to other jurisdictions to follow them (Bulkeley and Castán Broto, 2012). Besides, as they tend to be smaller, sub-national governments may be able to adapt to new situations in a swifter manner and therefore may have a greater flexibility to modify existing climate policies or to define new ones (Puppim de Oliveira, 2009; Galarraga et al., 2011).

Other general approaches to federalism, such as cooperative and democratic federalism, may also provide reasons for sub-national involvement in this area (Inman and Rubinfeld, 1997). On the one hand, cooperative federalism argues for allocating pure public goods to the local level, counting on the power of inter-jurisdictional bargaining to improve allocations. On the other hand, democratic federalism incorporates sub-national representation in central decision making on public goods. In any case, federal structures may be crucial for the transmission of mitigation policies because most sub-national governments are now responsible for matters that have huge effects on GHG emissions, namely: land use planning, building codes, waste management, traffic infrastructure and management, and public transport (Collier and Löfstedt, 1997; Bulkeley and Betsill, 2005; Doremus and Hanemann, 2008). But sub-national governments also have direct policies aimed at GHG mitigation, including: energy efficiency programmes, educational efforts, green procurement standards, partnership agreements with local businesses, or tree planting (Schreurs, 2008).

Yet another reason for a sub-national role in climate policies is beyond the standard collective action approach. By indicating that externality-correcting regulations and global agreements are not the only pace to tackling climate change problems, Ostrom (2010) suggested a polycentric approach in which mitigation activities are undertaken by multiple (public and private) units at diverse scales. The prevalence of sub-national actions in the field, contentious to other approaches, may be actually a proof of polycentrism in the area (Byrne et al., 2007; Sovacool, 2011b). The polycentric approach could be seen as a reinterpretation of the findings of the federalism literature, as actions should involve many different agents in a reinforcing manner.

Finally, further issues may explain sub-national allocation. Local authorities, for instance, may be more effective in reducing GHG emissions from some sources such as waste and transport, as this may provide significant co-benefits to local citizens (Kousky and Schneider, 2003). Moreover, sub-central administrations are usually closer to the places and citizens impacted by climate change. Even though climate change is a global phenomenon, the nature of its impacts and severity varies significantly across locations so some sub-national governments have reasons to be more protective than national or supranational administrations (Andreen, 2008). This is also the case of adaptation, where sub-national authorities can better manage challenges such as flood risk, water stress, or 'climate proofing' of urban infrastructure (Corfee-Morlot et al., 2009). In all the preceding situations, sub-national governments may tailor actions and policies to people's needs, with an easier identification of priorities and difficulties as they are closer to citizens than more centralized administrations (Lindseth, 2004; Galarraga et al., 2011).

15.8.4 Summary

As in other environmental areas (Dalmazzone, 2006), there is theoretical backing for the allocation of climate-related policies to sub-national levels of government, although there are several limiting factors to a widespread reliance on these administrations. A federal structure that provides coordination and enables an easier transmission of climate policies throughout the agents of the economy is likely to increase the effectiveness of actions against climate change. Moreover, the lessons learned in the design and application of climate policies at different jurisdictional levels could be used in a global setting.

15.9 The role of stakeholders including NGOs

This section considers the role of stakeholders and civil society in developing and delivering concrete mitigation action and focuses on how stakeholders impact policy design and implementation. The range of stakeholders is immense given the extent and complexity of climate change. Devising policy in an inclusive manner may be lengthy and politically challenging (Irvin and Stansbury, 2004), however adopting an inclusive approach to climate policy can bring advantages, notably through increasing the legitimacy of policy design, its durability and implementation (Lazo et al., 2000; Beierle, 2002; Dombrowski, 2010).

15.9.1 Advocacy and accountability

Some of the major functions and roles of NGOs can include raising public awareness, which often involves translating scientific and technical knowledge into actionable forms, lobbying, influencing business investment decisions, and monitoring and implementing agreements (Gulbrandsen and Andresen, 2004; Guay et al., 2004; Betsill and Corell, 2008; Newell, 2008; Dombrowski, 2010). Their domains of action also include engagement in sub-national and national policies and institutions as well as international processes like UNFCCC (Wapner, 1995; Lisowski, 2005). It is in these diverse forms that NGOs play a role in "connecting knowledge with responsibility" (Szarka, 2013) and promoting norms of accountability (Gough and Shackley, 2001; Newell, 2008).

Stakeholders can also affect when and how evidence of climate change translates into policies via the domestic political system (Social Learning Group, 2001). The differing results of the same scientific evidence, for instance, the political polarization in the United States versus more proactive and consensual attempts to find solutions in Europe (Skjærseth et al., 2013) demonstrate how stakeholder interests can filter scientific evidence.

Evidence also indicates that that some fossil fuel companies went further and promoted climate scepticism by providing financial resources to like-minded think-tanks and politicians (Antilla, 2005; Boykoff and Boykoff, 2007), although other fossil fuel companies adopted a more supportive position on climate science (van den Hove et al., 2002a). Differences in the attitudes of oil companies towards climate change are explained in part by domestic institutional contexts and management structures as well as the structure of assets or technologies of different energy companies (Rowlands, 2000; Kolk and Levy, 2002).

15.9.2 Policy design and implementation

Three factors have been considered important for lobbying success in policy design namely: how institutions shape the space for participation (Kohler-Koch and Finke, 2007), organizational resources (Eising, 2007), and the policy environment (Mahoney, 2008; Coen and Richardson, 2009).

In the case of the EU ETS, Skodvin et al. (2010) find that interest groups are able to limit "spectrum of politically feasible policy options." Instrument choice is a function of the extent of resources these interest groups control, the role of veto players in the political process, policy networks and entrepreneurs (Skjærseth and Wettestad, 2009; Skodvin et al., 2010; Braun, 2013; Skjærseth et al., 2013).

The role of business interests in supporting emissions trading as opposed to taxation, in the UK, has also been recognized (Bailey and Rupp, 2006; Nye and Owens, 2008). The political opposition to Australia's Carbon Pollution Reduction Scheme has been explained largely by the opposition of fossil fuel interests (Crowley, 2010, 2013; Macintosh et al., 2010; Bailey et al., 2012). Similarly, in New Zealand, the agriculture sector has played a major role in obtaining a transition period for the sector, use of an intensity-based accounting system, and free credits (Bullock, 2012). This has led to questions regarding the environmental effectiveness of the ETS (Bührs, 2008).

Stakeholders also affect policy durability, flexibility, and implementation. For example, European Climate Change Programme featured consultation processes that ensured policy credibility by having the buy-in of stakeholders. Similarly, the persistence of climate legislation in California has been explained by the stability of coalition groups supporting the legislation due to path dependence despite the economic downturn in contrast to the emerging coalition at the national level which broke down after economic shocks (Knox-Hayes, 2012).

15.9.3 Summary of the role of stakeholders

Early findings indicate the importance of institutions in creating spaces for stakeholder participation, the organizational resources of the stakeholders themselves, and the general policy environment as being critical factors that determine the effectiveness of stakeholder engagement. However, the degree to which policy design and implementation to mitigate climate change is dependent on stakeholder engagement is as yet under-researched and it must be stressed that the evidence base is thin and that these results primarily derive from case studies.

15.10 Capacity building

As national and sub-national governments around the globe confront the multifaceted challenge of climate change mitigation and adaptation, capacity is essential. According to the Agenda 21, building a country's capacity "encompasses the country's human, scientific, technological, organizational, institutional, and resource capabilities" (United Nations, 1992).

The priority for capacity building is strongly reflected in the Johannesburg Plan of Implementation (United Nations, 2002), where capacity building, especially for developing countries and countries with economies in transition, features prominently. It is also stressed in the UNFCCC's capacity building framework for developing countries (Decision 2/CP.7; UNFCCC, 2001). The goal of capacity building under this framework is "to strengthen particularly developing country parties, to promote the widespread dissemination, application and development of environmentally sound technologies and know-how, and to enable them to implement the provisions of the Convention. In addition, the COP under the UNFCCC requested the Subsidiary Body for Implementation to organize an annual in-session Durban Forum for in-depth discussion on capacity-building following COP-17" (Decision 2/CP.17; UNFCCC, 2011). The Durban Forum provides an opportunity for representatives from governments, UN organizations, intergovernmental and non-governmental organizations, academia, and the private sector to share ideas, experiences, and good practices on implementing capacity-building activities.

15.10.1 Capacity to analyze the implications of climate change

Climate change is a severe and major problem that has the potential to seriously derail poverty alleviation in a number of low income countries (Dell et al., 2009). Climate change will affect livelihood assets by impacting health, access to natural resources and infrastructure (Skoufias, 2012). It is also likely to erode agricultural productivity in tropical climates (Skoufias, 2012). Given that the implications of climate change differ so dramatically between countries, to inform climate negotiations and allow countries to realize the full extent of their adaptation needs, substantial capacity would be required to analyze the implications of climate change and to formulate country positions. So far, the academic capacity is geographically very skewed. For example, the International Social Science Council (ISSC) commissioned a bibliometric study on social science research on climate change and global environmental change in the period from 2000 until 2010. It found that OECD countries completely dominated this research and that the poorest countries, notably in Africa, hardly were visible at all in the statistics (Hackmann and St Clair, 2012).

15.10.2 Capacity to design, implement and evaluate policies

The design, implementation, and evaluation of national and sub-national climate policies necessitate in-country human capital. National governments and civil society require that climate policies be adapted to local economic, cultural, and social conditions to ensure their effectiveness and public support. To be politically acceptable, such work generally needs to be done by citizens of the country in which the policies are to be implemented. Political feasibility is mainly determined by policy design to improve environmental and economic effectiveness and distributional equity (Bailey and Compston, 2012b). A high level of scientific knowledge and analytical skills are required for such work. Capacity building allows the leadership to be sensitive to environmental constraints and encourages policymaking to meet the needs of the people within these parameters (United Nations, 1992).

Many studies analyze the technological options for achieving deep reductions in GHG emissions, however they do not necessarily reflect the need for capacity building. For example, while Pacala and Socolow (2004), through their 'stabilization wedges', increased the understanding of the technological options that could be deployed to reach stabilization targets, they did so without pointing out the capacity necessary to reach such a potential. These do however need local adaptation. Through the collaborative dialogue under the Durban Forum, key areas for capacity building on mitigation have emerged, including: low-carbon development strategies; NAMAs; Monitoring, Reporting and Verification; Technology Needs Assessments (TNAs); and mitigation assessments.

15.10.3 Capacity to take advantage of external funding and flexible mechanisms

Climate change, and the global policies to mitigate and adapt to it, also imply additional capacity challenges in order to take advantage of international funding and flexible mechanisms such as the CDM in the Kyoto Protocol, and REDD+. So far, the distribution of projects under flexible mechanisms has been very skewed towards countries with greater capacity. As an example, only 2.5 % of normal CDM projects have been hosted by African countries (Fenhann and Staun, 2010).

In the preparations for the UNFCCC Durban Forum on Capacity Building (UNFCCC, 2011) it was noted that capacity-building in developing countries should be improved by (1) ensuring consultations with stakeholders throughout the entire process of activities; (2) enhancing integration of climate change issues and capacity-building needs into national development strategies, plans and budgets; (3) increasing country-driven coordination of capacity-building activities; and (4) strengthening networking and information sharing among developing countries, especially through South-South and triangular cooperation.

15.10.4 Capacity building modalities

Capacity building is about equipping people, communities, and organizations with the tools, skills, and knowledge to address the challenges of climate change. It can be delivered through education, outreach, and awareness, but it can also be facilitated through peer learning, knowledge platforms, information exchanges, and technical assistance (Mytelka et al., 2012). The need for capacity building is large. Hundreds of thousands of scientists of various disciplines need to be trained globally in the coming decades as well as policymakers, civil servants, businessmen, and civil society. These needs are not limited to developing countries, as it is needed at all levels of society and in all regions of the world.

There are many different modalities. Since the 15th Conference of the Parties (COP-15), partnerships have formed at the international, national, and sub-national level aimed at climate readiness activities. Capacity building in the private sector is also important. Studies indicate that good management, trained workers, and clean manufacturing increase energy efficiency while reducing CO_2 emissions. Substantive carbon reductions can be achieved at zero or negative cost through improved workplace practices, optimized processes, and behavioural changes in production (Bloom et al., 2010). Even this requires human resources and capacity to be undertaken.

Capacity building requires a long time horizon, and this is particularly evident in education-poor countries. Building in-country academic programmes that can graduate well-trained masters and PhD students can take decades. When students graduate from such programmes it takes an additional 5–10 years of post-doctoral and junior faculty positions to build the experience and skills to contribute at a high international level (Sterner et al., 2012). Capacity building initiatives are therefore fragile and require continued support and nurturing by both national governments and international organizations. This may be one additional and important area for climate finance.

15.11 Links to adaptation

This section discusses links between national and sub-national policies and institutions for mitigation and adaptation. Links between adaptation and mitigation policies at the international level are discussed in Chapter 13, while adaptation in general is discussed in WGII. Adaptation will be needed because some climate change is inevitable (Chapter 5). Indeed, some governments have started to plan and implement policies aimed at tackling changes that are likely to take place or have taken place already (Aaheim et al., 2009). In the longer term, the level of adaptation needed will depend on the success of mitigation efforts and the resulting GHG concentrations, thus there is an obvious linkage between mitigation and adaptation. However, the level of adaptation needed will also depend on the climate response to any given GHG level, around which there is high uncertainty. Mitigation will help to reduce the uncertainty on future changes and is therefore helpful for planning adaptation.

It has been argued that mitigation and adaptation policies are related to each other (Smith and Olesen, 2010). This, however, is a controversial issue (Hamin and Gurran, 2009). Any given mitigation policy at the national or sub-national level is unlikely to have a significant effect on the global climate, so that the climatic consequences of that policy for the purpose of planning adaptation can usually be ignored. The direct side-effects of a mitigation policy for adaptation are more relevant. Examples of such direct effects are mainly in land use (discussed in Section 15.11.3 below) where synergies and tradeoffs between mitigation and adaptation policies may arise.

It is, of course, true that mitigation policies can have effects on adaptation across sectors. For example, carbon pricing can make air-conditioning more expensive, thus hindering adaptation to a warmer climate. However, this is simply one of many costs of a mitigation policy that will be taken into account while making policies. Conversely, adaptation to higher temperatures has led to increased electricity consumption for cooling (Gupta, 2012) that has to be taken into account while planning mitigation, but so do all changes in demand arising for other reasons such as income growth.

On the national scale, the approach to mitigation and adaptation differs between high or upper-middle income countries and low or lower-middle income countries due to the balance of responsibilities and the focus on mitigation versus adaptation.

The early national policy focus in high or upper-middle income countries was largely on mitigation. These policies were largely developed without in-depth consideration of adaptation linkages. Those high or upper-middle income countries that are developing national adaptation strategies and policies (e.g., see Bizikova et al., 2008; Stewart et al., 2009; Bedsworth and Hanak, 2010; Biesbroek et al., 2010) have shown limited consideration of the effects of adaptation policies on greenhouse gas emissions to date. Neufeldt et al. (2010) investigated the reasons for this disconnect in Europe and found it was due to a strong sectoral separation: sectors that were major emitters have been mitigation focused, and have received little attention on adaptation, whereas climate sensitive sectors such as agricultural, although a potential contributor to emission reductions, have focused on adaptation. They also report that adaptation policy and actions have lagged behind mitigation more generally, and the difference in timing also contributes to the separation of the two domains. This is now starting to change: Bruin et al. (2009) in the Netherlands considered the potential GHG emissions of adaptation measures as part of a national multi-criteria ranking of options.

To date, most of the national climate policy initiatives in low-income countries, especially in the LDCs, have focused on adaptation, notably through the National Adaptation Programme of Action (NAPAs). However, more recently there has been a shift with a number of national policy initiatives that aim to develop climate resilient, low carbon economies (also known as low-emission development strategies or green growth). These include Ethiopia's Climate Resilient Green Economy Vision (EPA Ethiopia, 2011) and Rwanda's Green Growth and Climate Resilience National Strategy for Climate Change and Low Carbon Development (Government of Rwanda, 2011). Given the importance of climate change in these highly vulnerable countries, these initiatives look to build climate resilience, but also recognize the benefits in advancing low carbon development. Research on the linkages between emission reductions and adaptation is still at an early stage and most of the synergies between adaptation and mitigation are centred on the agricultural and forestry sectors.

Some local activities, such as those regarding land-use decisions, have important implications for both mitigation (e.g., by means of carbon sequestration) and adaptation (e.g., by means of increasing resilience to climate change). Ravindranath (2007) explores the synergies between mitigation and adaptation in the forestry sector. As forests are highly vulnerable to climate change, but provide opportunities for mitigation (e.g., through afforestation), efforts to enhance carbon sequestration need to embed adaptation elements so that exposure to climate impacts can be addressed. Mitigation efforts through forest management regimes such as conservation areas and sustainable forestry contribute to adaptation. Conversely, adaptation efforts such as urban forestry and measures to conserve soil and water also have mitigation effects (Ravindranath, 2007).

Similar issues have emerged for the agricultural sector, with the focus on climate-smart agriculture. This focus recognizes the high vulnerability of agriculture as a climate-sensitive sector, but also addresses the fact that it is a major source of greenhouse gas emissions in developing economies. A number of options have been identified as potentially beneficial for mitigation and adaptation, including (McCarthy et al., 2011) soil and water conservation (including conservation agriculture, low or minimum tillage, vegetation strips, terraces, structures such as bunds contours, shade trees, tied ridges, small-scale water harvesting, compost production, cover crops, improved fallows, crop residues), agroforestry, and improved pasture and grazing management including restoration. These options generally are based on sustainable agricultural land management (SALM) practices. These practices reduce climate related risks in the form of rainfall variability and soil erosion, increase soil organic matter and soil fertility (thus increasing productivity), and reduce emissions by either reducing soil emissions or preventing other more emission intensive activities. More traditional measures to increase productivity, such as fertilizer use or increased irrigation, have the potential to increase greenhouse gas emissions because of the high energy intensity of fertilizer production and the energy use in water abstraction and pumping; however, they may still reduce land-use emissions by increasing the productivity and yields per hectare, as well we reduce future land-use pressures that may lead to deforestation (Chapter 11). However, as highlighted by McCarthy et al. (2011), many of these climate-smart options involve important opportunity or policy costs, higher risks, or may involve benefits that arise over longer time periods (e.g., improved soil function), or involve wider environmental benefits that are not immediately useful to farmers. They also frequently involve institutional, financial, and capacity barriers, and so may not happen autonomously.

Both the forest and agricultural sectors also link through to issues of rural land-use change and land planning/management, which can have synergistic effects on mitigation and adaptation (Pimentel et al., 2010), but which can also involve complex tradeoffs.

Overall, the emerging evidence suggests that while there may be a potential for synergistic mitigation and adaptation policy linkages in the agricultural and forest sectors, the translation of these policies through to implementation may well be challenging because of the different characteristics of mitigation and adaptation (e.g., the global public good nature of mitigation versus the local benefits from adaptation), because of the additional costs involved (e.g., involving higher capital costs or opportunity costs associated with synergistic options), because of institutional, technological or behavioural barriers, and because different actors maybe involved in mitigation and adaptation decisions, including the need to address cross-sectoral aspects.

15.12 Investment and finance

15.12.1 National and sub-national institutions and policies

The justification for investment and finance and the description of the various financial agreements have been elaborated in Chapter 13. Chapter 16 assesses in more detail the range of institutional arrangements for mitigation finance at the global, regional, national, and sub-national levels. This section concentrates on institutional mechanisms which parties to the UNFCCC, developed and developing countries, have been using or introducing to facilitate, tap, channel, and catalyze climate change investment and finance. It also briefly touches on some of the major policy directions and trends affecting mitigation finance and investments. Earlier sections of this chapter presented the variety of policy instruments available and being used both in developed and developing countries. Public finance is needed for subsidies and public provision (Sections 15.5.2 and 15.5.6). In this section we track the consequences with a view to the aggregate funding needed.

Without dedicated financial policy, other policy instruments alone may be insufficient to mobilize the large-scale investments needed to move the world away from its current high-emission path.

Recent case studies and some empirical evidence highlight the importance of targeted public finance to help catalyze and leverage private investment in some mitigation activities (CPI, 2012). For this purpose, governments have at their disposal a variety of mechanisms that include credit lines, bonds, guarantees, equity, venture capital, carbon finance, and grants (Maclean et al., 2008). These mechanisms exist and are effective mostly in developed and emerging economies (Kennedy and Corfee-Morlot, 2012).

In addition, a number of innovative mechanisms are being promoted in some developed countries with success. These include, 'property assessed financing districts' where residential and commercial property owners are provided with loans for renewable energy and energy efficiency, 'direct cash subsidies' to promote the installation of energy efficiency measures and renewable energy systems, 'power purchase agreements', and ESCOs—Energy Service Companies to implement performance-based energy efficiency projects (Ellingson et al., 2010).

National development banks are increasingly playing a critical role in leveraging public and private resources in both developed and developing countries. National development banks, which operate mainly domestically, have an advantage in accessing local financial markets and dealing with barriers that they understand better than others (Smallridge et al., 2013).

International financing for mitigation and adaptation has impacted the domestic climate discourse and has created incentives for sustainable development at national and local levels in developing countries (Metz and Kok, 2008). National and sub-national efforts to finance climate change often have an explicit link to international processes or support through the various mechanisms of the Convention and Kyoto Protocol or those encouraged to facilitate funding for developing countries such as bilateral and multilateral channels. Some of these mechanisms have led to significant investment in developing countries. An estimated USD 215.4 billion had been invested in 4832 Clean Development Mechanism projects by June 15, 2012 (UNFCCC, 2012). Similarly, the Global Environment Facility (GEF) estimates that since the start of its operations (1991–2013), it has leveraged over USD 27 billion for climate change projects (GEF, 2013).

A new trend is the establishment by several developing countries of funds and national funding entities dedicated to climate change. Table 16.2 lists some of these institutions, their objectives, governance, and sources of funding. The missions and objectives are diverse and their level of institutionalization varies from country to country. All are designed to tap and blend funding available from international and domestic sources—public and private—to catalyze climate investment in their country (Flynn, 2011).

National funding entities have the potential to help countries cope with the proliferation of funds and entities offering financial resources for mitigation activities (Glemarec, 2011; Smith et al., 2011). Increased fragmentation of international assistance has increased transaction costs for recipients while the multiplicity and competitive nature of sources has challenged national and sub-national capacities (Knack and Rahman, 2007; Anderson, 2012). Limited absorptive and human capacity resources do however present serious challenges. Evidence of the ability of national funding entities to ensure coherence between national institutions dedicated to climate change and cabinet entities such as the Ministry of Finance or the Office of the President relies on case studies and, currently, does not yet offer general conclusions (Thornton, 2010).

15.12.2 Policy change direction for finance and investments in developing countries

There have been some significant trends in recent years regarding climate finance and the actors involved. Three are particularly relevant for their impact on the way climate finance is being managed and who does the management.

First, financing climate objectives by mainstreaming climate change into development planning has been gaining ground. This is particularly the case of countries wanting to integrate adaptation strategies into their overall national strategy as a way to build resilience. It is also evident in some of the climate change action plans and strategies of some countries that are clearly linked to poverty reduction and national development objectives (Garibaldi et al., 2013). However, the benefits and costs of integrating climate change considerations into development planning may be difficult to attain in practice. The OECD (OECD, 2005) warns of 'mainstreaming overload' as climate change competes with other issues like governance and gender to be mainstreamed into development planning. Barriers to integrating climate and development objectives include: lack of human and institutional capacity and lack of coordination among line ministries (Knack and Rahman, 2007; Kok et al., 2008).

Second, is the growing recognition that financing climate actions can have large co-benefits. Investments in clean energy, for example, may result in improvement in health indicators as air pollution levels decrease. Similarly, investing in forest conservation may result in a reduction of GHG emissions from deforestation. Thus, the increasing interest in the concept of co-benefits or climate and development as 'win-win' outcomes. Reducing emissions has been seen as a by-product of reducing energy costs in the case of China (Richerzhagen and Scholz, 2008). Reducing emissions from deforestation and forest degradation is seen as another major opportunity to deliver both emissions reductions and livelihood benefits. However, Campbell (2009) and Adams and Hulme (2001) argue that the ability to define these win-win objectives is a major factor for success.

Third, the number of actors involved in climate finance and investment is growing. Climate change finance is no longer a monopoly of the public sector. There is now a multiplicity of actors from the private and business world whose level of financing exceeds that of the public sector several fold, particularly in the middle-income and emerging economies (Gomez-Echeverri, 2013). This development has the potential to address implementation gaps, generate greater participation from stakeholders, and encourage public-private partnerships that promote sustainable development (Pattberg, 2010).

Two areas of need emerge from the literature (Cameron, 2011; Zingel, 2011). First, attracting climate finance investments will require strengthening institutional and governance capacities at the national and sub-national levels in recipient countries. Specifically, the ability to formulate strategies and action plans, including policies and measures, formulate, assess and approve projects, demonstrate accountability and transparency to their own populations, as well as to the development partners to raise levels of investment confidence will be needed. Second, robust mechanisms are needed to ensure accountability. This would involve greater transparency in both donor and recipient countries. The role of civil society organizations and the media could be strengthened for good governance and accountability.

15.13 Gaps in knowledge and data

- Cross-country comparisons of institutional design options, particularly mechanisms for coordinating and mainstreaming climate and other related sector policies, are limited. Wider use of evaluation methods would allow for the understanding of relative effectiveness of different options and designs to be used to improve outcomes over time.
- Evaluating the economic and environmental effectiveness of individual policy instruments and packages is difficult as various jurisdictions produce policy instruments influenced by context-specific factors such as co-benefits and political economy considerations. As a result, the cost of committing to a target and the actions needed to meet it, are difficult to estimate. For example, fuel taxes in the transport sector are implemented for multiple purposes including energy security, congestion and pollution reduction, revenue for road construction, mitigation of climate change, and so forth. It is difficult to gauge the contribution of fuel taxes to mitigation efforts.
- While the distributional incidence of taxes has been studied quite extensively, much less is known about the distributional incidence of other policy instruments and packages. Similarly, knowledge gaps remain uneven across policy instruments on other criteria such as institutional, political, and administrative feasibility.
- The asymmetry of methodologies regarding 'negative cost' policies regarding regulation and information measures with case studies arguing for negative private and social cost polices while critiques basing results on economic theory and models has meant that conclusive results are not yet available.
- Understanding of the relative balance between demand pull and supply push policies needed to accelerate technological innovation remains an important gap. Data on global private investment in research and development is a major gap along in addition to public R&D figures in middle income and low-income countries.
- The valuation of co-benefits from emission reduction has been studied comprehensively in the United States (Muller et al., 2011), but much less is known about other countries. This is important because taking these co-benefits into account could significantly lower the cost of emission reduction, and perhaps offer negative costs, in several sectors.

15.14 Frequently Asked Questions

FAQ 15.1 What kind of evidence and analysis will help us design effective policies?

Economic theory can help with policy design at a conceptual level, while modelling can provide an ex-ante assessment of the potential impact of alternative mitigation policies. However, as theory and modelling tend to be based on sets of simple assumptions, it is desirable that they are complemented by ex-post policy evaluations whenever feasible. For example, theory and bottom up modelling suggest that some energy efficiency policies can deliver CO_2 emission reductions at negative cost, but we need ex-post policy evaluation to establish whether they really do and whether the measures are as effective as predicted by ex-ante assessments (Section 15.4).

As climate policies are implemented, they can generate an empirical evidence base that allows policy evaluation to take place. If evaluation is built into the design of a programme or policy from its inception, the degree of success and scope for improvement can be identified. Policies implemented at the sub-national levels provide sites for experimentation on climate policies. Lessons from these efforts can used to accelerate policy learning.

Much of the evidence base consists of case studies. While this method is useful to gain context-specific insights into the effectiveness of climate policies, statistical studies based on large sample sizes allow analysts to control for various factors and yield generalizable results. However, quantitative methods do not capture institutional, political, and administrative factors and need to be complemented by qualitative studies.

FAQ 15.2 What is the best climate change mitigation policy?

A range of policy instruments is available to mitigate climate change including carbon taxes, emissions trading, regulation, information measures, government provision of goods and services, and voluntary agreements (Section 15.3). Appropriate criteria for assessing these instruments include: economic efficiency, cost effectiveness, distributional impact, and institutional, political, and administrative feasibility (Section 15.5).

Policy design depends on policy practices, institutional capacity and other national circumstances. As a result, there is no single best policy instrument and no single portfolio of instruments that is best across many nations. The notion of 'best' depends on which assessment criteria we employ when comparing policy instruments and the relative weights attached to individual criteria. The literature provides more evidence about some types of policies, and how well they score against the various criteria, than others. For example, the distributional impacts of a tax are relatively well known compared to the distributional impacts of regulation. Further research and policy evaluation is required to improve the evidence base in this respect (Section 15.12).

Different types of policy have been adopted in varying degrees in actual plans, strategies, and legislation. While economic theory provides a strong basis for assessing economy-wide economic instruments, much mitigation action is being pursued at the sectoral level (Chapters 7–12). Sectoral policy packages often reflect co-benefits and wider political considerations. For example, fuel taxes are among a range of sectoral measures that can have a substantial effect on emissions even though they are often implemented for other objectives.

Interactions between different policies need to be considered. The absence of policy coordination can affect environmental and economic outcomes. When policies address distinct market failures such as the externalities associated with greenhouse gas emissions or the undersupply of innovation, the use of multiple policy instruments has considerable potential to reduce costs. In contrast, when multiple instruments such a carbon tax and a performance standard are employed to address the same objective, policies can become redundant and undermine overall cost effectiveness (Section 15.8.4.2).

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16

Cross-cutting Investment and Finance Issues

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Contents

Executive Summary

For the first time, an assessment report by the Intergovernmental Panel on Climate Change (IPCC) contains a chapter dedicated to investment and finance. These are the chapter's key findings:

Scientific literature on investment and finance to address climate change is still very limited and knowledge gaps are substantial; there are no agreed definitions for climate investment and climate finance. Quantitative data are limited, relate to different concepts, and are incomplete. Accounting systems are highly imperfect. Estimates are available for current total climate finance, total climate finance provided to developing countries, public climate finance provided to developing countries, and climate finance under the United Nations Framework Convention on Climate Change (UNFCCC), as well as future incremental investment and incremental cost for mitigation measures. Climate finance relates both to adaptation and mitigation, while under the scope of this chapter, estimates of future investment needs are presented only for mitigation. [Section 16.1]

Total climate finance for mitigation and adaptation is estimated at 343 to 385 billion USD (2010/11/12 USD) per year using a mix of 2010, 2011, and 2012 data, almost evenly being invested in developed and developing countries (*medium confidence*). The figures reflect the total financial flow for the underlying investments, *not the incremental investment*, i.e., the portion attributed to the emission reductions. Around 95% of reported total climate finance is for mitigation (*medium confidence*). [16.2.1.1]

The total climate finance currently flowing to developing countries is estimated to be between 39 to 120 billion USD per year using a mix of 2009, 2010, 2011, and 2012 data (2009/2010/2011/2012 USD) (*medium confidence*). This range covers public and private flows for mitigation and adaptation. Public climate finance is estimated at 35–49 billion USD (2011/2012 USD) (*medium confidence*). Most public climate finance provided to developing countries flows through bilateral and multilateral institutions, usually as concessional loans and grants. Climate finance under the UNFCCC is funding provided to developing countries by Annex II Parties. The climate finance reported by Annex II Parties averaged nearly 10 billion USD per year from 2005 to 2010 (2005–2010 USD) (*medium confidence*). Between 2010 and 2012, the 'fast-start finance' (FSF) provided by some developed countries amounted to over 10 billion USD per year (2010/2011/2012 USD) (*medium confidence*). Estimates of international private climate finance flowing to developing countries range from 10 to 72 billion USD (2009/2010 USD) per year, including foreign direct investment as equity and loans in the range of 10 to 37 billion USD (2010 USD and 2008 USD) per year over the period of 2008–2011 (*medium confidence*). [16.2.1.1]

Emission patterns that limit temperature increase from pre-industrial level to no more than 2 °C require considerably different patterns of investment. A limited number of studies have examined the investment needs to transform the economy to limit warming to 2 °C. Information is largely restricted to energy use with global total annual investment in the energy sector at about 1200 billion USD. In the results for these scenarios, which are consistent to keeping carbon dioxide equivalent (CO_2eq) concentration in the interval 430–530 ppm until 2100, annual investment in fossil-fired power plants without carbon dioxide capture and storage (CCS) would decline by 30 (median: −20% compared to 2010) (2 to 166) billion USD during the period 2010–2029, compared to the reference scenarios (*limited evidence, medium agreement*). Investment in low-emissions generation technologies (renewable, nuclear, and electricity generation with CCS) would increase by 147 (median: +100% compared to 2010) (31 to 360) billion USD per year during the same period (*limited evidence, medium agreement*) in combination with an increase by 336 (1 to 641) billion USD in energy-efficiency investments in the building, transport, and industry sector (*limited evidence, medium agreement*), frequently involving modernization of existing equipment. Higher energy efficiency and the shift to low-emission energy sources contribute to a reduction in the demand for fossil fuels, thus causing a decline in investment in fossil fuel extraction, transformation, and transportation. Scenarios suggest that the average annual reduction of investment in fossil fuel extraction in 2010–2029 would be 116 (−8 to 369) billion USD (*limited evidence, medium agreement*). Such 'spillover' effects could yield adverse effects on economies, especially of countries that rely heavily on exports of fossil fuels. Model results suggest that deforestation could be reduced against current deforestation trends by 50% with an investment of 21 to 35 billion USD per year (*low confidence*). Information on investment needs in other sectors in addition to energy efficiency, e.g., to abate process or non-CO_2 emissions is virtually unavailable. [16.2.2]

Resources to address climate change need to be scaled up considerably over the next few decades both in developed and developing countries (*medium evidence, high agreement*). Increased financial support by developed countries for mitigation (and adaptation) measures in developing countries will be needed to stimulate the increased investment. Developed countries have committed to a goal of jointly mobilizing 100 billion USD per year by 2020 in the context of meaningful mitigation action and transparency on implementation. The funding could come from a variety of sources—public and private, bilateral and multilateral, including alternative sources of finance. Studies of how 100 billion USD per year could be mobilized by 2020 conclude that it is challenging but feasible. [16.2]

Public revenues can be raised by collecting carbon taxes and by auctioning carbon allowances (*high confidence*). Putting a price on greenhouse gas (GHG) emissions, through a carbon tax or emissions trading, alters the rate of return on high- and low-carbon investments. It makes low-emission technologies attract more investment and at the same time it raises a considerable amount of revenue that can be used for a variety of purposes, including climate finance. These carbon-related sources are already sizeable in some countries

[16.2.1.2]. The consideration of alternative sources of public revenue like taxes on international bunker fuels has the potential to generate significant funds but is still in its infancy. Reducing fossil fuel subsidies would lower emissions and release public funds for other purposes [16.2.3].

Within appropriate enabling environments, the private sector, along with the public sector, can play an important role in financing mitigation (*medium evidence, high agreement*). Its contribution is estimated at 267 billion USD per year in 2010 and 2011 (2010/2011 USD) and at 224 billion USD (2011/2012 USD) per year in 2011 and 2012 on average, which represents around 74% and 62% of overall climate finance, respectively (*limited evidence, medium agreement*) [16.2.1]. In a range of countries, a large share of private sector climate investment relies on low-interest and long-term loans as well as risk guarantees provided by public sector institutions to cover the incremental costs and risks of many mitigation investments. In many countries, therefore, the role of the public sector is crucial in helping these private investments happen. The quality of a country's enabling environment—including the effectiveness of its institutions, regulations and guidelines regarding the private sector, security of property rights, credibility of policies and other factors—has a substantial impact on whether private firms invest in new technologies and infrastructures. Those same broader factors will probably have a big impact on whether and where investment occurs in response to mitigation policies [16.3]. By the end of 2012, the 20 largest emitting developed and developing countries with lower risk country grades for private sector investments covered 70% of global energy-related CO_2 emissions (*low confidence*). This makes them attractive for international private sector investment in low-carbon technologies. In many other countries, including most least developed countries, low-carbon investment will often have to rely mainly on domestic sources or international public finance [16.4.2].

A main barrier to the deployment of low-carbon technologies is a low risk-adjusted rate of return on investment vis-à-vis high-carbon alternatives often resulting in higher cost of capital (*medium evidence, high agreement*). This is true in both developed and developing countries. Dedicated financial instruments to address these barriers exist and include inter alia credit insurance to decrease risk, renewable energy premiums to increase return, and concessional finance to decrease the cost of capital. Governments can also alter the relative rates of return of low-carbon investments in different ways and help to provide an enabling environment. [16.3, 16.4]

Appropriate governance and institutional arrangements at the national, regional, and international level need to be in place for efficient, effective, and sustainable financing of mitigation measures (*high confidence*). They are essential to ensure that financing to mitigate and adapt to climate change responds to national needs and priorities and that national and international activities are linked and do not contradict each other. An enabling environment at the national level ensures efficient implementation of funds and risk reduction using international resources, national funds, as well as national development and financial institutions. [16.5]

Important synergies and tradeoffs between financing mitigation and adaptation exist (*medium confidence*). Available estimates show that adaptation projects get only a minor fraction of international climate finance. Current analyses do not provide conclusive results on the most efficient temporal distribution of funding on adaptation vis-à-vis mitigation. While the uncertainties about specific pathways and relationships remain, and although there are different considerations on its optimal balance, there is a general agreement that funding for both mitigation and adaptation is needed. Moreover, there is an increasing interest in promoting integrated financing approaches, addressing both adaptation and mitigation activities in different sectors and at different levels. [16.6]

Increasing access to modern energy services for meeting basic cooking and lighting needs could yield substantial improvements in human welfare at relatively low cost (*medium confidence*). Shifting the large populations that rely on traditional solid fuels (such as unprocessed biomass, charcoal, and coal) to modern energy systems and expanding electricity supply for basic human needs could yield substantial improvements in human welfare for a relatively low cost; 72–95 billion USD per year until 2030 to achieve nearly universal access. [16.8]

16.1 Introduction

This is the first time an assessment report by the Intergovernmental Panel on Climate Change (IPCC) contains a chapter dedicated to investment and finance to address climate change. This reflects the growing awareness of the relevance of these issues for the design of efficient and effective climate policies.

The assessment of this topic is complicated by the absence of agreed definitions, sparse data from disparate sources, and limited peer-reviewed literature. Equity, burden sharing, and gender considerations related to climate change are discussed in other chapters, inter alia Sections 3.3 and 4.6.2. This chapter does not include a separate discussion of these considerations in relation to climate finance.

There is no agreed definition of climate finance (Haites, 2011; Stadelmann et al., 2011b; Buchner et al., 2011; Forstater and Rank, 2012). The term 'climate finance' is applied both to the financial resources devoted to addressing climate change globally and to financial flows to developing countries to assist them in addressing climate change. The literature includes multiple concepts within each of these broad categories (Box 1.1). The specific mitigation and adaptation measures whose costs qualify as 'climate finance' also are not agreed. The mea-

Box 16.1 | Different concepts, different numbers

Different concepts of climate finance are found in the literature. The corresponding values differ significantly.

Financial resources devoted to addressing climate change globally:

Total climate finance includes all financial flows whose expected effect is to reduce net GHG emissions and/or to enhance resilience to the impacts of climate variability and the projected climate change. This covers private and public funds, domestic and international flows, expenditures for mitigation and adaptation to current climate variability as well as future climate change. It covers the full value of the financial flow rather than the share associated with the climate change benefit; e.g., the entire investment in a wind turbine rather than the portion attributed to the emission reductions. The estimate by Buchner et al. (2012, 2013b) of current climate finance of 343 to 385 billion USD (2010/2011/2012 USD) per year using a mix of 2010, 2011, and 2012 data, corresponds roughly to this concept.

The *incremental investment* is the extra capital required for the initial investment for a mitigation or adaptation project in comparison to a reference project. For example, the investment in wind turbines less the investment that would have been required for the coal or natural gas-generating unit displaced. Since the value depends on the unknown investment in a hypothetical alternative, the incremental investment is uncertain. Incremental investment for mitigation and adaptation measures is not regularly estimated and reported, but estimates are available from models. It can be positive or negative. Many agriculture and reducing emissions from deforestation and forest degradation (REDD+) mitigation options that involve ongoing expenditures for labour and other operating costs rather than investments are excluded.

The *incremental costs* reflect the cost of capital of the incremental investment and the change of operating and maintenance costs for a mitigation or adaptation project in comparison to a reference project. It can be calculated as the difference of the net present values of the two projects. Many mitigation measures—such as energy efficiency, renewables, and nuclear—have a higher capital cost and lower operating costs than the measures displaced. Frequently the incremental costs are lower than the incremental investment. Values depend on the incremental investment as well as projected operating costs, including fossil fuel prices, and the discount rate. Models can estimate the incremental costs of energy supply and demand but data are not immediately available and aggregate estimates cannot be provided. Estimates are available for single-mitigation options (see, e.g., Chapter 7).

The *macroeconomic costs of mitigation policy* are the reductions of aggregate consumption or gross domestic product induced by the reallocation of investments and expenditures induced by climate policy. These costs do not account for the benefit of reducing anthropogenic climate change and should thus be assessed against the economic benefit of avoided climate change impacts. Models have traditionally provided estimates of the macroeconomic costs of climate policy (see Chapter 6).

Financial flows to developing countries to assist them in addressing climate change:

The *total climate finance flowing to developing countries* is the amount of the total climate finance invested in developing countries that comes from developed countries. This covers private and public funds for mitigation and adaptation. Estimates from a few studies suggest the current flow is between 39 and 120 billion USD per year (2009–2012 USD).

Public climate finance provided to developing countries is the finance provided by developed countries' governments and bilateral institutions as well as multilateral institutions for mitigation and adaptation activities in developing countries. Most of the funds provided are concessional loans and grants. Estimates suggest that public climate finance flows to developing countries were at 35 to 49 billion USD per year in 2011 and 2012 (2011/2012 USD).

Private climate finance flowing to developing countries is finance and investment by private actors in/from developed countries for activities in developing countries whose expected effect is to reduce net GHG emissions and/or to enhance resilience to the impacts of climate variability and the projected climate change.

Under the *United Nations Framework Convention on Climate Change (UNFCCC), climate finance* is not well-defined. Annex II Parties provide and mobilize funding for climate related activities in developing countries. Most of the funds provided are concessional loans and grants. The climate finance provided to developing countries reported by Annex II Parties averaged nearly 10 billion USD per year from 2005 to 2010 (2005–2010 USD). In addition, some developed countries promised FSF amounting to over 10 billion USD per year between 2010 and 2012 (2010/2011/2012 USD).

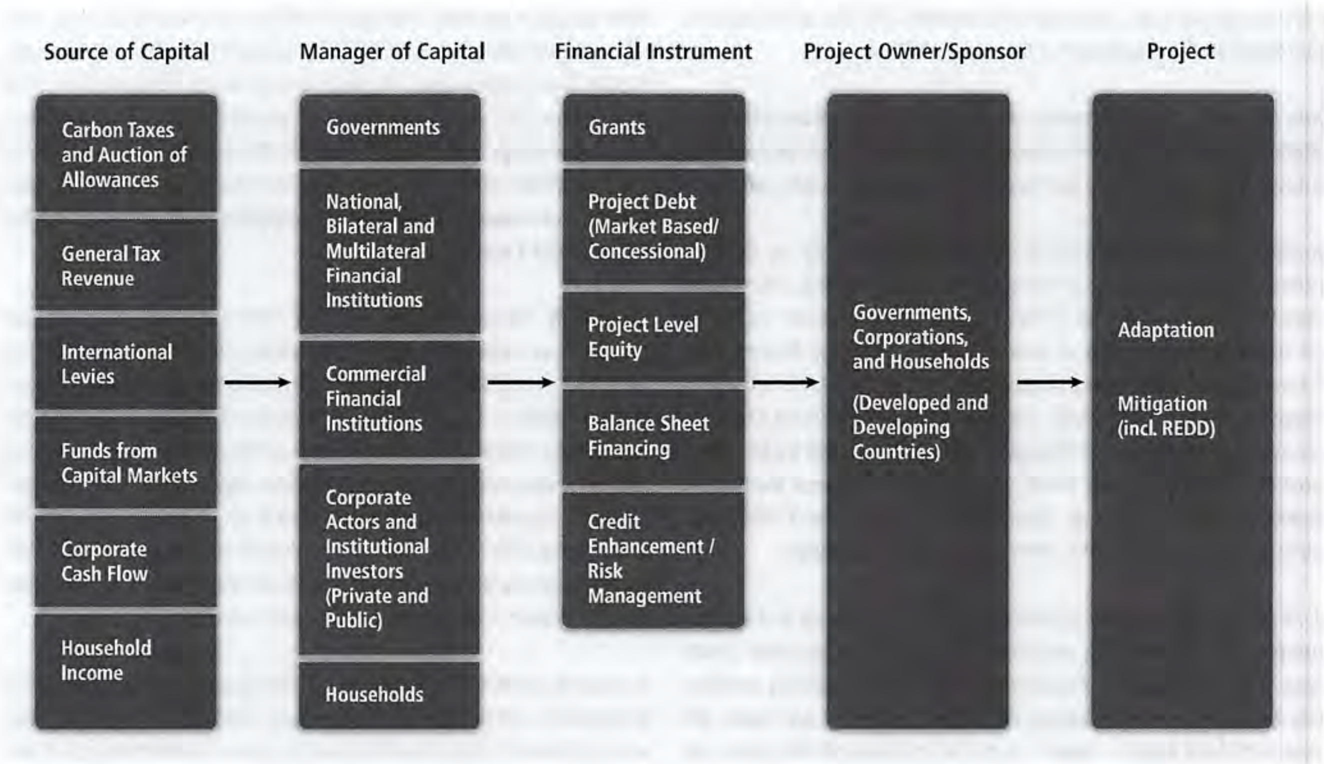

Figure 16.1 | Overview of climate finance flows. Note: Capital should be understood to include all relevant financial flows. The size of the boxes is not related to the magnitude of the financial flow.

sures included vary across studies and often are determined by the data available[1].

The rest of the chapter is structured as follows: Section 16.2 reviews estimates of current climate finance corresponding to the different concepts in Box 1, projections of global incremental investment and incremental costs for energy-related mitigation measures to 2030, and options for raising public funds for climate finance. Enabling factors that influence the ability to efficiently generate and implement climate finance are discussed in Section 16.3. Section 16.4 considers opportunities and key drivers for low-carbon investments. Institutional arrangements for mitigation finance are addressed in Section 16.5. Synergies and tradeoffs between financing mitigation and adaptation are discussed in Section 16.6. The chapter concludes with sections devoted to financing mitigation activities in developed (Section 16.7) and developing countries (Section 16.8) and a review of important gaps of knowledge (Section 16.9).

16.2 Scale of financing at national, regional, and international level in the short-, mid-, and long-term

16.2.1 Current financial flows and sources

Figure 16.1 provides an overview of climate finance and the terms used in this chapter. The term 'capital' is used because most climate finance involves an investment, but it should be understood to include all relevant financial flows[2]. One or more capital managers mobilize the required capital and invest it in an adaptation or mitigation project. Project owners or sponsors—governments, corporations, or households—implement a project using their own and other sources of capital. However, projects often obtain capital from multiple capital managers (Buchner et al., 2011, 2012; Jürgens et al., 2012). An instrument defines the financial agreement between a project owner/sponsor and a manager of capital. A project that obtains capital from sev-

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[1] Most of the financial flow data in this chapter originate from 2010, 2011, and 2012 and were published in USD. The exchange rates used by each source to convert other currencies to USD are not specified in the published sources. In these cases, the published USD figure has been maintained and the base year is similar to the year the commitment/investment/flow was announced/reported. If no base year is indicated, as for most monetary values in Section 16.2.2, the base year is 2010.

[2] Terms that cover both capital and operating costs, such as 'financial resources' or 'funds' are cumbersome (sources/managers of financial resources) or potentially confusing ('funds' can also be institutions).

eral managers would use multiple instruments. The size of the boxes is not related to the magnitude of the financial flow.

Data on current climate finance, summarized below, indicate that most capital deployed is private—private corporations and households. That is not surprising since they dominate the economy in most countries.

Domestically, government funds are disbursed directly as financial incentives or tax credits, or through national financial institutions. Climate finance under the UNFCCC currently is provided mainly by the national governments of Annex II Parties. Climate finance from the budgets of these government flows through bilateral institutions being a national public entity, such as Japan International Cooperation Agency (JICA), Agence Française de Développement (AFD), Kreditanstalt für Wiederaufbau (KfW), or through multilateral institutions having several countries as shareholders, such as the World Bank, regional development banks, and multilateral climate funds.

There is no internationally agreed definition of mitigation and adaptation projects; for example, whether a high-efficiency gas-fired generating unit is a mitigation project or which capacity building activities help to address climate change. The relevant projects, and hence the scale of climate finance, depend upon the definition of mitigation and adaptation projects adopted. In practice, the definition varies across studies and is often determined by the data available.

16.2.1.1 Estimates of current climate finance

This section reviews estimates of current global total climate finance, total climate finance flowing to developing countries, public climate finance provided to developing countries and climate finance under the UNFCCC.

There is no comprehensive system for tracking climate finance (Clapp et al., 2012; Tirpak et al., 2012), therefore, estimates must be compiled from disparate sources of variable quality and timeliness, sources that use different assumptions and methodologies and have gaps and may occasionally duplicate coverage. Available data typically relate to commitments rather than disbursements, so the amount reported may not equal the amount received by the project owner during a given year. Changes in exchange rates further complicate the picture. For these and other reasons, estimates of current climate finance exhibit considerable uncertainties.

Global total climate finance is estimated at 343 to 385 billion USD per year for 2010/11 (2010/11 USD) and 356 to 363 billion USD per year for 2011/12 (2011/12 USD), with mitigation accounting for approximately 95 % of this amount (350 billion USD and 337 billion USD, respectively) (Buchner et al., 2012, 2013b). This estimate includes a mix of instruments, e.g., grants, concessional loans, commercial loans and equity, as well as the full investment in mitigation measures such as renewable energy generation technologies that also produce other goods or services[3]. The figures reflect new commitments by capital managers using a mix of 2010/11 and 2011/12 data, respectively. Private finance dominates the total, but its share declined from 74 % (267 billion USD) on average in 2010 and 2011 to 62 % (224 billion USD) on average in 2011 and 2012 (2010/2011 USD and 2011/2012 USD) (Buchner et al., 2012, 2013b). Investment in renewable generation technologies dominates the mitigation investment (Frankfurt School-UNEP Centre and BNEF, 2012).

Reasonably robust estimates of *total climate finance for individual countries* are available for only a few cases, for instance, for Germany (Jürgens et al., 2012). However, some institutions report on their financing commitments for climate and environment. Data from 19 development banks indicate that commitments of mitigation finance increased from 51 billion USD in 2011 to 65 billion USD in 2012 with commitments of adaptation finance rising from 6 to 14 billion USD over the same period (2011/2012 USD). Concessional funding provided by public development banks plays an important role in financing domestic climate projects, e.g., in Brazil, China, and Germany.

A growing number of developed and developing countries, including Bangladesh, Colombia, Indonesia, Nepal, Samoa, Tanzania, Uganda, and the United States as well as the European Commission, calculates the share of their annual budget devoted to climate change mitigation and adaptation often using a methodology known as a Climate Public Expenditure and Institutional Review (UNDP, 2013a). Country estimates range from 3–15 % of the national budget.

A few estimates of *total climate finance flowing to developing countries* are available. Clapp et al. (2012) estimate the total at 70–120 billion USD per year based on 2009–2010 data (2009/2010 USD). Data from Buchner et al. (2013a) suggest a net flow to developing countries of the order of 40 to 60 billion USD for 2010 and 2011 (2010/2011 USD).[4] For 2011 and 2012, North-South flows are estimated at 39 to 62 billion USD (2011/2012 USD) (Buchner et al., 2013b). Clapp et al. (2012) estimate the private investment at 37–72 billion USD (2009/2010 USD) per year based on 2009–2010 data and Stadelmann

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[3] Methodology used by Buchner et al. (2012, 2013b): Finance flows are limited to 'climate-specific finance', capital flows targeting low-carbon, and climate-resilient development with direct or indirect mitigation or adaptation objectives/outcomes. The focus is on current financial flows (upfront capital investment costs and grants expressed as commitments, so risk management instruments are excluded). Data are for total rather than incremental investment because incremental investment requires assumptions on the baseline on a project-by-project basis. The data are for 'gross' investment, the full value of the investment, and reflect commitments because disbursement data is not widely available. The data are a mix of 2010 and 2011 data, and 2011 and 2012 data, respectively.

[4] Buchner et al. (2013) estimate that developed countries mobilized 213 to 255 billion USD climate finance per year during 2010 and 2011 while 160 to 208 billion USD climate finance had been committed to climate change projects in developed countries. Developing countries mobilized 120 to 141 billion USD climate finance per year during 2010 and 2011 and 162 to 202 billion USD had been committed to climate change projects in developing countries. Those figures suggest a net flow to developing countries of the order of 40 to 60 billion USD per year (2010/2011 USD).

et al. (2013) estimate foreign direct investment as equity and loans in the range of 10 to 37 billion USD per year based on 2008–2011 data (2010 USD and 2008 USD).

The investment in registered **Clean Development Mechanism (CDM)** projects is estimated at over 400 billion USD over the period 2004 to 2012 (2004–2012 USD) (UNEP Risø, 2013). Of that amount almost 80 billion USD was for projects registered during 2011 and 195 billion USD for projects registered during 2012 (2011 USD and 2012 USD). The majority of the investment in CDM projects is private. Renewable energy projects account for over 70% of the total investment. The share of CDM renewable energy projects with some foreign investment has grown over time, representing almost 25 billion USD in 2011 (2011 USD) (Kirkman et al., 2013).[5]

Since 1999 almost 100 **carbon funds** with a capitalization of 14.2 billion USD have been established (Alberola and Stephan, 2010).[6] Carbon funds are investment vehicles that raise capital to purchase carbon credits (52%) and/or invest in emission reduction projects (23%). A fund may have only private investors (48%), only public investors (29%) or a mix of both (23%) (Alberola and Stephan, 2010). Investment may be restricted to a specific region or project type (e.g., REDD+). Financial data, especially for private funds, is often confidential so the amount of finance provided to developing countries via carbon funds is not available. Scaling up data from 29 funds on the amount invested in projects suggests a maximum cumulative investment of 18 billion USD (1999–2009 USD) (Kirkman et al., 2013).

Public climate finance provided to developing countries was estimated at 35 to 49 billion USD per year in 2011 and 2012 (2011/2012 USD) (Buchner et al., 2013b).[7] These public funds flow mainly through bilateral and multilateral institutions[8]. Most of the climate finance is implemented by development banks, frequently involving the blending of government resources with their own funds. There are two main reporting systems for public support in place that are not fully comparable due to differences in respective methodologies.

The Organisation for Economic Co-operation and Development (OECD) Development Assistance Committee (DAC) reports the amount of official development assistance (ODA) committed bilaterally for projects that have climate change mitigation or adaptation as a 'principal' or 'significant' objective by its 23 member countries and the European Commission. The DAC defines ODA as those flows to countries on the DAC List of ODA Recipients and to multilateral institutions provided by official agencies or by their executive agencies. Resources must be used to promote the economic development and welfare of developing countries as a main objective and they must be concessional in character, meaning as grants or as concessional loans including a grant element of at least 25%, calculated at a rate of discount of 10%. The amount is the total funding committed to each project, not the share of the project costs attributable to climate change (OECD, 2013a). Researchers have questioned the accuracy of the project classification (Michaelowa and Michaelowa, 2011; Junghans and Harmeling, 2013). Bilateral commitments averaged 20 billion USD per year in 2010 and 2011 (2010/2011 USD) (OECD, 2013a) and were implemented by bilateral development banks or other bilateral agencies, provided to national government directly or to dedicated multilateral climate funds (Buchner et al., 2012, 2013b).

Seven multilateral development banks (MDBs)[9] reported climate finance commitments of about 24.1 and 26.8 billion USD in 2011 and 2012, respectively (2011/2012 USD). The reporting is activity-based allowing counting entire projects but also project components. Recipient countries include developing countries and 13 European Union (EU) member states. It covers grant, loan, guarantee, equity, and performance-based instruments, not requiring a specific grant element. The volume covers MDBs' own resources as well as external resources managed by the MDBs that are also reported to OECD DAC (such as contributions to the Global Environment Facility (GEF), Climate Investment Funds (CIFs), and Carbon Funds) (AfDB et al., 2012a; b, 2013).

Under the UNFCCC, climate finance is not well-defined. Annex II Parties committed to provide new and additional financial resources to cover the "agreed full incremental costs" of agreed mitigation measures implemented by developing countries (Article 4.3), to "assist the developing country Parties that are particularly vulnerable to the adverse effects of climate change in meeting costs of adaptation" (Article 4.4) and to cover the agreed full costs incurred by developing countries for the preparation of their national communications (Article 4.3) (UNFCCC, 1992). None of these terms are operationally defined (Machado-Filho, 2011). These commitments are reaffirmed by the Kyoto Protocol (UNFCCC, 1998, Art. 11). The Conference of Parties (COP) has agreed that funds provided to developing country Parties may come from a wide variety of sources, public, and private, bilateral and multilateral, including alternative sources (UNFCCC, 2010, para. 99).

Annex II Parties report the financial resources they provide to developing countries through bilateral and multilateral channels for climate

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[5] CDM projects sell emission reduction credits, Certified Emission Reductions (CERs), to developed country buyers, which provide a return to developed country investors.

[6] United Nations Environment Program (UNDP) estimates that in addition up to 6000 private equity funds have been established for the purpose of funding climate change-related activities (UNDP, 2011).

[7] Buchner et al. (2013b) count climate finance provided by bilateral finance institutions, multilateral finance institutions, government bodies, and climate funds as public flows. The difference between lower- and upper-bound results when taking the ownership structure of multilateral institutions into account and excluding all bilateral flows marked as having climate as 'significant' objective.

[8] Ryan et al. (2012) estimate the annual average finance provided to developing countries for energy efficiency at 18.9 billion USD in 2010 from bilateral financial institutions and 4.9 billion USD from multilateral financial institutions over the period 2008–2011.

[9] African Development Bank (AfDB), the Asian Development Bank (ADB), the European Bank for Reconstruction and Development (EBRD), the European Investment Bank (EIB), the Inter-American Development Bank (IDB), the World Bank (WB) and the International Finance Corporation (IFC).

change action to increase transparency about public flows of climate finance vis-à-vis expectations and needs. The latest summary of the Annex II reports on their provided climate finance indicates that they provided a total of 58.4 billion USD for the period 2005 through 2010, an average of nearly 10 billion USD per year (2005–2010 USD) (UNFCCC, 2011a).[10] Most of the funds provided are concessional loans and grants. In addition, a range of developed countries promised FSF of about 10 billion USD per year from 2010 to 2012 (2010/2011/2012 USD) (see Section 16.2.1.3).[11]

Operating entities of the financial mechanism of the UNFCCC deal with less than 10 % of the climate finance reported under the Convention, although that could change once the Green Climate Fund (GCF) becomes operational. Annex II Party contributions to the Trust Fund of the GEF, the Special Climate Change Fund (SCCF) and the Least Developed Countries Fund (LDCF) amounted to about 3.3 billion USD for 2005 through 2010, an average of less than 0.6 billion USD per year (2005–2010 USD) (UNFCCC, 2011a). Most of the funds are used for mitigation. The Adaptation Fund derives most of its funds from the sale of its share of the CERs issued for CDM projects[12].

16.2.1.2 Current sources of climate finance

Climate finance comes from the sources of capital shown in Figure 16.1 including capital markets, carbon markets, and government budgets. Most government funding comes from general revenue but some governments also raise revenue from sources—carbon taxes and auctioned GHG-emission allowances—that have mitigation benefits. Most corporate funding comes from corporate cash flow including corporate borrowing, often called balance-sheet finance (Frankfurt School-UNEP Centre, 2013).[13] Household funding comes from household income from wages, investments, and other sources. Governments, corporations, and households can all access capital markets to mobilize additional funds.

This section summarizes estimates of the revenue currently generated by carbon taxes and auctioned GHG-emission allowances. Fuel taxes, fossil fuel royalties, and electricity charges can be converted to CO_2eq charges but they are excluded here because they are usually implemented for different policy goals.

Carbon taxes generate about 7 billion USD in revenue annually mainly in European countries (2010/2011 USD).[14] Denmark, Finland, Germany, Ireland, Italy, Netherlands, Norway, Slovenia, Sweden, Switzerland, and the United Kingdom—generated about 6.8 billion USD in 2010 (2010 USD) and 7.3 billion USD (2011 USD) in 2011. India[15], Australia, and Japan introduced carbon taxes in July 2010, July 2012, and October 2012, respectively. In some countries, part or all of the revenue is dedicated to environmental purposes or reducing other taxes; none is earmarked for international climate finance.

Auctioned allowances, fixed price compliance options, and the international sale of surplus Assigned Amount Units (AAUs) generate about 2 billion USD per year for national governments (2010/2011 USD). Among the 30 countries participating in the EU emissions trading scheme, Austria, Germany, Hungary, Ireland, the Netherlands, Norway, and the United Kingdom auctioned some emission allowances during the second (2008–2012) phase (European Commission, 2012). Buchner et al. (2011, 2012) estimate auction revenue at 1.4 and 1.6 billion USD for 2010 and 2011 (2010/2011 USD). Germany has so far earmarked a portion of its auction revenue for international climate finance (Germany Federal Ministry for the Environment Nature Conservation and Nuclear Safety, 2012). New Zealand collected 1.25 and 1.42 million USD for 2010 (6 months) and 2011, respectively, from its fixed price compliance option of 10.8 USD per tonne of CO_2 (15 NZD) (New Zealand Ministry for the Environment, 2012).

Several eastern European countries (Estonia, Czech Republic, Poland, and Russia) sell surplus AAUs to generate revenue. Others such as Bulgaria, Latvia, Lithuania, Slovakia, and Ukraine, sell their surplus AAUs to fund Green Investment Schemes that support domestic emission reduction measures (Linacre et al., 2011).[16] Revenue rose from 276 million USD in 2008 (2008 USD) to 2 billion USD in 2009 (2009 USD) and then declined to less than 1.1 billion USD in 2010 (2010 USD) (Kossoy and Ambrosi, 2010; Linacre et al., 2011; Tuerk et al., 2013). Buchner at al. (2011, 2012) estimate the revenue at 580 and 240 million USD for 2010 and 2011, respectively (2010 and 2011 USD).

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[10] Although there is an agreed reporting format, the UNFCCC Secretariat notes that many data gaps and inconsistencies persist in the reporting approaches of Annex II Parties. The information is compiled by the UNFCCC Secretariat from Annex II national communications. The figures represent 'as committed' or 'as spent' currency over the 6 years. The procedures used by different countries and the Secretariat to convert currencies into USD are not known.

[11] Although COP took note of the 'fast start finance' (FSF) commitment in paragraph 95 of Decision 1/CP.16 (UNFCCC, 2010) and the funds committed have been reported annually to the UNFCCC, the FSF is not formally climate finance under the UNFCCC.

[12] Currently the only international levy is the 2 % of the CERs issued for most CDM projects provided to the Adaptation Fund. The Fund sells the CERs and uses the proceeds for adaptation projects in developing countries. Sale of CERs generated revenue of over 90 million USD for FY 2010 (2010/2011 USD) and over 50 million USD for FY 2011 (World Bank, 2012a). In December 2012 Parties agreed to extend the share of proceeds levy to the issuance of emission reduction unit (ERUs) and the first international transfers of AAUs (UNFCCC, 2012a, para. 21).

[13] General revenue includes revenue collected from all taxes and charges imposed by a government. Balance sheet finance means that a new investment is financed by the firm rather than as a separate project. The firm may seek external funding (debt and/or equity) but that funding is secured by the operations of the firm rather than the new investment.

[14] Revenue from taxes explicitly named carbon taxes in the OECD database of environmentally related taxes, available at http://www2.oecd.org/ecoinst/queries/index.htm.

[15] In India, the carbon tax is on coal only.

[16] The Green Investment Schemes are a source of climate finance for these countries.

16.2.1.3 Recent developments

Climate finance has been affected by the financial crisis of late 2008, the subsequent stimulus packages and the FSF commitment of 30 billion USD for 2010–2012 made by developed countries in December 2009 for climate action in developing countries.

The **financial crisis** in late 2008 reduced investment in renewable energy (Hamilton and Justice, 2009). In late 2008 and early 2009, investment in renewable generation fell disproportionately more than that in other types of generating capacity (IEA, 2009). Global investment in renewable energy fell 3 % during 2009 but rebounded strongly in 2010 and 2011. In developed countries, where the financial crisis hit hardest, investment dropped 14 % while renewable energy investment continued to grow in developing countries (Frankfurt School-UNEP Centre and BNEF, 2012).

In response to the financial crisis, Group of Twenty Finance Ministers (G20) governments implemented **economic stimulus packages** amounting to 2.6 trillion USD. Of that amount, 180 to 242 billion USD was low-carbon funding (2008 and 2009 USD) (IEA, 2009; REN21, 2010). The stimulus spending supported the rapid recovery of renewable energy investment by compensating for reduced financing from banks. Some countries facing large public sector deficits scaled down green spending when the economy started recovering (Eyraud et al., 2011).

At the UNFCCC in Copenhagen in 2009, developed countries committed to provide new and additional resources approaching 30 billion USD of **FSF** to support mitigation and adaptation action in developing countries during 2010–2012 (UNFCCC, 2009a). The sum of the announced commitments exceeds 33 billion USD (UNFCCC, 2011b, 2012b; c, 2013a)[17]. Japan, United States, United Kingdom, Norway, and Germany being the five biggest donors have reported commitments amounting to 27 billion USD (2010/2011/2012 USD). Nakooda et al. (2013) finds that around 45 % have been provided as grants and around 47 % in the form of loans, guarantees, and insurance. Approximately 61 % of the funds had been committed for mitigation, 10 % for REDD+, ,18 % for adaptation, 9 % for multiple objectives and for 2 % of the funding the purpose is unknown. The funders reported commitments to recipient country governments via bilateral channels (33 %), multilateral climate funds (20 %), recipient countries companies (12 %), and multilateral institutions (9 %). Data on actual disbursements is not available to date because of the multi-year time lag between commitment and disbursement.

The announced pledges triggered questions as to whether they were 'new and additional' as promised (Fallasch and De Marez, 2010; BNEF, 2011). Some countries explain the basis on which they consider their pledge to be 'new and additional'. Criteria have been proposed that indicate, when applied to the pledges, that proportions ranging from virtually none to almost all are new and additional (Brown et al., 2010; Stadelmann et al., 2010, 2011b). For Germany, Japan, the United Kingdom, and the United States annual FSF contributions were significantly higher than the 2009 expenditure related to climate activities in developing countries (Nakooda et al., 2013).

16.2.2 Future low-carbon investment

As noted in Chapter 6, the stabilization of GHG concentrations will ultimately require dramatic changes in the world's energy system, including a dramatic expansion in the deployment of low-carbon energy sources. This change will require significant shifts in global investment in the energy, land use, transportation, and infrastructure sector. The future investment flows summarized in this section are based on several large-scale analyses conducted over the past few years. For the most part these analyses explore scenarios to achieve specified temperature or concentration goals. Hence, the estimates of investment flows drawn from these studies should not be interpreted as forecasts, but rather, as some probable future states of the world.

Figure 16.2 presents estimates of baseline, i. e., current investment in energy supply sub-sectors as a reference for the following considerations. It illustrates the very substantial nature of investments in today's energy sector with global total annual investment at about USD_{2010} 1200 billion and very strong roles for investments in fossil fuel extraction, transmission and distribution (T&D), and electricity generation.

16.2.2.1 Investment needs

While a large number of studies and many modelling comparison exercises have assessed technological transformation pathways and the macroeconomic costs of transforming the global economy, only a handful of studies estimate the associated investment needs. Section 16.2.2.2 summarizes available estimates of investment needs under climate policy between 2010–2029 and 2030–2049, for the world as a whole and for non-OECD and OECD countries. Models and scenarios differ so the focus is on incremental investment, i. e., the differences in the estimated investment between the reference and mitigation scenarios.[18] It must also be noted that the model estimates crucially rely on assumptions about the future costs of technologies and of subsidies, on the possibility of nuclear phaseout in some countries, and on the mitigation policies already included in the reference scenarios.

Without climate policy, investments in the power sector would mainly be directed towards fossil fuels, especially in non-OECD countries that rely on low-cost coal power plants to supply their growing

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[17] The information is compiled by the UNFCCC Secretariat from national reports on FSF. The figures represent 'as committed' currency over the three years. The procedures used by different countries and the Secretariat to convert currencies into USD are not known.

[18] Adaptation costs and economic losses from future climate change are not considered in any of these estimates.

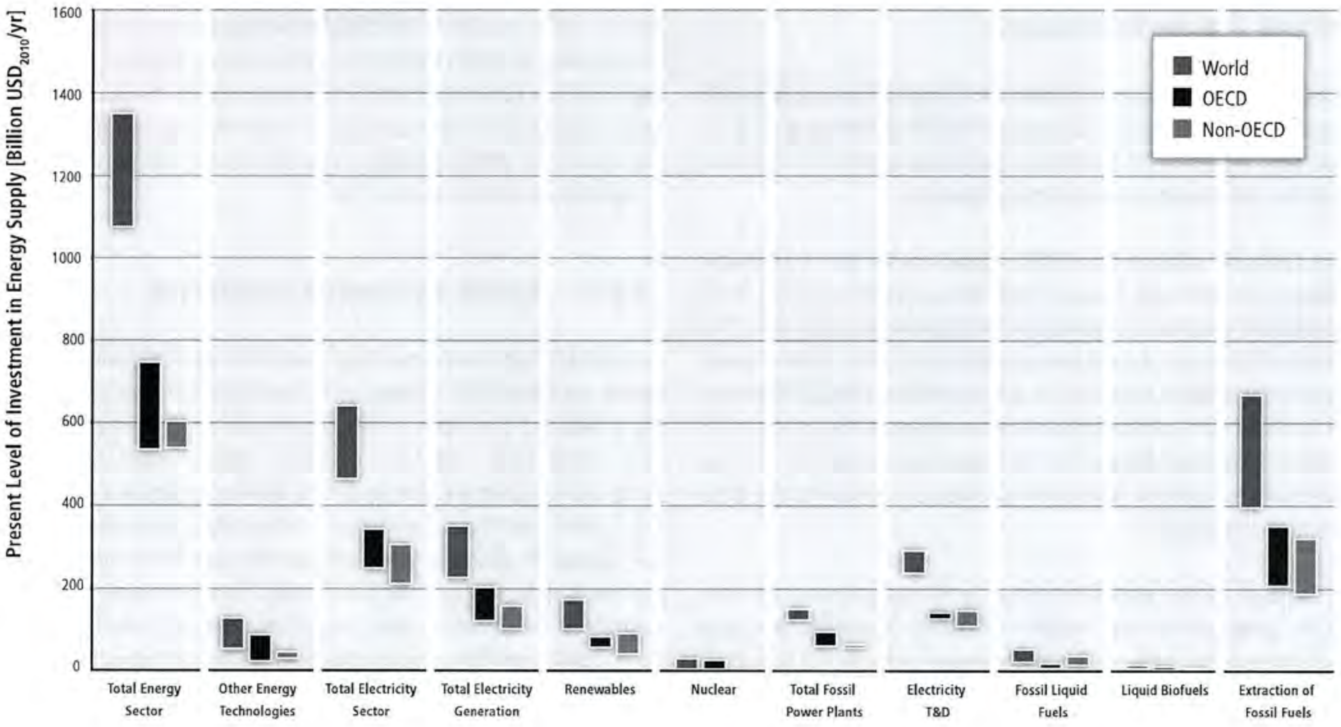

Figure 16.2 | Present level of investment in energy supply. Note: The bars indicate the minimum and maximum level of investments found in the literature. Ranges result from different sources of market information and differing definitions of the investment components to be included. Source: From McCollum et al. (2013) based on data from IEA World Energy Outlook 2011 (IEA, 2011) and GEA (Riahi et al., 2012).

demand for electricity. At the global level, fossil fuel-based power generation would require an average annual investment of 182 (95 to 234) billion USD in 2010–2029 and 287 (158 to 364) billion USD in 2030–2049;[19] the bulk of investments (roughly 80 %) goes to non-OECD countries.[20] There is greater uncertainty in models about the future of renewable and nuclear power without climate policy. Modelled global investment in renewable power generation is expected to increase over time from 123 (31 to 180) billion USD per year in 2010–2029 to 233 (131 to 336) billion USD over 2030–2049. Nuclear power generation would attract 55 (11 to 131) billion USD annually in 2010–2029 and 90 (0 to 155) billion USD per year in 2030–2049.

The **introduction of an emission reduction target** in the models abruptly changes the investment pattern. Figures 16.3 and 16.4 report the investment change for major power generation technologies, fossil fuel extraction, and for end-use energy efficiency, for emission scenarios compatible with a long-term target of keeping mean global temperature increase below 2 °C in 2100.[21] Although the policy targets are not identical, they are close enough to allow a broad comparison of results. The dispersion across estimated emission reductions over 2010–2029 and 2010–2049 is mainly due to differences in reference scenario emissions and because models choose different optimal emission trajectories among the many compatible with the long-term climate goal.

The results of an analysis of investment estimates in Figures 16.3 and 16.4 show that climate policy is expected to induce a major reallocation of investments in the power sector. Investments in fossil-fired power plants (without CCS) were equal to about 137 billion USD per year in 2010. Investment would decline by 30 (2 to 166) billion USD per year (about −20 % for the median) during the period 2010–2029, compared to the reference scenarios. Investment in low-emissions generation technologies (renewable, nuclear, and electricity generation with CCS) would increase by 147 (31 to 360) billion USD per year (about 100 % for the median) during the same period.

Based on a limited number of studies (McKinsey, 2009; IEA, 2011; Riahi et al., 2012), annual incremental investments until 2030 in energy-efficiency investments in the building, transport, and industry sector increase by 336 (1 to 641) billion USD. The only three studies with sectoral detail in end-use technologies show an increase of investments of 153 (57 to 228) billion USD for the building sector, 198 (98 to 344) billion USD for the transport sector, 80 (40 to 131) billion USD for the

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[19] The mean should not be considered as an expected value. It is not possible to attribute any probability distribution to models' outcomes. Therefore policymakers face pure uncertainty in face of future investment needs. The range is presented to provide information on the degree of uncertainty in the literature.

[20] See captions of Figures 16.3 and 16.4 for a list of the studies surveyed.

[21] Also in this case, the mean and median are used as synthetic indicators having no predictive power.

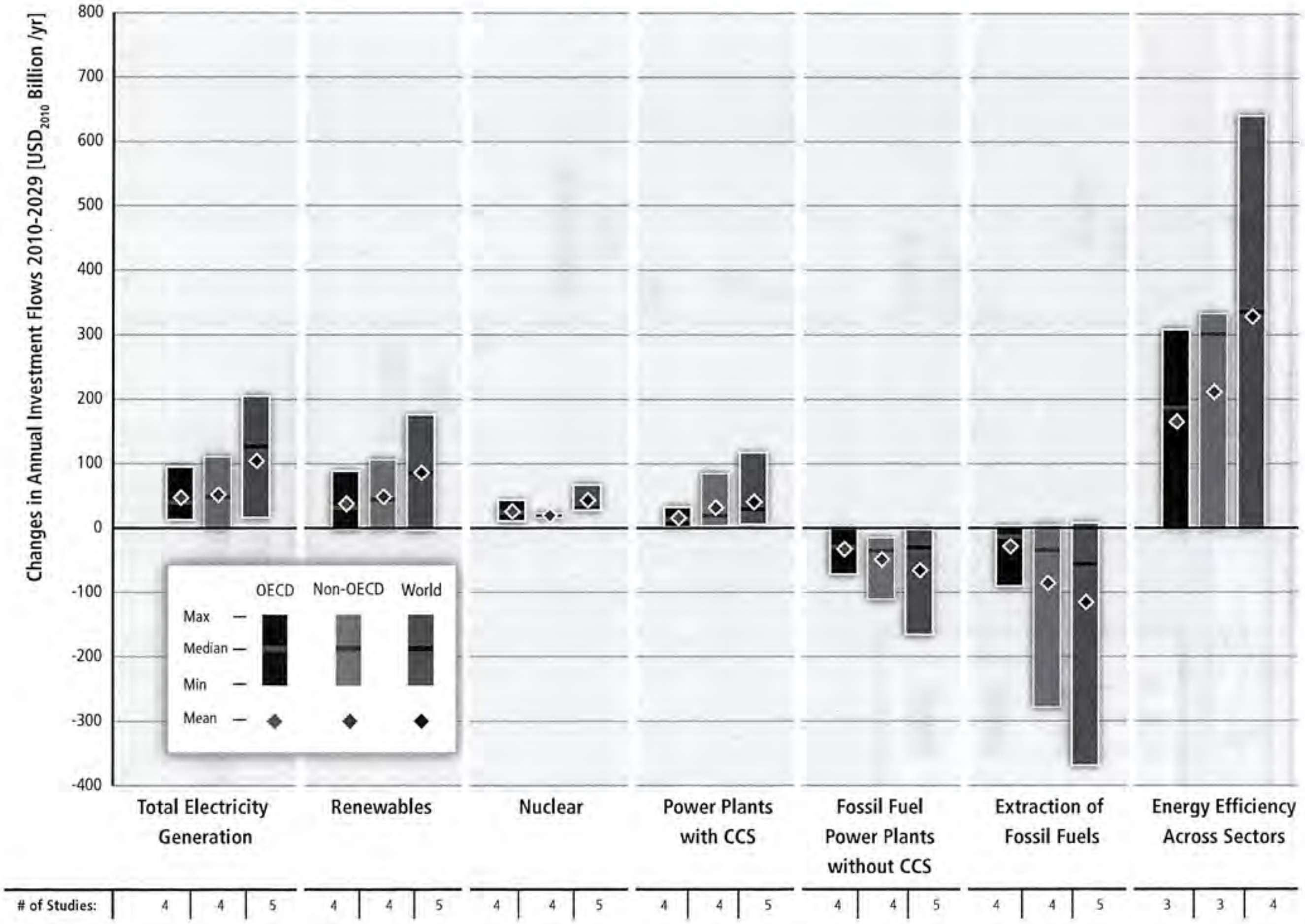

Figure 16.3 | Change of average annual investment in mitigation scenarios (2010–2029). Investment changes are calculated by a limited number of model studies and model comparisons for mitigation scenarios that stabilize concentrations within the range of 430–530 ppm CO_2eq by 2100 compared to respective average baseline investments. Note: The vertical bars indicate the range between minimum and maximum estimate of investment changes; the horizontal bar indicates the median of model results. Proximity to this median value does not imply higher likelihood because of the different degree of aggregation of model results, low number of studies available, and different assumptions in the different studies considered. The numbers in the bottom row show the total number of studies available in the literature. Sources: UNFCCC (2008). IEA (2011): 450 Scenario (450) relative to the Constant Policies Scenario (CPS). The CPS investment in CCS is also included under Coal and Gas (retrofitting); World investment in biofuels includes international bunkers; investment in solar photovoltaic (PV) in buildings is attributed to power plants in supply-side investment. Riahi et al. (2012): the Global Energy Assessment Mix scenario (GEA-Mix) relative to the GEA reference scenario. Carraro et al. (2012): 460 ppm CO_2eq in 2100 (t460) relative to reference scenario. McCollum et al. (2013): the Low Climate Impact Scenarios and Implications of Required Tight Emission Control Strategies (LIMITS), RefPol-450 scenario (2.8 W/m^2 in 2100) relative to the reference scenarios, mean of six models. McKinsey (2009): data obtained from Climate Desk, S2015 scenario with full technological potential, 100 % success rate, negative lever of costs, beginning of policy in 2015 | Regions: OECD, non-OECD, and World.

industry sector. Incremental investments in end-use technologies are particularly hard to estimate and the number of studies is limited (Riahi et al., 2012). Results should therefore be taken with caution.

While models tend to agree on the relative importance of investments in fossil and non-fossil power generation, they differ with respect to the mix of low-emission power generation technologies and the overall incremental investment. This is mainly due to different reference scenarios (e.g., population, economic growth, exogenous technological progress), and assumptions about (1) the structure of the energy system and the costs of reducing the energy intensity of the economy versus reducing the carbon intensity of energy, (2) the investment costs of alternative technologies over time, and (3) technological or political constraints on technologies. Limits to the deployment of some key technology options or the presence of policy constraints (e.g., delayed action, limited geographical participation) would increase investment needs (Riahi et al., 2012; McCollum et al., 2013).

Higher energy efficiency, technological innovation in transport, and the shift to low-emission generation technologies—all contribute to a drastic reduction in the demand for fossil fuels, thus causing a sharp decline in investment in fossil fuel extraction, transformation, and transportation. Scenarios from a limited number of models suggest that average annual investment reduction in 2010–2029 would be equal to 56 (–8 to 369) billion USD. The contraction would be sharper in 2030–2049, in the order of 451 (332 to 1385) billion USD per year.

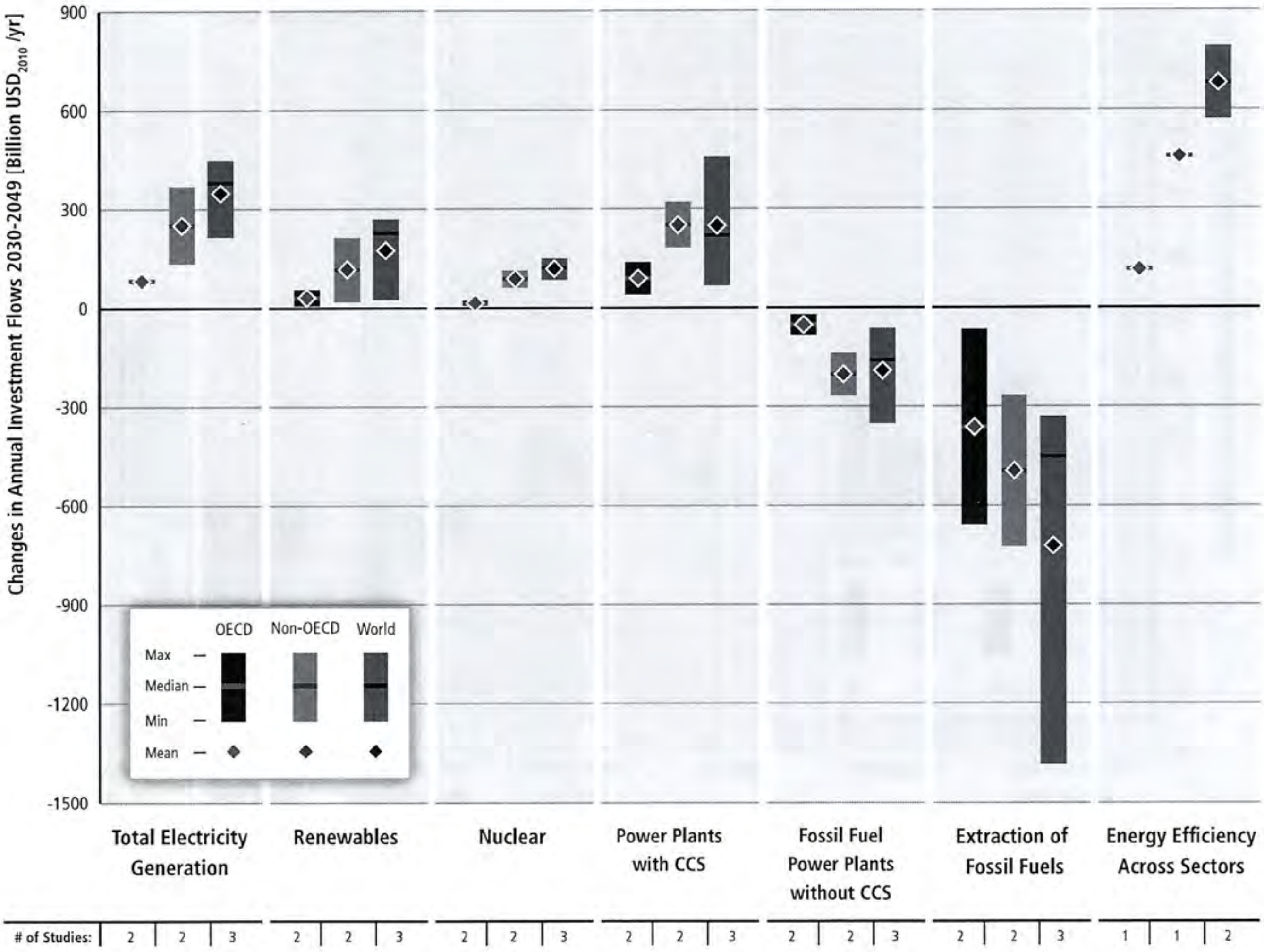

Figure 16.4 | Change of average annual investment in mitigation scenarios (2030–2049). Investment changes are calculated by a limited number of model studies and model comparisons for mitigation scenarios that stabilize concentrations within the range of 430–530 ppm CO_2eq by 2100 compared to respective average baseline investments. Note: The vertical bars indicate the range between minimum and maximum estimate of investment changes; the horizontal bar indicates the median of model results. Proximity to this median value does not imply higher likelihood because of the different degree of aggregation of model results, low number of studies available, and different assumptions in the different studies considered. The numbers in the bottom row show the total number of studies available in the literature. Sources: Riahi et al. (2012): the Global Energy Assessment Mix scenario (GEA-Mix) relative to the GEA reference scenario. Carraro et al. (2012): 460 ppm CO_2eq in 2100 (t460) relative to reference scenario. McCollum et al. (2013): the Low Climate Impact Scenarios and Implications of Required Tight Emission Control Strategies (LIMITS), RefPol-450 scenario (2.8 W/m^2 in 2100) relative to the reference scenarios, mean of six models. Regions: OECD, non-OECD, and World.

All models that provide data on investments for fossil fuel extraction show that overall investments in energy supply would decrease against the baseline trends in scenarios consistent with the 2 °C limit (IEA, 2011; Carraro et al., 2012; Riahi et al., 2012; McCollum et al., 2013).

According to a range of models, climate policy would thus substantially change the allocation of baseline energy investments rather than increase overall demand for energy investment.

Models with a separate consideration of energy-efficiency measures foresee the need for significant incremental investment in energy efficiency in the building, transport, and industry sector in addition to the reallocation of investment from high-carbon to low-carbon power supply.

There is wide agreement among model results on the necessity to ramp up investments in research and development (R&D) to increase end-use energy efficiency and to improve low-emission generation energy carriers and energy transformation technologies. Estimates of the additional funding needed for energy-related R&D range from 4.5 to 78 billion USD per year during 2010–2029 (UNFCCC, 2007; Carraro et al., 2012; McCollum et al., 2013) and from 115 to 126 billion USD per year in 2030–2049 (Carraro et al., 2012; Marangoni and Tavoni, 2013; McCollum et al., 2013). Because of the need for new low-carbon alternatives, investments in R&D are higher in case of nuclear phaseout and other technological constraints (Bosetti et al., 2011).

Land-use is the second largest source of GHG emissions and within land use, tropical deforestation is by far the largest source (see Chapters 5 and 11). Efforts to stabilize atmospheric concentrations of GHGs will require investments in land use change (LUC) as well as in the energy sector.

Kindermann et al. (2008) use three global forestry and land use models to examine the costs of reduced emissions through avoided deforestation over the 25 year period from 2005–2030.[22] The models' results suggest substantial emission reductions can be achieved. The models estimate that 1.6 to 4.3 $GtCO_2$ per year could be reduced for 20 USD tCO_2 with the greatest reductions coming from Africa followed by Central and South America and Southeast Asia. They also use the models to estimate the costs to reduce deforestation by between 10 % and 50 % of the baseline. Deforestation could be reduced by 10 % (0.3–0.6 $GtCO_2$ per year) over the 25-year period for an investment of 0.5 to 2.1 billion USD per year in forest preservation activities, and a 50 % reduction (1.5–2.7 $GtCO_2$ per year) could be achieved for an investment of 21.2 to 34.9 billion USD per year. This is comparable to what has been found by UNFCCC (2008) and McCollum et al. (2013).

Investment needs in other sectors commonly relate to energy-efficiency measures included above. Information on global or regional investment needs to abate process emissions or non-CO_2 emissions in sectors like the waste, petroleum, gas, cement, or the chemical industry is virtually unavailable. For instance, McKinsey (2009) does not provide information that could be separated from energy-efficiency measures in the sectors. An indicative estimate for the waste sector can be derived from Pfaff-Simoneit (2012) suggesting investment needs of approximately 10–20 billon USD per year if access to a modern waste management system were to be provided for an additional 100 million people per year.

16.2.2.2 Incremental costs

Incremental costs can be calculated for an individual project, a programme, a sector, a country, or the world as a whole. The incremental costs reflect the incremental investment and the change of operating and maintenance costs for a mitigation or adaptation project in comparison to a reference project. It can be calculated as the difference of the net present values of the two projects. Estimates of the incremental costs of mitigation measures for key sectors or the entire economy have been prepared for over 20 developing countries (Olbrisch et al., 2011). When estimates of both the incremental costs and the incremental investment are available, the former is generally lower because of the annualization of incremental investments for the calculation of incremental costs.

From an economic perspective, macroeconomic incremental costs can be defined as the lost gross domestic product (GDP). This measure provides an aggregate cost of the mitigation actions (estimates provided in Chapter 6), but it does not provide information on the specific micro-economic investments that must be made and costs incurred to meet the mitigation commitments. This distinction is important if international climate finance commitments will be implemented through institutions designed to provide financial support for specific investments and costs rather than macro-level compensation.

Other than on the project-level, investment needs are thus frequently only a fraction of incremental costs on the level of the macro-economy. This difference is largely due to reduced growth of carbon-constrained economies in many models. Adaptation costs and economic losses from future climate change, which are not considered in these estimates, should be lower for climate policy scenarios than in the reference scenario.

16.2.3 Raising public funding by developed countries for climate finance in developing countries

Comparison of the model estimates of future mitigation investment (Section 16.2.2) with the current level of global total climate finance (Section 16.2.1.1) indicates that global climate finance needs to be scaled up. Increased financial support by developed countries for mitigation (and adaptation) in developing countries will be needed to stimulate the increased investment. This section reviews possible sources of additional funds that could be implemented by developed country governments to finance mitigation in developing countries.

In December 2009, developed countries committed to a goal of mobilizing jointly 100 billion USD a year by 2020 to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation. This funding will come from a wide variety of sources, public and private, bilateral and multilateral, including alternative sources of finance (UNFCCC, 2009a).[23] This goal has been recognized by the COP (UNFCCC, 2010, para. 98). This recognition does not change the commitments of Annex II Parties specified in Article 4 of the Convention to provide financial resources for climate-related costs incurred by developing countries.

Studies by the High-level Advisory Group on Climate Change Financing (AGF) (AGF, 2010) and the World Bank Group et al. (2011) at the request of G20 finance ministers have analyzed options for mobilizing 100 billion USD per year by 2020. The AGF concluded that it is challenging but feasible to reach the goal of mobilizing 100 billion USD

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[22] The models used are the Dynamic Integrated Model of Forestry and Alternative Land Use (DIMA) (Roktiyanskiy et al., 2007), the Generalized Comprehensive Mitigation Assessment Process Model (GCOMAP) (Sathaye et al., 2006), and the Global Timber Model (GTM) (Sohngen and Mendelsohn, 2003).

[23] There is currently no definition of which 'climate' activities count toward the 100 billion USD, what 'mobilizing' means, or even which countries are covered by this commitment (Caruso and Ellis, 2013).

Table 16.1 | Summary of potential sources of public funds for climate finance in 2020.

Option	Projected amount generated in 2020 (billion USD_{2010}/year)	Share assumed to be dedicated to international climate finance
1) Options that contribute to developed country national budgets, dependent on national decisions		
Domestic auctioned allowances	AGF: 125–250[b]; G20: 250	AGF: 2–10 %; G20: 10 %
Domestic carbon tax[c]	AGF: 250	AGF: 4 %
Phase out of fossil fuel subsidies	AGF: 8; G20: 40–60	AGF: 100 %; G20: 15–25 %
Higher fossil fuel royalties	AGF: 10	AGF: 100 %
Wires charge on electricity generation	AGF: 5	AGF: 100 %
2) Options that contribute to national budgets, dependent on international agreements		
Border carbon cost levelling	Grubb 2011: 5*	
Financial transactions tax	AGF: 2–27	AGF: 25–50 %
3) Funds collected internationally pursuant to an international agreement		
Extension of the 'share of proceeds'	AGF: 38–50	AGF: 2–10 %
Auctioning a portion of AAUs	AGF: 125–250[b]	AGF: 2–10 %
Carbon pricing for international aviation***,[a]	UNFCCC: 10–25**; AGF: 6; G20: 13	AGF: 25–50 %; G20: 33–50 %
Carbon pricing for international shipping***,[a]	UNFCCC: 10–15**; AGF: 16–19; G20: 26	AGF: 25–50 %; G20: 33–50 %

Notes: AGF, G20, and UNFCCC refer to estimates from AGF (2010), World Bank Group et al. (2011) and UNFCCC (2007), respectively.* = Date not specified; ** = 2006 USD; *** Could fall into category 2 depending upon the method of implementation; [a] The AGF and G20 estimates for international aviation and international shipping assume that a substantial fraction (30 to 50 %) of the global revenue is allocated to developing countries. [b] The AGF combines auctioned AAUs and auctioned domestic allowances, here half of the total is included in each category; [c] The AGF estimates revenue of 10 billion USD per 1 USD tax per tonne of CO_2, that is equivalent to potential revenue of 250 billion USD and a 4 % share for international climate finance as reported here. Sources: Compiled from AGF (2010), World Bank Group et al. (2011), UNFCCC (2007), and Grubb (2011).

annually for climate actions in developing countries. Both reports conclude that a mix of sources is likely to be required to reach the goal.

Both reports estimate the revenue that could be mobilized in 2020 by various options to finance climate action in developing countries in the context of a carbon price of 25 USD per tonne of CO_2eq in Annex II countries. The feasibility of the options was not assessed. For some options, only a fraction of the revenue was assumed to be available for international climate finance. Their estimates of the international climate finance that could be generated by each option, together with other estimates, where available, are summarized in Table 16.1. Only options to mobilize public funds and that yield mitigation benefits are included in the table; options for increased borrowing by multilateral institutions and mobilizing more private finance are excluded.

Virtually all of the options put a price on GHG emissions thus providing a mitigation benefit in addition to generating revenue. The options are grouped into the following categories (Haites and Mwape, 2013):

1. Options that contribute to developed countries national budgets, dependent on national decisions;
2. Options that contribute to national budgets, dependent on international agreements; and
3. Funds collected internationally pursuant to an international agreement.

Funds mobilized by options in the first two categories flow into national budgets, so the amount allocated for international climate finance depends on national decisions. In contrast, funds mobilized by options in the third category go directly to an international fund.

The AGF and G20 reports assume for many options that only small fraction of the total revenue mobilized is dedicated to international climate finance. Hence, these options would mobilize revenue to meet the international climate finance goal and at the same time mobilize substantial revenue for domestic use by Annex II governments. The domestic share of the revenue could be used by Annex II treasuries to reduce deficits and debt, or to reduce existing distortionary taxes and so help stimulate economic growth.

Global modelling estimates

Using integrated models, it is possible to estimate the potential carbon revenues when all emissions are taxed or all permits are auctioned. These estimates reflect a scenario in which all world regions commit to reduce GHG emissions using an efficient allocation of abatement effort, i.e., globally equal marginal abatement costs. Therefore, it should be used to gain insights rather than exact revenue forecasts.

From the analysis of scenarios already presented in this chapter (Carraro et al., 2012; Calvin et al., 2012; McCollum et al., 2013) it is possible to derive the following messages:

Carbon revenues are potentially large, in the order of up to 200 billion USD each in China, the European Union and the United States in 2030. At the global level, they could top 1600 billion USD in 2030.

Carbon revenues may peak in the mid-term and decline in the long-term, as decreasing emissions (the tax base) more than offset the increase in the carbon price (Carraro et al., 2012). In regions with lower marginal abatement costs, the tax base shrinks faster so carbon revenues fall faster. Fast-growing regions may see growing carbon revenues for several decades more.

Scenarios and/or regions in which absorption of emissions—e.g., by means of bioenergy with CCS—plays an important role may exhibit net negative emissions. This implies net reduction of carbon revenues so governments must finance net negative emissions using either the general budget or international funding (Carraro et al., 2012).

16.3 Enabling environments

This section highlights the importance of a supportive enabling environment in facilitating low-carbon investments. The concept of enabling environment is not clearly defined, so it has many different interpretations. One is government policies that focus on "creating and maintaining an overall macroeconomic environment" (UNCTAD, 1998).[24] Another (Bolger, 2000), interprets an 'enabling environment' as the wider context within which development processes take place, i.e., the role of societal norms, rules, regulations, and systems. This environment may either be supportive (enabling) or constraining.

According to Stadelmann and Michaelowa (2011), capacity building and enabling environment are separate but interrelated concepts. Capacity building targets knowledge and skills gaps, while the enabling environment for low-carbon business activities is "the overall environment including policies, regulations and institutions that drive the business sector to invest in and apply low-carbon technologies and services." According to this definition, the enabling environment has three main components: (1) the core business environment, which is relevant for all types of businesses, e.g., tax regime, labour market, and ease of starting and operating a business; (2) the broader investment climate, including education, financial markets, and infrastructure, which is partially low-carbon related, e.g., via climate change education or investments in electricity grids; and (3) targeted policies that encourage the business sector to invest in low-carbon technologies.

Capacity building can also be seen as a subcomponent of an enabling environment (UNFCCC, 2009b) as it aims to improve the enabling environment by overcoming market, human, and institutional capacity barriers. Support for capacity building can increase the probability that the recipient country will succeed in implementing mitigation policies, and hence may reduce the total funding needed (Urpelainen, 2010).

Reliability and predictability are important elements of an enabling environment. While stable and predictable government policies reduce uncertainty about expected return on investment, frequent and unpredictable changes to policies can undermine market efficiency (Blyth et al., 2007; Brunner et al., 2012). Predictability and stability require well-established legal institutions and rule of law. Institutional capacity across sectors and at various levels is also important (Brinkerhoff, 2004).

In their econometric examination, Eyraud et al. (2011) found that lowering the cost of capital is particularly effective in boosting investment in low-carbon activities. Hence, macro-economic factors and policy regulatory frameworks that are good for private investment as a whole are also important determinants of climate investment. Put differently, obstacles that impede private investment also hamper investment in low-carbon technologies. More elements related to the drivers of low-carbon investments, which are part of enabling environments, are found in the next sub-section.

16.4 Financing low-carbon investments, opportunities, and key drivers

Financing mitigation projects is, in principle, similar to financing any other investment. This section provides an overview of factors that attract private capital for low-carbon investments. First, different categories of capital managers and their key investment criteria are introduced. Next, challenges that hamper investors, such as investment risks and access to capital, are assessed. Finally, selected financial instruments used in low-carbon transactions are presented and discussed.

16.4.1 Capital managers and investment decisions

Mitigation measures often are financed through investments by several different capital managers (see Figure 16.1). It is crucial to understand the basic investment logic and the preferred financial instruments of each type of capital manager.[25] Box 16.2 characterizes some of the major types of capital managers.

Risk and return are crucial decision factors in any investment finance decision, including low-carbon activities. The higher the perceived risk,

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[24] For enabling environments for technology transfer see McKenzie Hedger et al. (2000).

[25] For the different types of financing typically used, i.e., required, in the different stages of renewable technologies, such as R&D, commercialization, manufacturing, and sales, see Mitchell et al.(2011).

Box 16.2 | Types of capital managers relevant for investment and finance in low-carbon activities

Governments commit to mitigation measures to comply with international agreements and self-imposed targets. Their role as capital managers is limited to mitigation measures where they invest directly. In 2011 and 2012, the public sector provided on average 135 billion USD per year (2011/2012 USD) of public funding for climate finance, thereof 12 billion USD provided directly by government bodies[1] (Buchner et al., 2013b).

Public financial institutions include national, bilateral, multilateral, and regional finance institutions, as well as UN agencies and national cooperation agencies. These institutions invested 121 billion USD in mitigation and adaptation measures in 2012 (2012 USD), more than 50 % was provided as concessional loans (Buchner et al., 2013b).

Commercial financial institutions, such as banks, pension funds, life insurance companies, and other funds, manage over 71 trillion USD in assets. They can have long-time horizon investments diversified across asset classes with varying risk return profiles and investment tenors, sectors, and geographies (Inderst et al., 2012). The ability of institutional investors to invest in mitigation measures depends on their investment strategy, restrictions agreed upon with their clients, as well as the regulatory framework. Life insurance and pension funds are especially constrained by the latter (Glemarec, 2011). Their contribution was estimated at 22 billion USD in 2012 (2012 USD) (Buchner et al., 2013b).

Energy corporations including power and gas utilities, independent power producers, energy companies, and independent project developers can design, commission, and operate renewable energy projects. They provided approximately 102 billion USD (2012 USD) for climate finance in 2012 (Buchner et al., 2013b).

Non-energy corporations invest in mitigation measures to reduce their energy bills, meet voluntary commitments or comply with emission trading schemes. Altogether, they provided around 66 billion USD in 2012 for low-carbon investment (2012 USD) (Buchner et al., 2013b).

Households' investments are funded by income and savings supplemented by loans. In 2012, households provided around 33 billion USD for climate finance projects; 83 % of households' contributions were in developed countries, especially in Germany, Japan, and Italy (Buchner et al., 2013b).

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[1] This estimate excludes financing by public financial institutions and by dedicated climate fund, the latter providing approximately 1.6 billion USD (2012 USD) in 2012 (Buchner et al., 2013b).

the higher the cost of capital and required return needing to be generated to cover the costs (i. e., higher risk results in a higher discount rate for cash flow) (Romani, 2009).

Equity and debt are basically the two basic types of finance. Both come at a certain cost, which is very sensitive to risk, i. e., risk premium or risk margin. The type of finance required depends on the type of activity, its development phase, and its application.

Project finance is usually the preferred financing approach for infrastructure or energy projects worth more than 21.4 million USD (UNEP, 2005). In this financing structure, debt and equity are paid back exclusively from the cash flows generated by the project and there is no recourse to the balance sheet (also call non-recourse finance); as opposed to balance-sheet financing, where all *'on-balance sheet'* assets can be used as collateral. In 2012, around 70 billion USD of project-level market rate debt went towards emission reduction (70 % provided by the public sector). Project-level equity was estimated at approximately 11 billion USD. However, the largest share of mitigation , 198 billion USD, consisted of balance-sheet financing (2012 USD) (Buchner et al., 2013b).

Risk profile, tenor (i. e., loan duration) and **size** are the primary criteria to characterize the financing demand. The total financing demand can be split into tranches with varying risk profiles (e.g., debt vs. equity) and varying tenors that match the characteristics of existing financing instruments. For renewable energy projects, higher cost of capital will increase start-up costs, which are generally front-loaded and higher per unit of capacity than for fossil fuel-based projects even if financing conditions are identical (Brunnschweiler, 2010). Lenders require a higher equity share if a project is perceived as risky. A typical project finance structure in an industrialized country consists of 10–30 % equity, whereas in developing countries this share tends to be higher (UNEP, 2007). However, equity tends to be scarce in many developing countries (see Section 16.4.2.2).

16.4.2 Challenges for low-carbon investment

Factors that reduce the relative attractiveness of implementing a low-carbon technology shall be considered as a challenge. Many factors pertaining to the general investment environment can have an enabling character or can act as a challenge (see Section 16.3). However, there are also low-carbon specific factors—especially in absence of a clear price signal for carbon emissions—that, if they remain, may keep the market penetration of these technologies to low percentages (Gillingham and Sweeney, 2011). The latter will be assessed in this subsection.

Challenges vary significantly within the different investment categories, dependent upon the investor and the type of activity. For instance, each group is faced with some additional typical financial challenges. Energy-efficiency measures, for instance, often face misaligned incentives between the asset owner, user, and lender. It is more complex for energy-efficiency projects to structure and share the underlying risks. In addition, energy savings are intangible as collateral (Hamilton and Justice, 2009; Ryan et al., 2012; Venugopal and Srivastava, 2012).

Investment risks: Investments in low-carbon activities face partly the same risks as other investments in the same countries analogous to the core and broader investment climate. These risks can be broadly grouped into political risks (e.g., political instability, expropriation, transfer risk, breach of contract, etc.) and macro-economic risks (e.g., currency risk, financial risks, etc.). In some developing countries, political and macroeconomic risks represent a high barrier to investment (Ward et al., 2009; World Bank, 2011a; Venugopal and Srivastava, 2012).

There are also types of risks characteristic for low-carbon investments: **Low-carbon policy risks** are one type of these risks that concern the predictability, longevity, and reliability of policy, e.g., low-carbon regulations might change or not be enforced (Ward et al., 2009; Venugopal and Srivastava, 2012; Frisari et al., 2013). Private capital will flow to those countries, or markets, where regulatory frameworks and policies provide confidence to investors over the time horizon of their investment (Carmody and Ritchie, 2007).

Mitigation activities also face **specific technology and operational risk**. For relatively new technologies, these are related to performance of the technology (i.e., initial production and long-term performance), delay in the construction, and the risk of not being able to access affordable capital (see Section 16.4.2.2). Some low-carbon activities also tend to depend on an expected future development, e.g., steep learning curves for certain technologies. Operational risks include the credit quality of the counterparties, off-take agreements, especially in a scenario where the mitigation technology has a higher costs of production, supply chain scalability, unreliable support infrastructure, and maintenance costs (Jamison, 2010; Venugopal and Srivastava, 2012).

Moreover, risks may be overestimated due to limited information in markets that are undergoing a technological and structural transition (Sonntag-O'Brien and Usher, 2006) and the longer time frame used to assess the risk increases uncertainty. A lack of quantitative analytical methodologies for risk management may add to the perceived risk.

Return on investment: The basic challenge is to find a financing package that provides the debt and equity investors with a reasonable return on their investment given the perceived risks. Debt financiers have a strong interest in seeing that their loans are paid back and hence provide funds to less risky, proven technologies and established companies (Hamilton, 2010). It is estimated that in 2009 they required an average internal rate of return (IRR) of around 3 to 7 % above the London Interbank Offered Rate (LIBOR) reference interest rate, for renewable energy projects in industrialized countries. Venture capitalists, angel investors, and some foundations (through so-called programme-related investments) are situated on the other side of the financing continuum. They typically invest in new companies and technologies, and are willing to take higher risks while expecting commensurately larger returns. These investors may require an IRR of 50 % or higher because of the high chances that individual projects will fail. Private equity companies that invest in more established companies and technologies may still require an IRR of about 35 % (Hamilton and Justice, 2009). However, these typical IRRs have to be considered with care since they may vary according to the prevailing basis interest rates (i.e., the current LIBOR rate), perceived risks of the investment category and the availability of alternative investment opportunities. Many renewable energy projects, especially in developing countries where additional risk margins are added, are struggling to reach returns of this level to satisfy the expectations of financiers of equity and debt.

Cost of capital and access to capital: In many countries, there are imperfections in the capital market restricting the access to affordable long-term capital (Maclean et al., 2008). This is particularly the case in many developing countries where local banks are not able to lend for 15–25 years due to their own balance sheet constraints (Hamilton, 2010), e.g., to match the maturity of assets and liabilities.

Attracting sufficient equity is often critical for low-carbon activities, especially for renewable energy projects in developing countries (Glemarec, 2011). The equity base of a company is used to attract (leverage) mezzanine or debt finance especially in project finance investments. Since equity is last in the risk order and can be recovered only by means of sale of shares of the asset or its liquidation, return expectations are significantly higher than for debt or mezzanine finance. Often, equity is also the key limiting factor in the expansion of a low-carbon activity, e.g., through growth of a company, expansion into new markets, R&D, or multiplication of a project approach (UNEP, 2005).

Market and project size: Since the pre-investment costs vary disproportionally with the project size, smaller low-carbon projects incur much higher transaction costs than larger ones of conventional energy projects (Ward et al., 2009). These costs include feasibility and due diligence work, legal and engineering fees, consultants, and permitting costs. Hamilton (2010) finds that small low-carbon projects in developing countries seeking less than 10 million USD of debt are generally not attractive to an international commercial bank. Due to the higher transaction costs, small projects might also generate lower gross returns, even if the rate of return lies within the market standards (Sonntag-O'Brien and Usher, 2006).

There is basically no secondary market to raise debt for low-carbon projects. Hence, institutional investors, whose major asset class is bonds, lack opportunities to invest in low-carbon energy projects because they do not issue bonds or the issuance size is too small (Hamilton and Justice, 2009; Kaminker and Stewart, 2012). The minimum issuance size for investment grade bonds tends to be about 460 million USD, so few projects can achieve this standard (Veys, 2010). Many renewable energy projects need investment in the range of 70–700 million USD, with only a few big ones towards the upper end (Hamilton and Justice, 2009). In 2011, clean energy bonds amounted to only about 0.2 % of the global bond market (Kaminker and Stewart, 2012).

Tenor-risk combination: Capital markets tend to prefer a combination of long tenor with low risk and are willing to finance high risk only in the short term. Due to higher political and macro-economic instability in developing countries, investors are particularly reluctant to invest in projects with such a long investment horizon. Although pension funds and insurance companies are long-term investors, concerns about quality and reliability of cash flow projections, credit ratings of off-takers for power purchase agreements, short-term performance pressures, and financial market regulations often inhibit them from investing in long-term low-carbon assets (Kaminker and Stewart, 2012). Industrial firms also face constraints with extended payback periods, since they typically operate with a short-term horizon that requires rapid positive returns on investment (Della Croce et al., 2011). A significant positive consideration, however, is that low-carbon projects like waste heat, geothermal, wind, and solar have zero or negligible fuel price volatility risk.

Human resources and institutional capacity: The lack of technical and business capabilities at the firm, financial intermediary and regulatory level are significant barriers to harness low-carbon technologies, especially in many developing economies (Ölz and Beerepoot, 2010). In countries where private sector actors do not only own the low-carbon technology but are also predominately responsible for the diffusion of technologies in the market, capacity building efforts need to focus on these actors' ability to develop, fund, and deploy the respective technologies (Lall, 2002; Figueiredo, 2003; Mitchell et al., 2011).

16.4.3 Financial instruments

Policy instruments to incentivize mitigation activities are assessed in depth in Chapters 13, 14, and 15. Evidently a missing price signal for carbon emissions is a major obstacle for low-carbon investments. But not only in absence of such a price signal, other important measures can be applied to reduce critical barriers for low-carbon investment. Basic financial instruments are illustrated in Figure 16.1 and introduced in Section 16.4.1. This subsection focuses on three types of financial instruments with the following purposes: reducing risk, reducing the cost of capital, and providing access to capital, as well as enhancing cash-flows. Figure 16.5 illustrates in a simplified manner how these instruments can enhance market competitiveness of low-carbon projects. There is a growing literature on how the public sector can use these instruments to mobilize additional private finance, and can help to improve the risk-return profile of investments for low-carbon activities.

16.4.3.1 Reducing investment risks

Risk mitigation can play an essential part in helping to ensure that a successful project financing structure is achieved by transferring risk away from borrowers, lenders, and equity investors. Various instruments provided by private insurers, and by means of public mechanisms, can help to partially or fully reduce the exposure of investors to

Figure 16.5 | Instruments to enhance market competitiveness of low-carbon projects.

political risk, exchange rate fluctuations, business interruption, shortfalls in output, delays or damage during fabrication, construction, and operation of a product, project, and company (Marsh, 2006).

There is a wide portfolio of proven commercial- and government-supported risk mitigation products that can be instrumental in efficiently expanding low-carbon investment. Their allocation and application requires a substantial level of expertise, experience, and resources available in specialized insurance companies, export credit agencies, and selected commercial and development banks. Examples of such products are highlighted below. They signal the potential for expanded use of risk mitigation instruments to support low-carbon investment (Frisari et al., 2013).

Credit enhancements/guarantees, such as commercial credit insurance and government guarantees, usually cover part of the loan and reduce the loss incurred by a lender if the borrower is unable to repay a loan. The lender must still evaluate the creditworthiness and conditions of the loan, but these instruments can reduce the interest rate and improve the terms, thereby expanding the available credit or reducing the costs (Stadelmann et al., 2011a).

Trade credit insurance provides partial protection against certain commercial risks (e.g., counterparty default) and political risks (e.g., war and terrorism, expropriation, currency transfer, or conversion limitations) and other risks like non-honouring of sovereign financial obligations or breach of contract by sovereign actors (MIGA, 2012; OPIC, 2012). Such insurance is provided by commercial insurance companies and by governments to their manufacturers, exporters, or financiers.

Production and savings guarantees are typically provided to their clients by energy service companies (ESCOs) and large energy performance contracting (EPC) contractors. Only proven practices and technologies are eligible to receive these guarantees, covering both technical risk (from customer payment default due to non-performance attributable to the ESCO or EPC contractor), and comprehensive risk (defaults due to technical and financial creditworthiness of the customer) (IDB, 2011).

Local currency finance can be used if currency fluctuations are particularly risky for a project or company because a major investment is made in foreign currency and revenues are in local currency. Loans in local currency or risk management swaps to hedge foreign currency liability back into respective local currency can be provided by development finance institutions (IFC, 2013; TCX, 2013a). Structured funds like the Currency Exchange Fund (TCX) are dedicated to hedge these cross-border currency and interest rate mismatches (TCX, 2013b).

By the end of 2012, the 20 largest emitting developed and developing countries with lower risk country grades for private sector investments were producing 70 % of global energy-related CO_2 emissions (Harnisch and Enting, 2013). In investment-grade countries, risk mitigation instruments and access to long-term finance can be provided at reasonably low costs, and have the potential to mobilize substantial additional private sector mitigation investments. In other countries, low-carbon investment would have to rely mainly on domestic sources or international public finance.

16.4.3.2 Reducing cost of and facilitating access to capital

In many situations, mitigation measures imply additional or incremental investments. Independent of the specific role of equity or debt finance in these individual investments, and irrespective of potential future reductions of operating and maintenance costs, the level of these investments can be a severe barrier to the investment decisions of different investors (as outlined in Section 16.4.2).

Concessional or 'soft' loans are repayable funds provided at terms more favourable than those prevailing on the market including lower interest rates, longer tenor, longer grace period, and reduced level of collateral. Providers of concessional loans are typically development banks on behalf of governments. In international cooperation, concessional loans of varying degree and type have been established as main financing instruments to support public sector entities and local banks by bilateral and multilateral development banks (Maclean et al., 2008; Birckenbach, 2010; UNEP, 2010, 2011, 2012). In 2011, bilateral finance institutions, for instance, disbursed 73 % of their mitigation finance as concessional loans (UNEP, 2012). National finance institutions provided around 87 % of their climate funding in 2010/2011 via soft loans (Buchner et al., 2012).

Grants are non-repayable funds provided to a recipient for a specific purpose by a government, public financial institution or charity. Grants can play an important role in reducing up-front capital investment costs, and meeting viability gaps for projects that are more expensive than business-as-usual (Buchner et al., 2012).

Rebates provide immediate price reductions for purchase of an eligible product. Rebates can be structured to decline over time, encouraging early adopters and reflecting anticipated technology cost reductions (de Jager and Rathmann, 2008). Rebates are typically administered by retailers of respective products, in cooperation with a government agency.

Tax deductions or tax credits increase the after-tax cash flow for a specific investment. Hence, they can have a similar effect as soft loans by reducing the net annual payments for the amortization of a capital investment. They can be useful in enticing profitable enterprises to enter the market for renewable energies to reduce their tax liabilities. However, they require to be embedded in a country's tax system and a base in the tax code. Additionally, the specific level cannot be easily adapted to changed market conditions and will depend on the specific tax burden of the taxed entity (Wohlgemuth and Madlener, 2000).

Equity plays a critical role in financing a project and it is potentially attractive for governments to provide equity to companies or projects to support desirable activities. At the same time, limited expertise of the public sector in allocating capital in risky operations and in management of companies, and problems arising from the relationships of owners and regulators, are frequently cited as reasons against a broad public engagement as equity investor. In support of emission mitigation activities, a number of approaches have been successfully demonstrated. Because of the challenges discussed above, some public sector investors have decided to limit their equity investment to minority stakes and apply clear investment criteria to avoid crowding-out of private investors and to use defined exit strategies (IFC, 2009).

16.4.3.3 Enhancing cash flow

Nationally agreed **feed-in tariffs** (FITs) or **third-party guaranteed renewable energy premiums** for individual power purchase agreements provide a secure long-term cash-flow to operators of renewable energy systems—based on technology, system size, and project location. Debt and equity for a project can hence be secured due to the long duration, the guaranteed off-take of the electricity generated, and the grid access. Consequently, FITs do not only increase and stabilize the return, but also reduce the risks for developers, lenders, and investors. As a result, the cost of capital and required rate of return can be reduced as well (Cory et al., 2009; Kubert and Sinclair, 2011). The FITs for renewable energy have been implemented in a broad range of industrialized and developing countries (Fulton et al., 2010). The level of the FIT for a specific technology, region and time determines the effectiveness and efficiency of the programme, but it is difficult to establish the appropriate level up front and to adapt it as the market evolves and the technology matures.

CO_2 Offset-Mechanisms can also provide additional cash flow via the sales of credits to support the economics of a mitigation investment. Unlike renewable energy premiums, however, there is uncertainty about the future level of this payment stream. This has made many financiers hesitant to provide debt finance for these projects. Some MDBs, like the ADB have a provision to buy credits upfront contributing to investment capital and reducing uncertainty on the future cash-flows from the sale of carbon credits (ADB, 2011; Asian Development Bank, 2012).

16.5 Institutional arrangements for mitigation financing

Institutions are essential to channel climate finance to mitigation and adaptation measures (Stadelmann, 2013) and to ensure that the actions funded respond to national needs and priorities in an efficient and effective way.[26] Through institutions, knowledge is accumulated, codified, and passed on in a way that is easily transferable and used to build capacities, share knowledge, transfer technologies, help develop markets, and build enabling environments for effective climate investments. Without proper institutions, some actions and investments may remain simply as stand-alone projects with no lasting effects, or a one-off capital equipment supply rather than a transaction with a transfer of skills, know-how, full knowledge of the technology, and a contribution to a broader system of innovation and technological change (Ockwell et al., 2008).

16.5.1 International arrangements

Global arrangements for climate change mitigation finance are essential for several reasons. Most commonly cited is the fact that because the earth's climate is a public good, investing within borders is often not seen as beneficial to a particular country unless doing so becomes a collective effort (Pfeiffer and Nowak, 2006). The UNFCCC, among others, was established to address this dilemma and turn the global effort on climate change into a collective action that would be seen by all as beneficial to the whole (Burleson, 2007). Trusted institutions are needed to channel and implement the funding in an orderly and efficient process.

Funds that are part of the financial mechanism of the UNFCCC are subject to guidance from the COP. Until recently, these included only the GEF Trust Fund, the SCCF and the LDCF, all of which are administered by the GEF (see Section 16.2.1.1) (UNFCCC, 2013b). In 2010, the COP decided to establish the GCF to be designated as a new operating entity of the Financial Mechanism (UNFCCC, 2010). The GCF, that is currently being operationalized, is expected to become the main global fund to support climate action in developing countries, but it has not yet been capitalized. In addition, the Adaptation Fund has been established under the Kyoto Protocol.

The UNFCCC recognizes that funding for mitigation may come from a variety of sources and through a variety of channels beyond the financial mechanism, such as multilateral and bilateral institutions engaged in official development assistance. There has been an expansion in the number of public and private climate funds in the last decade. The UNDP estimates that over the last decade some 50 international public funds, 45 carbon market funds, in addition to 6000 private equity funds (set up largely independent of international climate policy) have been established for the purpose of funding climate change-related activities (UNDP, 2011). Some of these, such as CIFs are multi-donor funds administered by the World Bank but with their own governance and

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[26] The term 'institution' in this context is defined narrowly to mean an established organization dedicated to facilitate, manage, or promote mitigation finance, as opposed to the broader meaning of the term commonly used in the study of the social sciences and used to mean a structure or mechanism of social order and cooperation governing the behaviour of individuals in society, e.g., the institutions of marriage or religion.