Chapter 13: National and Sub-national Policies and Institutions

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Executive summary

Since AR5, there has been a substantial increase in climate-related activity at the national and sub-national levels. The numbers of policies and their scope has grown, as has direct and indirect climate legislation, executive orders, strategies, targets, sectoral policies and actions. The literature, as yet, does not allow a complete assessment of the impact of these increases. However, it does show considerable experimentation, such as a rise in sub-national action, the development of policy mixes, greater attention to integration with adaptation, and a rise in social forms of action such as climate litigation and protests.

The prevalence of national climate legislation, strategies, and targets, which can provide important policy signals and facilitate action, has increased considerably from 2007 to 2017, but also partially reversed course. Over this period, legislation that directly addressed climate change was added in a range of countries, such that coverage of global emissions by climate legislation increased from 16% of emissions in 2007 to 44% in 2017. When non-binding national executive strategies are included, this proportion increased from 43% in 2007 to 69% in 2017. In addition, more countries added targets, increasing from 44% of emissions in 2007 to 90% of emissions in 2017. However, there were also reversals, as the proportion of emissions covered by legislation or strategy decreased from a high of 82% during this period. Indirect climate legislation, decrees or policies – that have the effect of impacting emissions – has increased substantially. A review of 66 jurisdictions covering 90% of global emissions found an increase from 500 laws, decrees and policies in 2013 to 1500 in 2018. There is limited literature on the aggregate effect of these increases, but case studies suggest they play an important role in setting frameworks, establishing credible targets and creating institutional structures for policymaking and implementation. {13.2.1}

The creation of dedicated national institutions focused on climate change can enable a shift from national climate mitigation objectives to practical action, although there is wide variation in the prevalence and form of institutions, shaped by national circumstances. Institutions play an important role by enabling a strategic approach such as by identifying key opportunities for low-carbon transition; by facilitating a positive feedback loop of action and support by interests in low-carbon futures; by strengthening inter-agency coordination across policy domains including finance ministries; and by building systems for accountability. There is no single template for climate institutions. Countries do not start with a blank slate, but rather institutions are shaped by international negotiating positions and diffusion of institutional models from other countries, and by domestic factors such as bureaucratic traditions and practice, forms of federalism, and established mechanisms of engagement with business and other interests. There is limited evidence that NDC processes help stimulate institutional formation {13.2.2}.

Subnational and urban actors are playing a growing role in climate governance, as they have remit over key areas of mitigation, including land use planning and infrastructure. A diverse set of subnational actors, spanning states, regions, cities, companies, investors, foundations, civil society organizations, and cooperatives are engaged in climate action. Estimates of the scale of action is uncertain due to numerous and overlapping transnational initiatives. While there is growing participation from the Global South, there is currently greater organised action in Europe and North America. {13.3.1}, {13.3.2}

Subnational action deploys a diverse set of actions, including local targets and place-based decarbonisation, creating new institutional entities or buttressing existing ones, experimenting with and scaling local solutions, and deploying the full range of policy instruments. In addition, in the Global South, subnational climate action is often tied to local concerns such as air pollution. Challenges for subnational action include developing the potential to be transformational rather than incremental, engaging the diverse framings and priorities of various jurisdictions, addressing the needs of the urban poor with what are frequently technical solutions, internalising climate justice, and addressing complex governance contexts of political fragmentation, few resources, and weak governance. {13.3.3; 13.3.4}

Estimates of the impact of subnational action vary widely, due to overlapping initiatives, differing methodologies, the potential for under-reporting and challenges estimating the additionality of action. Estimates range from small-scale studies finding that 25 U.S. cities' could mitigate up to 30 megatons of additional CO_2e ($MtCO_2e$) in 2030 to larger studies finding that over 9,149 cities could mitigate 1,400 $MtCO_2e$ in 2030. The benefits of subnational climate action may also be indirect, including experimentation and policy innovation, establishing best practices; setting new norms for ambitious climate action, helping build coalitions; and translating into knowledge sharing or capacity building. {13.3.5}

Principles of justice are insufficiently incorporated in climate change framing and action, and are related to issues of differential capacity, vulnerability and competing objectives. The institutional capacities, including resources, legal frameworks, knowledge, political access, and democratic process, vary widely within and among national and subnational governments globally. Potentially negative inequality effects of climate change mitigation policies also exist, which in the presence of poverty, inequality and corruption, have been found to aggravate inequalities in many countries. Adaptive capacities tend to be lower in low emission countries. The enabling condition and transition acceleration literatures increasingly include justice and sustainable development as necessary conditions {13.2.2; 13.8; 13.10.1, 13.10.3}.

Climate governance is constrained and enabled by countries' political systems, material endowments, culture and traditions, but these factors do not determine domestic climate targets, strategies and measures (*medium evidence, medium agreement,*). Cultural-institutional features, such as norms, world views, traditions, frames and institutional logics, contribute to shape which climate actions are regarded as good and appropriate (*limited evidence, medium agreement*). For instance, climate governance may be influenced by sector-specific regulatory traditions; traditional approaches to application of scientific information in policy making; cultural understandings of climate science; approaches to international climate cooperation; domestic political cultures; national identities; media discourses; and corporate cultures (*limited evidence, medium agreement*). {13.4}.

Features of national political systems can have implications for climate policy processes. For example, proportional representation may facilitate the emergence of parties with a strong climate agenda, because they create opportunities for climate advocates to win seats, and reduces the political risks of strong climate positions. The number of 'veto points' in a political system is also salient to the prospects for advancing climate positions, although the literature does not enable robust conclusions. {13.4}

A range of actors navigate specific climate governance contexts to their advantage, which helps explain why similar policy elements have differing characteristics in differing countries and regions, such as emission trading systems and feed-in schemes for renewable energy (*medium evidence, medium agreement,*) These actors include corporations, environmental groups, indigenous communities, politicians and international organisations, who interact in political processes around influencing, adopting and implementing policies around climate change. For example, in influencing policy processes corporate actors may have greater access to political systems, environmental groups and indigenous communities may be able to draw on networks to shape frames of understanding, politicians can draw on financial authority, while international organisations bring material resources. The resolution of these interactions is issue and place specific. {13.4}

Policy instruments can be evaluated according to their environmental effectiveness, economic effectiveness, distributional effects, feasibility, their transformative potential, as well as co-benefits, adverse side-effects and potential to contribute to Sustainable Development Goals. For policy packages, coordination, coherence and consistency are also important evaluation criteria. {13.5.2}

Subsidies for fossil fuel consumption and production remain in place in many jurisdictions. They artificially increase consumption of fossil fuels and thus of greenhouse gas emissions and have other adverse economic and social effects. Their removal would reduce emissions. Governments also use subsidies to achieve mitigation goals, for example by subsidizing R&D or deployment of energy saving equipment or zero-emissions energy supply installations. {13.5.2}

Economic or market-based instruments are used for greenhouse gas emissions reductions in an increasing number of jurisdictions, and with increasing effectiveness. In 2018, emissions trading schemes and carbon taxes covered about 20 percent of total global emissions, an increase from around 5 percent in 2011. Lessons from the operation of these have informed the evolution of existing and the design of new policies, in particular new emissions trading schemes. {13.5.3}

Regulatory instruments play an important role in climate change mitigation, as a complement or alternative to emissions pricing. Performance standards can allow businesses a degree of flexibility in meeting defined outcomes, which may include trading between businesses. Technology standards are more prescriptive. Both tend to be less economically efficient than emissions pricing. {13.5.4}

Other, less compulsory approaches can support and accelerate the socio-economic transformation needed for deep emissions reductions. Information programs, government provision of goods and services, divestment approaches, and voluntary agreements exist in different forms in many jurisdictions. {13.5.5}

Combinations of climate policies can lead to positive or negative interaction effects; understanding these interactions is necessary when layering on new policies or developing mixes of policies. With a cap and trade program, if an additional standard is binding and applies to a sector under the cap, the emissions reduction that results from the standard may be offset by increased emissions in other sectors under the cap. Empirical evidence from the EU ETS suggests that despite the presence of multiple instruments, the ETS has had an effect on emissions, although studies do not allow estimating the relative effect across instruments. Emissions 'leakage' notably is not a concern when a standard is implemented with a tax. However, there may have efficiency costs due to *de facto* different marginal abatement costs across sectors. Leakage can also exist across jurisdictional scale: leakage rates for electricity generation for the California and Regional Greenhouse Gas Initiative (RGGI) ETSs are estimated to be close to 50%. {13.6.2}.

Because climate change is a complex problem that cuts across policy domains and scales, and requires balancing competing objectives, climate policy-making requires attention to integration across domains as well as the way trade-offs are undertaken. Important elements of integration are clear framing or goal definition, identification of the subset of salient policy domains and interactions among them; specific goals across policy domains; and implementing policy instruments. {13.6.1; 13.6.4}

An important tool for integration across domains is the design of policy mixes or packages, that are intended to address the multiple aspects of bringing about a low-carbon transition in particular domains while addressing and designing for other objectives such as development, equity and political feasibility. Key design elements of an effective policy mix are comprehensiveness – addressing market failures, structural change and transformation; balance – whether the mix addresses the full range of objectives in ways that complement each other; and consistency – the alignment of instruments and the objectives. Policy mixes can usefully also consider 'exnovation' policies designed to truncate fossil fuel-based trajectories in addition to promoting low carbon pathways. {13.6.1; 13.6.3; 13.10.3}

Climate mitigation policies can have effects on fossil fuel prices and on the distribution of fossil fuel resource rents across importer and exporter countries. Empirical evidence on the magnitude of these effects is limited. There is an emergent literature on policies for the supply side of the fossil fuel market and the concept of 'unburnable carbon' that shows a substantial proportion of fossil fuel reserves cannot be used given a finite carbon budget, leading to the risk of stranded assets. {13.7.1}

Emissions 'leakage' – the change in emissions arising from shifts in production, consumption and investment elsewhere as a result of mitigation policies in one country – has been shown in modelling but the accuracy of estimates has been questioned. Empirical studies assessing the competitiveness effects of climate policy find limited or no effects of carbon taxes, and studies of the EU ETS find no significant effects on output, employment and other competitiveness metrics. {13.7.2}

International knowledge spillovers can generate positive and negative effects on technology innovation. An important mechanism for transmission of knowledge is international value chains. Another is diffusion of policy innovations. Negative effects can arise through incentives to free ride on policy innovation by other countries. Deliberate efforts at fostering international cooperation can enhance the public good aspect of knowledge spillovers. {13.7.3}

Effective implementation of mitigation and adaptation measures depends on policies and cooperation at all scales, and can be enhanced through integrated responses that link adaptation and mitigation with other societal objectives. Adaptation and mitigation includes technological, institutional and behavioural options. Various economic and policy instruments are used to encourage the use of these options, but there are knowledge gaps and uncertainties about the use of these instruments to maximise the synergies and reduce the tradeoffs in various sectors. There are also significant barriers to address. {13.8.1, 13.8.2}

Sectors which offer adaptation and mitigation synergies (frequently highlighted in the adaptation component of NDCs) include the following sectors: agriculture, forestry and other land-use, including livestock; human settlements and infrastructure; water; energy; ecosystems; and tourism. IPCC WGII considers the concepts of an "adaptation gap" which is related to the adaptation measures which are implemented but constrained in their extent by their resources and other priorities. Developing countries are more likely to suffer from an "adaptation deficit" -- when a country is unable to respond to the current impacts of climate variability -- and will likely face more impacts of extreme events than developed countries. Those countries usually produce marginal impact of emissions, and therefore climate adaptation and mitigation need to be considered in the context of broader political, economic and development goals {13.8.2}.

A number of factors have been shown to influence an individual's attitudes to climate mitigation measures, including values, political orientation/ideology personal norms, social norms, climate concerns and beliefs, as well as the person's levels of trust (*medium evidence, high agreement,*). Scholars across disciplines highlight that a combination of tools are necessary in order for the public to support and respond to policies aimed at influencing their behavior. Achieving the potential from consumption and behavioral changes requires recognizing that households are embedded within larger socioeconomic, sociotechnical, sociocultural and natural systems that affect the possibilities for mitigation, {13.9.2}

Civic engagement with respect to climate mitigation is diverse and ranges from tactics that involve citizens working collectively to change their individual behaviours, employing tactics to work through the political and economic system, as well as more confrontational tactics like boycotts, strikes, and riots (*high evidence, high agreement*). Although there is research that provides evidence of civic engagement working to encourage, as well as limit, efforts to reduce carbon emissions, there is much more evidence that it encourages direct and indirect pro-environmental behaviours. {13.9.3}

Media coverage of climate change mitigation has influenced public discussions through political, economic, ecological/meteorological, scientific and cultural themes about climate change (*high evidence, high confidence*). Media can be a useful conduit to build public support to accelerate mitigation action as well as shine a light on individuals, groups and organizations that impede these decarbonisation endeavours {13.9.4}.

Climate change litigation is increasingly used as a tool to influence policy outcomes and/or to change corporate and societal behaviour (multi-actor, across scales, global north and south) (*high evidence, medium agreement*). Climate change litigation involves multiple actors (governmental and non-governmental), across all jurisdictional levels (local, regional, national and international). Of the more than 1400 cases brought world-wide, 1110 have occurred in the global north but are increasingly reaching the courts in the global south. {13.9.4}

Attention to the temporal aspects of policy processes helps to conceptualize, understand and improve policy responses to climate change and accelerate mitigation action. Institutional path dependence created by policies and institutions can constrain, slow, and otherwise act as a barrier to climate mitigation (*high evidence, high agreement*). Climate mitigation policies themselves can also create self-reinforcing path dependent processes that accelerate mitigation. {13.10.2}

A multi-disciplined literature argues for 'enabling conditions' to be in place to successfully deliver a policy goal or system transition. This literature views policy instruments and institutions as necessary, but insufficient, conditions for the most effective delivery. It argues for particular attention to context specific conditions. In addressing all elements, effective policy making requires paying attention to local governance context, including the political environment for decision-making, questions of coordination across scales, enforcement capabilities, bureaucratic traditions, and judicial functioning; ensuring the more hard-to-tie-down conditions such as justice, coordination, inclusivity and meaningful engagement, and the more structural system conditions such as confronting the strength of system regime. {13.10.1; 13.10.3; 13.6.4}

The literature exploring how to accelerate climate mitigation has grown rapidly over the last few years (*high evidence*, *high agreement*). Acceleration of climate mitigation efforts depends heavily on country-specific dynamics in political coalitions, industry strategy, cultural discourses, and civil society pressures. Acceleration literature focuses on necessary conditions for scaling up mitigation and adaptation efforts (*high evidence, high agreement*) and on the beneficial role that intermediary actors or 'coordinating agents' (individuals or a group of people within organisations at multiple geographical levels) can play (*medium evidence, medium agreement*).

13.1 Introduction

Chapter 13 addresses national and sub-national policies and institutions. This is a dynamic area, with new institutional forms, policy experiments and actions continually emerging in different national and sub-national jurisdictions.

Several important developments since AR5 animate this chapter and have shaped its organisational structure. First, formal governmental attention to climate change has increasingly been formalised, in the form of legislation, executive strategies and targets. Notably, many of these are stimulated by the international negotiating context, but are firmly national statements, rooted in national law and processes. Sec 13.2 examines the spread of enabling legislation, coordinating formal governance institutions and their associated tasks. Climate legislation and institutions can either be primarily animated by climate change, or animated by other concerns or policy domains, such as development issues, yet of great important to climate outcomes. This section addresses both. Collectively, they constitute the underlying machinery of state action, explicit development of which provides the basis for sustained and effective climate action. While these institutions and governance arrangements are built by, and are within, governments, they have implications for citizens and stakeholder of all sorts. Institutions are important in part because they structure politics and shape or undermine channels for enhanced action.

A second important dimension that has expanded since AR5 is the emergence of the sub-national scale as an arena for climate mobilisation, policy formulation, and institutional development. Interestingly, much of this organising happens through transnational networks of local actors. A significant tension for sub-national action, particularly in the global south, is ensuing climate action is synergistic with local needs, and also addresses questions of weak capacity and demands for equity in distribution.

Section 13.4 unpacks the policy process through which national policies salient to climate change emerge. It begins by examining structural features of the policy landscape that affect climate policy processes, such as political systems, the broader national administrative context, and a country's material endowment. The section goes on to examine policy processes through the lens of various actors, or players, in the policy process, who play roles of influencing, adopting and implementing.

A discussion of institutions and policy process sets the stage for an assessment of policy instruments, in Sec 13.5 and policy mixes in 13.6. Notably, both sections address policies, and mixes, that are explicitly designed to address climate change, but also those that may have the effect of addressing climate change, such as sectoral policies. The discussion of policy instruments attempts to focus on *ex post* empirical analysis of policies, along a range of different evaluation criteria, that include environmental effectiveness, economic effectiveness, distributional effects, transformational potential, co-benefits and implementation feasibility.

Explicit climate policies and policies that effect climate outcomes are, in practice, shaped by real world considerations of winning political acceptance, managing competing objectives, and effecting transformation. As a result, policy instruments seldom exist in isolation but rather are layered on top of existing policies. Increasingly, there is attention to intentional combination of instruments into policy mixes or packages. The combination of policies is the subject of 13.6. The section also addresses the governance context for policy mixes, including processes of engagement with stakeholders and negotiation across objectives and interests. They are also dependent on the presence or absence of enabling governance conditions. Non-state actors play a considerable role, both as representing interests, as well as partners in policy formulation and implementation. A key theme that emerges from this discussion is the importance of attention to local context in the effective design and implementation of climate policy.

While this section focuses on national policies, many national climate policies also have international spillover effects which are discussed in Section 13.7. The chapter examines market price and demand effects, carbon 'leakage' and technology spillover effects.

Section 13.8 explores the linkage between mitigation and adaptation outcomes. Effective implementation of climate mitigation depends on policies and cooperation at all scales and can be enhanced through integrated responses that link adaptation and mitigation. International policy frameworks provide an integrated approach for both adaptation and mitigation. Assessment of these integrated policies is just emerging and section 13.8 reviews the current status of policy implementation from different perspectives, contexts and scales. Barriers remain to effective integration, whilst enablers and solutions are discussed.

Section 13.9 provides an overview of literature related to building agreement and action. This includes how people perceive climate change and its policies, and how those policies can be structured so that people are more positive about them, and may change their behaviours. It also examines two particular active behaviour – citizen engagement and climate litigation. It also discusses the ways that media is able to both negatively and positively deliver messages about climate and how that affects people's views and behaviour.

Section 13.10 both captures the various conditions that can help sustain and accelerate action but also reviews literature concerning the way policies can be designed from the start to be attentive to the temporal aspects of policy processes. The latter can help to conceptualize, understand and improve policy responses to climate change, thereby accelerating mitigation action. .

This chapter particularly highlights a few aspects of policy and institutions that mark emergent features of the landscape of climate action:

- While past research has focused on *climate* institutions and policy, this chapter defines its scope as the focus to examine institutions and policy that have the effect of impacting climate outcomes. This expansion is necessary as a great deal of relevant policy is formulated in the context of other, related policy objectives such as energy security, energy access, urban development and so on. As a result, an important element of designing climate institutions and policy is to effectively enable an assessment, and coordination, of the synergy and trade-offs between climate and other objectives;
- While the chapter maintains an important focus on understanding means of creating incentives for economic actors through policy formulation, it also maintains an emphasis on the importance of behavioural change (suitably linked to Chapter 5) as a necessary component of climate action;
- In addition to the formal potential for effectiveness as represented in the literature, the chapter also seeks to understand empirical outcomes as they relate to a range of assessment criteria including but not limited to cost-effectiveness, as well as the reasons for those empirical outcomes, taking into account the importance of stakeholder interests, enabling conditions and governance arrangements;
- Different aspects of climate policy and different approaches to institutions are prevalent in different regions of the world, based on context, relative economic status, and underlying priorities. Our discussion aims to be sensitive to these variations and their underlying reasons;
- In the context of the urgent task of addressing climate change, we also seek to draw links (also discussed in other chapters) to the significant importance of the time dimension of climate policy. This includes attention to lock-in, feedback loops, and means of stimulating innovation and rapid adoption to enable an increase in the rate of climate mitigation.

13.2 National institutions and governance

Achieving climate mitigation requires addressing considerable and diverse challenges of coordination and organisation. These include inter-agency coordination (Zhou and Mori 2011); inducing innovation (Patt 2017; Mazzucato and Semieniuk 2018) identifying and managing synergies and trade-offs across climate and development objectives (Ürge-Vorsatz et al. 2014; von Stechow et al. 2015; McCollum et al. 2018), enabling experimentation as part of 'polycentric' governance (Jordan et al. 2015), and harnessing actions by non-state actors (Chan et al. 2015). Enabling climate mitigation therefore requires action by multiple actors within society, across a wide range of emitting sectors, at different scales of governance, and in ways that are transformative.

Institutions and governance arrangements are important means of enhancing climate mitigation. Institutions are rules, norms and conventions that organise and structure actions. Governance processes are the means for deciding, managing and implementing and monitoring policies and measures, drawing on both government and non-state actors. (See Glossary for complete definitions.) Collectively they help address the coordination challenges of addressing climate change. While the need for institutions and governance is common, countries have followed different approaches in developing institutions and governance for climate mitigation, based on national approaches and national circumstances. This section discusses the forms of institutions, including legislation and governance arrangements for climate mitigation. This section examines institutions and governance at the national level, while subsequent sections address the sub-national level.

13.2.1 Climate legislation

Climate legislation can enable effective climate action by signalling and facilitating action. Legislation provides an important signalling effect to actors by indicating intent to harness state authority behind climate action (Scotford and Minas 2019). It can also facilitate action by creating law-backed governance mechanisms for coordination, compliance and accountability (Scotford and Minas 2019); establishing a platform for transparent target setting and formulating an implementation approach (Bennett 2018); and creating incentives for mitigation action, mainstreaming mitigation into sector action, and instituting focal points around which social mobilisation for mitigation can occur (Dubash et al. 2013a). The realisation of these potential governance gains depends on local context, successful implementation, and complementary action including at different scales.

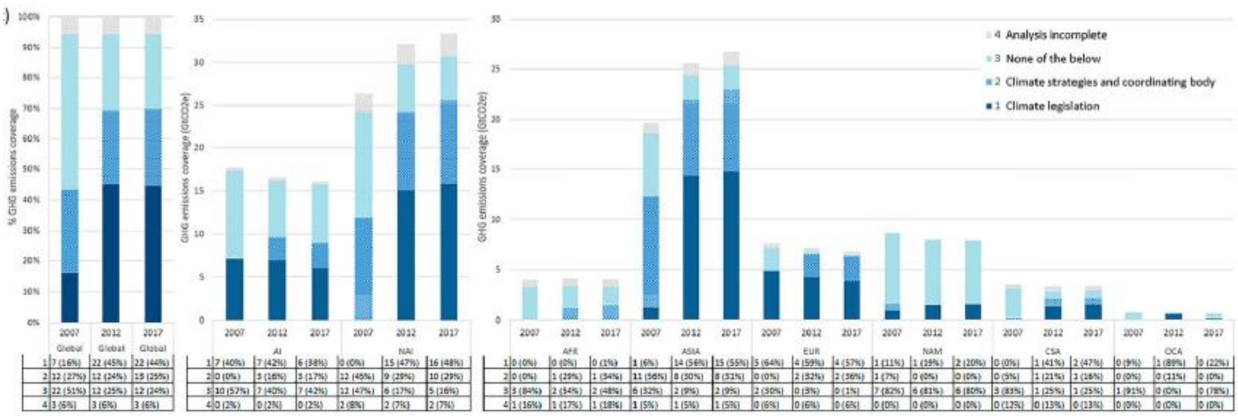
Understanding the spread of climate legislation and its effects is complicated by definitional issues. Conceptually, the literature distinguishes direct climate legislation, which explicitly consider climate change causes or impacts, from indirect legislation, which may have the effect of affecting emissions, for example, through consideration of co-benefits, policies such as subsidies, or through reporting protocols (Scotford and Minas 2019). Some direct climate legislation may also be considered framework or flagship legislation, in that it sets an overarching legal context within which other legislation and policies operate(Townshend et al. 2013; Averchenkova et al. 2017a). Yet another category is non-binding political strategies with a coordinating body that also signals political commitment, albeit less than binding legislation (Dubash et al. 2013a).

The prevalence of direct climate legislation has increased from 32 countries (of 194 studied) in 2007 accounting for 16% of emissions to 46 countries covering 44% of emissions in 2017 (Iacobuta et al. 2018). When non-binding climate strategies are included, the numbers increase from 41 countries covering 43% of emissions in 2007 to 94 countries covering 69% of emissions in 2017 (See Figure 13.1) Notably, much of this increase occurred in the years 2007 to 2012, with limited addition in legislation and strategy after 2012, and indeed a decrease from a high of 82% emissions covered to 69% emissions covered due to withdrawal of legislation in some countries. However, the number of countries adopting an emissions target, and the proportion of emissions covered by a target, increased from 44 countries covering 44% of emissions (of which 40% are legislative targets) in 2012 to 147 countries covering 90% of emissions (38% legislative) in 2017. (See Figure 13.1)

Reviews of indirect legislation reinforce the observation that the breadth of governmental action around climate change has grown considerably in the past decade. A data base of climate-relevant laws, sectoral legislation, executive decrees and policies in 66 jurisdictions covering 90% of emissions found almost 500 such indirect climate relevant legislation, decrees or policies in place by 2013, including relevant sectoral approaches. By 2018, this number had expanded to 1500, although the pace of increase has slowed as more countries add legislation (Nachmany and Setzer 2018). A broad distinction can be drawn between a legislative approach built around framework laws versus around sectoral approaches that modify existing legislation (Fankhauser et al. 2015; Rumble 2019). A framework approach promises a strategic approach and greater comprehensiveness, allows for creation of dedicated institutions to address climate change, and avoids the need to amend a broad suite of laws. A sectoral approach may be more expedient in allowing climate change to be internalised within prevailing policy priorities and thereby enable mainstreaming, and may also require less additional capacity.

There are three main mechanisms that account for the spread of legislation. First, landmark international negotiation events are associated with increases in national legislation (Iacobuta et al. 2018), with a stronger effect in countries where international commitments are binding (Fankhauser et al. 2016). Second, diffusion by example from other countries appears widespread (Fankhauser et al. 2016; Fleig et al. 2017; Torney 2019). For example, the UK Climate Change Act was an important influence in pursuing similar acts in Finland and Ireland, in part through the advocacy of campaigners who highlighted the UK experience (Torney 2019) and was also considered in the formulation of Mexico's General Law on Climate Change (Averchenkova and Guzman Luna 2018). Third, domestic factors are important: the presence of a flagship climate law is positively associated with additional legislation (Fankhauser et al. 2015); the business cycle can matter, whether by dampening enthusiasm for climate legislation in bad times or, conversely, by providing an opportunity for fiscal stimulus (Fankhauser et al. 2015); and there is a role for civil society groups as advocates for legislation (Lockwood 2013; Lorenzoni and Benson 2014; Carter and Childs 2018; Torney 2019).

There is limited evidence on the effectiveness of climate legislation, but some lessons can be gleaned from case studies. Mexico's General Law on Climate Change enshrined existing mandates into law, including setting sectoral emissions reduction targets, and created institutional structures for inter-ministerial coordination; scientific research, consultation with stakeholders, and deliberation by its Congress and sub-national authorities (Averchenkova and Guzman Luna 2018). Korea's Framework Act on Low Carbon, Green Growth seeks to shift Korean business and society toward green growth through a process of strategy setting and action plans(Jang et al. 2010). Kenya's framework Climate Change Act focuses on creation of institutional structure for mainstreaming climate considerations, one of several examples across Africa of efforts to create framework legislation at different levels of completion to promote mainstreaming (Rumble 2019). Assessing the effect of these legislative initiatives is challenging as they are likely to yield results over time. Key elements to examine include the variation in approach – framework versus sectoral; the framing and direction setting; extent and stringency of targets; and the institutional structure established for coordination, science and broad stakeholder engagement.



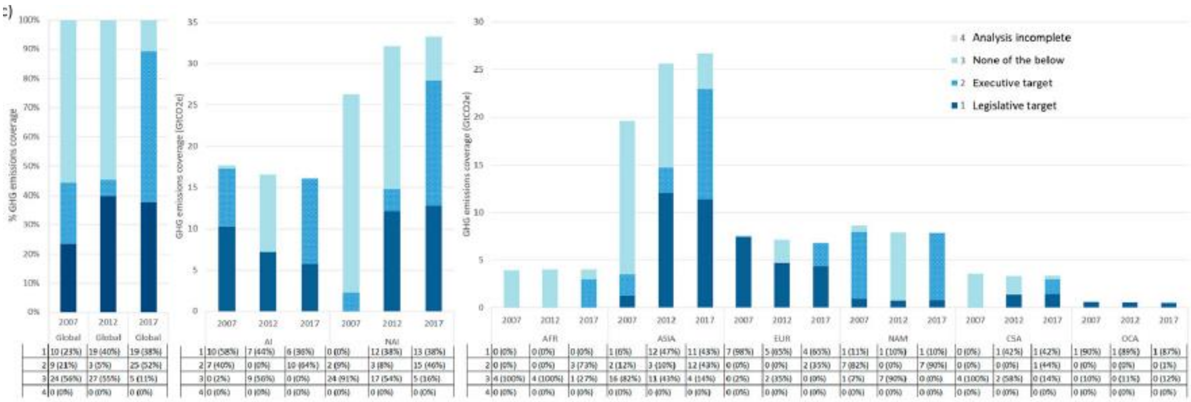


Figure 13.1 Share of GHG Emissions under Climate Legislation, Strategies and Targets

Panel 1: Shares of GHG emissions under climate legislations and strategies – in 2007, 2012 and 2017.
Panel 2: Shares of GHG emissions under executive or legislative GHG emissions reduction target – in 2007, 2012 and 2017.
Note: AI = Annex I countries; NAI = Non-annex I countries; AFR = Africa; ASIA = Asia; EUR = Europe (incl. Russia); NAM = North America; CSA = Central and South America; OCA = Oceania.

13.2.2 Variety of approaches to national institutions and governance

Country approaches to national climate governance vary considerably, shaped by national context and political priorities. One dimension of variance is the relative focus on greenhouse gas emissions versus simultaneous attention to other objectives as part of climate policymaking. The UK, among the first countries to pass a comprehensive climate law, organizes its climate mitigation around annual carbon budgets (Box 13.1). After the Act was passed, fuel poverty has become an important additional concern in response to national pressures (Lockwood 2013). China's climate governance structure has evolved over time (Box 13.2), starting with an energy intensity metric, followed by attention to emissions intensity, finally leading to a carbon limitation objective (Bomberg 2012; Gallagher and Xuan 2019). This evolution, in part, reflects China's shifting international negotiating position around climate change. India's climate mitigation approach has consistently followed a logic of pursuing co-benefits – understood as climate mitigation gains resulting from national development decisions -- driven by a domestic focus on poverty alleviation an development (Dubash et al. 2013b; Jogesh and Dubash 2015). South Africa's engagement with a long-term mitigation strategy has been complicated by a national concern with job creation and competitiveness (Chandrashekeran et al. 2017).

Creation of dedicated institutions focused on climate change can enable a shift from national climate mitigation objectives to practical action, although there is wide variation in the prevalence and form of climate institutions. The UK Climate Change Committee adopts a scrutiny-based approach, developing a credible analysis of departmental plans and policies against a national carbon budget, which is submitted to Parliament and the public, providing a mechanism of accountability (See Box 13.1). China's approach has been more directly hierarchical, enforced by a Department of Climate Change within the National Development and Reform Commission, which allocates targets and responsibilities to sub-national jurisdictions and enforces their implementation, although responsibility shifted in 2018 to the Ministry for Environment and Ecology (See Box 13.2). A comparative study of Philippines, Kenya, Mexico and South Africa suggests that a common institutional approach is a high-level coordinating body that aims at mainstreaming climate into sectoral actions (Oulu 2015). For example, India created an Executive Committee of Secretaries, the objective of which is to coordinate across line ministries tasked with implementing a series of national 'missions' largely around sectors, and consistent with India's co-benefits narrative (Dubash and Joseph 2016). The United States has not developed any overarching dedicated climate institutions, in part due to a lack of overall national political agreement on a way forward on climate mitigation. The result is the use of executive authority, the growth of sub-national action, and the lack of an overarching strategy (Harrison 2010; Rabe 2011; MacNeil 2013).

Box 133.1 Case study of climate change institutions in the UK

The central institutional arrangements of climate governance in the UK were established by the 2008 Climate Change Act (CCA): statutory five-year carbon budgets; an independent advisory body, the Committee on Climate Change (CCC), that recommends carbon budgets to the government; mandatory progress monitoring and reporting to Parliament, and a continuous adaptation planning following a five-yearly cycle. Although the CCC is required to take other policy goals into account when setting budgets, the primary focus is on greenhouse gas emissions.

Prior to the CCA, climate policy had been guided by a series of medium term international and domestic emission reductions targets, and cross-government climate policy programmes championed led by the department with responsibility for the environment. Faced with growing evidence that this approach was not effective (Darkin 2006; Carter and Jacobs 2014a; Lorenzoni and Benson 2014), a combination of civil society campaigning, business support and pressure from opposition parties led to the government adopting a new, legislative approach with top-down binding budgets (Lockwood 2013; Carter 2014; Lorenzoni and Benson 2014; Carter and Childs 2018). The idea of an independent advisory board was influenced by the concept of independent central banking (Helm et al. 2003) and the UK experience of the Monetary Policy Committee, created in 1997 (McGregor et al. 2012; Lockwood 2013). However, since the CCC only recommends rather than sets budgets (McGregor et al. 2012), accountability for meeting the carbon budgets works primarily through reputational and political effects rather than legal enforcement.

The CCC has established a reputation for independent high quality analysis and information dissemination, frequently referred to in Parliament and widely used by other actors in policy debates (Averchenkova et al. 2018). Together with Parliament it has also provided an accountability function, although this has not always led to complete compliance; for example the most recent government plans will not fully deliver the fourth and fifth budgets (CCC 2019).

While the adoption of the CCA plausibly helped drive some specific initiatives, such as the Electricity Market Reform (Bolton et al. 2016), the high-level nature of the carbon budgets mean that they are only loosely articulated with any single policy or sector. Consequently, while the CCA framework provides a degree of credible commitment, it has not ruled out episodes of policy instability (Lockwood 2016) or policy accommodation that deviates from least cost decarbonisation (Gillard and Lock 2017).

Policy in relevant areas such as energy, transport and agriculture is also to a significant extent determined by frameworks and packages determined at the level of the European Union (CCC 2016). Functions of policy design, formulation and cross-departmental prioritisation and coordination remain in UK government control, and are sometimes poorly provided (CCC 2019).

Finally, while the CCC has a remit to engage with the public its technocratic nature means that its role in creating legitimacy for climate policies and targets is limited. The framework has proven resilient, despite episodes of challenge (Lockwood 2013), perhaps in part be due to policy feedback effects (Rosenbloom et al. 2019) and due to the international reputation of the CCA.

In federal systems, the design of climate governance has to take into account additional complexities, such as overlapping authority across jurisdictions, multiple norms in place, and approaches to coordination across scales (Brown 2012). Some countries rely on explicit mechanisms of coordination, such as in Australia, where a council of governments has intermittently coordinated climate policy, and Germany, where cooperation is channelled through long-standing formalized mechanisms of cooperation such as periodic meetings of environment ministers and centre-state working groups (Weidner and Mez 2008; Brown 2012).

States with constitutionally empowered sub-national governments may rely on negotiation, such as in Canada, where the federal government relies on bilateral negotiations and side-payments to obtain consensus (Rabe 2007). In the US, a period of sub-national action in the absence of federal policymaking was followed by contestation during a subsequent period of federal intervention (Rabe 2011). States where agenda-setting powers on climate policy have traditionally rested with the central government may instead set targets, as with China, or the framework for policy action, as in India, and allow sub-national levels to devise means of acting upon those targets or frameworks (Qi and Wu 2013; Jogesh and Dubash 2015).

Box 133.2 China's Climate Change Institutions

China's climate change institutions evolved over time as a result of the country's socioeconomic transitions as well as cognitive shifts associated with climate change (Tsang and Kolk 2010; Barbi et al. 2016; Liu et al. 2017; Wang et al. 2018a; Gallagher and Xuan 2019) . In the 1990s, climate change was primarily viewed as a scientific issue, and addressed by the National Coordination Group on Climate Change (NCGCC) with a secretariat under the State Meteorological Bureau. NCGCC's role was to understand the processes and consequences of climate change, and support negotiations and engagement in IPCC led by the Ministry of Foreign Affairs (Qi and Wu 2013).

Since the late 2000s, China began to view climate change as both a serious long-term threat and a driver for economic restructuring (Zhang 2010). The Department of Climate Change was established in 2008 under the National Development and Reform Commission (NDRC), the central government agency for macroeconomic planning, and tasked with economy-wide low-carbon development strategies, particularly for climate-related sectors, such as power generation, manufacturing, transportation, and agriculture (Gemmer et al. 2011). Mandatory emissions intensity goals were formally incorporated in the 12th (2011-15) and 13th (2016-20) National Five-year Plans. These targets were divided among all provinces, which, in turn, divided the targets among municipalities and counties within its jurisdiction (Qi and Wu 2013).

The targets are enforced through a "targets and responsibilities" system that is directly linked to the evaluation of governments' performances (Lin 2012a; Li et al. 2016) Through these approaches, China's climate governance combines the top-down target-setting and planning with local and sector-specific mitigation initiatives. The Department of Climate Change has also been promoting the establishment of national carbon emissions trading system (ETS), in the hope of utilizing market mechanisms to optimize resource allocation and reduce the costs of emissions mitigation. The first phase of the national ETS only covers power sector, and the later phases are expected to expand the coverage to other carbon intensive sectors (Lo 2016; Wang et al. 2019).

In 2018 the Department of Climate Change moved from NDRC to the newly formed Ministry of Environment and Ecology (MEE), consistent with promoting "ecological civilization" by addressing climate change, along with other environmental challenges through the concept of "co-benefits." Different levels of governments are encouraged to shift away from a "GDP first" development philosophy and embrace the new paradigm of "green and high quality" development, which is intended to enable broader climate actions by more government agencies at multiple levels in the future.

In developing forms of governance for climate change, governments do not start with a blank slate, but are shaped and constrained by international factors and domestic context. With regard to international factors, international negotiating processes, such as the Paris COP, have been reported to induce strengthened national strategy processes and institutional structures (Höhne et al. 2017), for example through the development of Nationally Determined Contributions (NDCs). Globally, especially in developing countries, the process of formulating NDCs has produced an increasing number of climate plans and strategies (Höhne et al. 2017, 2018). While some countries draw on established institutions to implement their NDCs, several have triggered national processes to establish relevant policy frameworks (UNFCCC Secretariat 2015;

Höhne et al. 2017). The NDC preparation process in Colombia, for example, brought together research organisations, government and private sector in collaborative research and dialogue (De Pinto et al. 2018). International negotiating positions that countries adopt also are salient to their governance approach; Aamodt (2018) argues that the distinction between climate as a foreign policy objective in negotiations versus as an environmental outcome shaped domestic climate governance in Brazil and India. Another mechanism for international influence is diffusion of institutional models across countries.

Domestically, administrative and bureaucratic traditions are salient to building climate institutions. For example, the extent of dispersion of authority across levels of government, the presence of horizontal coordination mechanisms, the scope for polycentric and experimental policy approaches, and the availability and ability to absorb scientific advice are all salient factors (Biesbroek et al. 2018a,b). In addition, the ability and established practice of governments to coordinate with firms in "coordinated market economies" versus the more laissez faire approach of "liberal market economies" may be salient in systematically inducing low carbon transitions (Lockwood et al. 2017; Finnegan 2019) .

National institutions that support climate mitigation can enhance strategic outcomes, enable coordination and strengthen accountability. A strategic approach to climate mitigation can include high level target setting, including through framework laws (Averchenkova et al. 2017a), but also identifying and signalling key sectors and opportunities for low-carbon transition (Hochstetler and Kostka 2015). Realising strategic outcomes requires building institutional capacities in a variety of dimensions: the ability to identify areas that are ripe for innovation and transformation and the means to induce innovation (Patt 2017; Mazzucato and Semieniuk 2018); capacity to identify and manage synergies and trade-offs across climate and development objectives (Ürge-Vorsatz et al. 2014; von Stechow et al. 2015; McCollum et al. 2018); and generate and assimilate scientific and technical knowledge.

Institutions are an essential ingredient in in shifting political systems toward a positive feedback loop in favour of low carbon transition in their role as mediators of external interests, such as renewable energy industries (Aklin and Urpelainen 2013; Lockwood et al. 2017; Roberts et al. 2018; Finnegan 2019). In China, the emergence of a renewable energy policy community was facilitated by opening of political space for renewable energy industry interests in key institutionalised agenda setting meetings (Shen 2017). Similarly, in India, the creation of a National Solar Mission provided a platform and forum for articulation of India's embryonic renewable energy industry (Dubash 2011). In a story of contrasts, political openings for renewable energy in Germany due to its job creation potential at the time of unification were subsequently institutionalised through renewable energy associations backed by government support, while in the United States, interests failed to crystallize nor was there formal institutional support (Laird and Stefes 2009). Conversely, institutions can also exert a drag on change through 'regulatory inertia,' as in the case of the UK energy regulator Ofgem, the creation of which preceded the political importance of a sustainability agenda, resulting in its exercise of veto powers in ways that may limit a low carbon transition (Lockwood et al. 2017).

Within government, the scope of climate mitigation requires active coordination among agencies. In a review of four Asian countries, Zhou and Mori (2011) suggest that well-functioning inter-agency coordination mechanisms require political support from heads of government, that industry and environment agencies both need to be involved in coordinating action; and all sectoral agencies need to be engaged. The importance of adequate authority with regard to bureaucratic peers is emphasized by the Chinese example, where the coordination body was embedded within the powerful National Reform and Development Commission (See Box 13.2). In India, a period of effective coordination was managed by a Special Envoy located in the Prime Minister's office, but this gave way to weaker coordination under an administrative Executive Committee of Secretaries (Dubash and Joseph 2016). A particularly important aspect of intra-governmental coordination is the relationship with finance ministries. Skovgaard (2012) suggests that there is an important distinction between finance ministries that bring a limiting 'budget frame' to climate action, versus a 'market failure frame' that encourages broader engagement by relevant ministries.

Government institutions and governance networks both play an important role in ensuring accountability for mitigation actions. A study of governance networks finds that less transparent process, ineffective monitoring mechanisms, poor stakeholder representation and inconsistent performance outcome measures are common pitfalls (Zia and Koliba 2011). Formal governmental networks span the range from more directive and authority driven accountability mechanisms in China (See Box 13.2) to accountability through reputational and political effects rather than through legal enforcement in the UK (See Box 13.1). Building a transparency system required dedicated investment in capacity building (See Box 13.3).

Box 133.3 South Africa's Monitoring and Evaluation System

South Africa's National Climate Change Response M&E System Framework was published in 2015 (DEA 2015) to provide high-level guidance on information requirements and assessment methodologies. The country is developing a comprehensive, integrated National Climate Change Response Monitoring and Evaluation System which includes the current National Climate Change Response Database (NCCRD) and the National Greenhouse Gas Inventory System (NGHGIS) and will serve as a data and information coordination network (DEA 2019). The M&E system enables the country to assess, analyse and understand progress made in achieving its climate change commitments and actions, thus tracking the transition to a climate-resilient and lower-carbon society. South Africa's approach to climate change M&E is premised upon continuous learning and improvement of the system implemented in phased manner with full-implementation of this system envisaged in 2020 (DEA 2019). The most recent milestones in the process of developing the M&E system is the development and operationalisation of a web-based M&E system platform prototype and the launch of the South African Biennial Update Report (BUR) explorer.

13.3 Sub-national institutions, governance and partnerships

13.3.1 Introduction

While jurisdiction over many dimensions of climate mitigation resides at the national level, along with the relevant institutional, financial and technical capacities, subnational and urban actors are playing crucial roles for several reasons: They are the level where the impacts of climate change are felt, and often they have remit over land use planning, waste management, infrastructure, and community development. They are therefore key sites for developing, delivering and contesting decarbonization visions and pathways (*robust evidence, high agreement)* (Amundsen et al. 2018; Ryan 2015; Schroeder et al. 2013). Here, we assess literature on the subnational governance of climate change, and on how subnational actors are building institutional capacity to mitigate GHG emissions, as well as who is engaging, what issues they are targeting, how, why and what governance challenges they face.

13.3.2 Landscape of actors and actions

In recent years, subnational actors, including states, regions, cities, companies, investors, foundations, civil society organizations, and cooperatives, have become critical players in the climate arena (Hsu et al. 2018; Michaelowa and Michaelowa 2017; Romero-Lankao et al. 2018a). Their climate mitigation role as important agents of change globally, was formalized in the text of the Paris Agreement. They engage in other governance mechanisms, such as the New Urban Agenda, and the Sustainable Development Goals, which were traditionally the domain of national governments; they participate in transnational climate governance networks; and they facilitate learning and exchange among governmental and private organizations at multiple levels, gathering resources that can be applied in multiple contexts (Lee and Jung 2018; Heikkinen et al. 2019; Busch et al. 2018; Ürge-Vorsatz and Seto 2018; Romero-Lankao et al. 2018a; Bai et al. 2018; Amundsen et al. 2018; Sharifi and Yamagata 2016; Warbroek and Hoppe 2017).

Subnational climate change has increased in recent years (NewClimate Institute Data Driven Yale PBL German Development Institute Blavatnik School of Governement University of Oxford 2019). Examples include the Compact of States and Regions, representing 120 governments, 21% of the economy and 672 million people, which has pledged about 9% emissions reduction compared to a base year(The Climate Group with CDP 2018). More than 6,000 companies with at least US$36 trillion in revenue and more than 10,000 cities, representing 1.6 billion of the global population, participate in the Global Covenant of Mayors and C40 Cities (2018), and in ICLEI's - Local Governments for Sustainability carbon*n* registry among other transnational climate initiatives (Hsu et al. 2018). However, estimations of the number of subnational actors pledging voluntary climate action are challenging and underreporting is a concern (Chan and Morrow 2019; Hsu et al. 2018). **While an increasing number of large cities from the Global South are participating in transnational networks, subnational climate actions are primarily located in Europe and North America** (Bansard et al. 2017; NewClimate Institute Data Driven Yale PBL German Development Institute Blavatnik School of Governement University of Oxford 2019; Hsu et al. 2018).

Although subnational mitigation policies are further developed than adaptation policies, few set quantified emission reduction targets(Bulkeley and Castán Broto 2013; Heidrich et al. 2016; Reckien et al. 2018). Commitments to the Global Climate Action portal tend to target economy-wide mitigation (45% of regions and 85% of cities), followed by renewable energy (19% of regions and 9% of cities) and energy efficiency (18% of regions and 4% of cities). While state and regional mitigation actions primarily target buildings, lighting, and transportation, cities target energy infrastructure including renewable energy (Bulkeley and Castán Broto 2013; The Climate Group with CDP 2018; Reckien et al. 2018; Romero-Lankao and Gnatz 2019).

Subnational actors have institutionalized climate change by creating new entities or tying them to existing offices; by providing these with funding, staff and legal authority; or by experimenting with innovative solutions that could be transferred to other local governments or scaled nationally (Aylett 2015; Romero-Lankao et al. 2015; Hoffmann 2011; Hoornweg et al. 2011). They have also enacted strategies to mobilize support (e.g., through task forces and referendums), to coordinate financial and human resources, and build capacity through technical assistance, education and funding (Castán Broto 2017; Hughes 2019; Romero-Lankao et al. 2018b). Strategies to govern GHG emissions are highlighted below (see also taxonomy):

a) Direct regulation through performance standards for buildings and utilities, land use and transportation planning, zoning requirements for district heating or electrification of transport, and self-regulation of energy uses in their owned utilities, buildings and fleets (Jones 2013; Hewitt and Coakley 2019; Bulkeley 2013; ARUP 2015).

   Land-use planning, which is often under municipal jurisdiction, is significant to decarbonisation pathways as building form, density and transport shape emissions (Creutzig et al. 2015; Torabi Moghadam et al. 2017; Teske et al. 2018). However, comprehensive powers to act are often absent or fragmented, and higher national policies often restrict local government ability to enact more ambitious policies (Fudge et al. 2016; Petersen 2016; Gouldson et al. 2016). Additionally, many of the most rapidly growing smaller cities in Asia and Africa, lack capacity for urban planning and enforcement (Creutzig 2016). Countries like China, with strongly structured relationships between levels of government have supported rapid implementation of electric vehicle roll-out (Creutzig 2016; Teske et al. 2018; Zhang and Bai 2017; Zhang and Qin 2018).

b) Twenty-eight economic instruments are in use worldwide for GHG mitigation, such as carbon taxes, emission-permit trading and subsidies (World Bank 2019; Bernard and Kichian 2019; Xiang and Lawley 2019; Murray and Rivers 2015; Hibbard et al. 2018; Chan and Morrow 2019). Of these, common examples are an emission trading system within the U.S. Regional Greenhouse Gas Initiative, a carbon tax in British Columbia, and a cap-and-trade scheme in Metropolitan Tokyo.

c) Other policies include information and capacity building, such as carbon labelling aimed at providing carbon footprint information to consumers (Liu et al. 2016); mandatory building, performance, disclosure and benchmarking policies to increase awareness of energy issues and track mitigation progress (Papadopoulos et al. 2018; Hsu et al. 2017); and building retrofit program, initiated in New York and Melbourne to foster energy efficiency improvements through knowledge provision, training, and consultation (Trencher and van der Heijden 2019; Trencher et al. 2016).

d) Also significant are local low-carbon energy initiatives and provision of electricity, electric buses funded by national governments, (IEA 2019), among other public goods and services. Although local governments (apart from the German stadtwerke model and some Nordic countries) tend to have few formal competencies in energy (Rutherford and Coutard 2014), there is increasing involvement of local governments in local low-carbon energy initiatives, particularly in Europe and North America.

In the Global South, climate action often takes different forms and is frequently linked to existing environmental concerns like air pollution (Romero-Lankao et al. 2013, 2015)or to sustainable development, which is more likely to receive support from the national government or citizens (Jörgensen et al. 2015b; Floater et al. 2016; Dubash et al. 2019). For example, a major draw for Indian cities to engage in international climate cooperation is to find innovative solutions to address energy, water and urban infrastructure problems, where a co-benefit approach has gained traction in important policy documents, including India's National Action Plan for Climate Change(Beermann et al. 2016). In Brazil, a "win-win" discourse has proven effective in securing support for mitigation policies that are justified through their provision of economic and public health co-benefits (Setzer 2017).

Subnational climate action has a variety of drivers: high levels of citizen concern, jurisdictional authority and funding, institutional capacity, national level support and embedding into development objectives (*robust evidence, high agreement*) (Anderton and Setzer 2018; Dubash et al. 2019; Ryan 2015; Jogesh and Dubash 2015). Moving policies from words to deeds, from plan to implementation is influenced by local governance structures, such as the presence of a professional city manager and staff assigned specifically to climate and sustainability efforts (Simon Rosenthal et al. 2015). Another key factor is the availability of local data. Data on energy use and emissions are essential for GHG planning and policymaking (Ryan 2015; Hughes and Romero-Lankao 2014). The high technical competency of Tokyo's bureaucracy combined with a rich availability of historical and current data were essential components in the design and implementation of the city's unique cap-and-trade system on large building facilities (Roppongi et al. 2017).

Participation in national and international municipal networks such as the C40, the Covenant of Mayors for Climate and Energy, and ICLEI has proven to be useful for subnational governments (Heidrich et al. 2016; Hakelberg 2014). These networks help disseminate information on best practices and promote knowledge sharing between governments, helping overcome limitations in capacity and education (Lee 2013). Of not less relevance is the framing of climate action. Climate policies are more likely to be accepted by the public when framed around local issues and values (Ryan 2015). While concern for climate change is an obvious impetus for local-level climate policies (Simon Rosenthal et al. 2015), it is often not the primary driver, especially in rapidly developing cities in the global south; instead, linking climate action to travel congestion alleviation and air pollution reduction are often key drivers (Puppim de Oliveira 2013).

A question receiving increased attention is the extent to which mitigation initiatives are (or can become) truly transformative by promoting or providing the resources, skills and interactions that governments and other stakeholders currently use to deliver deep and radical change (Wiedenhofer et al. 2018; Amundsen et al. 2018; Shaw et al. 2014a; Wolfram 2016; Heikkinen et al. 2019). Some global level studies on urban mitigation have found that many measures support the status quo and only a few are transformational. However, there is still insufficient empirical evidence on how transformational capacity is created (Ziervogel 2019).

13.3.3 Building climate governance and addressing its challenges

This section summarizes scholarship on how subnational actors are creating governance structures and dealing with a series of governance challenges involved in addressing the mitigation gap of limiting warming to well below 2 C above pre-industrial levels in 2100.

Decarbonisation visions and targets are implemented at the subnational level, drawing on local governmental abilities to bring together actors involved in place-based decarbonisation across sectors (Huang et al. 2018; Hodson and Marvin 2009; Bush et al. 2016; Prendeville et al. 2018; Levenda et al. 2019)**. However, climate change mitigation depends on diverse cultural norms, values and identities of actors with varying levels of power, and shifting alliances** (Lachapelle et al. 2012; Damsø et al. 2016; Romero-Lankao et al. 2018b; Giampieri et al. 2019). These underpin the diverging framings, action priorities, and blind spots at the heart of action, and the counter-narratives, scepticism and denialism at the heart of inaction. Often, subnational policies need to meet different, unrelated and contrasting expectations (Trencher et al. 2016; Romero-Lankao et al. 2018a).

Instead of reflecting these differences, subnational actors tend to emphasize expert driven and technical solutions such as infrastructural interventions and best practices that frequently undermine the knowledge of those who do not participate in the dominant knowledge order, such as lower income countries, communities or indigenous knowledge holders (Ford et al. 2016; Brattland and Mustonen 2018; Nagorny-Koring 2019). Indeed, the lower presence of mitigation action in the Global South has been attributed to factors such as the dominating role of Global North actors in the selection and diffusion of "best practices" (Bouteligier 2013).

Case-based evidence shows that technological mitigation solutions rarely address the needs of the urban poor, particularly in Least Developed Countries (Mistry 2014). The implementation of best practices tends to be fragmented, because it is rearranged to suit the characteristics of specific contexts, and executed as pilot projects that rarely lead to structural change (Nagorny-Koring 2019). To move away from one-off recipes for action, scholars suggest considering the context specific conditions of values, cultures and governance that enable successful translation of best practices (Urpelainen 2018; Affolderbach and Schulz 2016).

Multi-level governance theory helps examine how different forms of multi-jurisdictional and multi-sectoral networks emerge across scales and institutional contexts to institutionalize climate change policies, coordinate and facilitate mitigation actions, social and institutional learning, or address gaps in national policy(Jordan et al. 2015; Holden and Larsen 2015; Lee 2019; Lee and Jung 2018; Setzer 2015; Haarstad 2016; Hermwille 2018; Westman and Broto 2018; Kammerer and Namhata 2018; Rashidi and Patt 2018; Schwartz 2019). In addition to being supported by strong links with other tiers of government and transnational networks, subnational actors can play a crucial mitigation role in situations such as political stalemate, where national actors have moved slowly or retreated altogether from climate mitigation action (Jones 2014; Schwartz 2019). Interagency organizations (e.g., in Australia, Europe, the US, Canada and Mexico) facilitate coordination and learning across multiple jurisdictions and sectors, and help connect ambiguous spaces between public, private and civil society actors (Romero-Lankao et al. 2015; Hughes 2019; Horne and Moloney 2019).

Insights from multi-level governance, however, cannot easily be translatable to situations where national governments exert top-down control (e.g., in China), while private business controls the governance of innovation (Westman et al. 2019). They also cannot explain Global South situations, where subnational actors face political fragmentation, lack of regulations, and financial and human resources to separate their interests from those of national governments that exercise top-down decision making or have verticallyintegrated governance. To overcome these, some subnational actors – e.g., State of Sao Paolo and Mexico City engage in transnational level networks, which allow them to extend the locus, agency, and scope of their action (Romero-Lankao et al. 2015; Setzer 2017).

The strategic positioning of subnational actors has led to a growing emphasis on forms of action such as experiments, laboratories and partnerships, **which promise to achieve the radical change required to address the climate mitigation gap** (Smeds and Acuto 2018; Marvin et al. 2018)**. Experiments span many domains, from smart technologies (e.g., in Malmö, Sweden** (Parks 2019)**, to Eco-Art, T-Labs and other approaches that question the cultural basis of the carbon society and seek reimagined or reinvented futures** (*robust evidence, strong agreement*) (Guy et al. 2015; Pereira et al. 2019; Voytenko et al. 2016; Hodson et al. 2018; Sengers et al. 2019; Peng and Bai 2018; Culwick et al. 2019; Castán Broto and Bulkeley 2013; Smeds and Acuto 2018).

The centrality and importance of partnerships, which span industry, civil society, academia, and national and supranational networks, is well established (Grandin et al. 2018; Bulkeley et al. 2016; Castán Broto and Bulkeley 2013; Fenwick et al. 2012; Hamilton et al. 2014). Partnerships take advantage of investments or enhance the scope or impact of mitigation globally. Subnational actors reporting high levels of partnerships are significantly more able to achieve measurable mitigation in areas outside of direct government control such as residential energy use, emissions from local businesses, or private vehicles(Aylett 2014). For example, the region of Metro Vancouver on the West Coast of Canada launched a partnership with seven municipalities and a selection of small and medium-sized enterprises (SMEs) to carry out GHG management training, employ a GHGs management tool and provide technical assistance for SMEs, the costs of which are shared equally amongst the initiative's partners (Burch et al. 2013).

Subnational governments are central to initiating and implementing experiments and often use an incremental, 'learning by doing' governing approach (*robust evidence, strong agreement)*(Peng and Bai 2018; Nagorny-Koring and Nochta 2018; Nevens et al. 2013; McGuirk et al. 2015; Bai et al. 2010; Sengers et al. 2019; Hodson et al. 2018; Culwick et al. 2019; Castán Broto and Bulkeley 2013; Smeds and Acuto 2018). Experiments relate to both technological learning and changes in policies, practices, services, user behavior, business models, institutions, and governance (Torrens et al. 2019; Castán Broto and Bulkeley 2013; Wieczorek et al. 2015; Kivimaa et al. 2017a).

These experiments, however, are often isolated and do not result in longer-term, more widespread or transformative changes (*medium evidence, high agreement*)(Webb et al. 2017; Bulkeley and Betsill 2013; Geels 2013; Bulkeley et al. 2016; Wittmayer et al. 2016; Nagorny-Koring and Nochta 2018; Sengers et al. 2019). Emerging research suggests that the transformative potential of experiments is constrained by uncertainty about locally relevant climate change solutions and effects; a lack of comprehensive, and sectorally inclusive national policy frameworks for decarbonization; budgetary and staffing limitations; and a lack of institutional and political capacity to deliver integrated and planned approaches (Evans and Karvonen 2014; Bulkeley et al. 2016; Bulkeley 2015; Bulkeley and Castán Broto 2013; Nagorny-Koring and Nochta 2018; Grandin et al. 2018; Nevens et al. 2013; Voytenko et al. 2016; Hölscher et al. 2018).

Many subnational actors are not equipped with the capacities needed to mobilize financial and human resources, build coalitions, facilitate coordination, develop relationships across old and new organizations, and create new competences at the individual and institutional level (robust evidence, high agreement) (Jörgensen et al. 2015a; Valenzuela 2014; Romero-Lankao et al. 2018b; Di Gregorio et al. 2019; Hughes 2019) **.** Particularly challenging are new knowledge requirements such as emissions inventories, risks assessments, scenarios and models of emissions reductions, which require the creation of new forms of science coproduction across academia and public institutions (Hughes and Romero-Lankao 2014).

13.3.4 Performance and global mitigation impact

While the evaluation of the performance and global mitigation impact of subnational policies is key, performance has been measured using different methodologies developed by transnational organizations (Hsu et al. 2019). Estimates range from small-scale studies finding that 25 U.S. cities' could mitigate up to 30 megatons of additional CO_2e ($MtCO_2e$) in 2030 (Roelfsema 2017) to larger studies finding that over 9,149 cities could mitigate 1,400 $MtCO_2e$ in 2030 (Global Covenant of Mayors for Climate and Energy 2018; Hsu et al. 2018). Analyses of city performance also present mixed results. On the one hand, they find no significant difference in emissions outcomes between cities that did and those that did not report commitments(Khan and Sovacool 2016) ; higher ambition in climate mitigation commitments did not translate into greater emission reduction commitments (Kona et al. 2016; Hsu et al. 2019). On the other hand, the participation of 512 global, larger and wealthier cities in the C40 Climate Leadership network was associated with increased solar PV investment (Steffen et al. 2019). Kona et al. (2016)found that by 2050, all EU Covenant of Mayors signatories could achieve carbon emissions per capita of around 1.4 tons per person, in line with a global 2 degrees C scenario.

Other difficulties exist in the assessment of mitigation contribution by subnational players. Reporting networks may attract high-performing cities, suggesting an artificially high level of cities interested in taking climate action or piloting solutions (self-selection bias) that may not be effective elsewhere(van der Heijden 2018). Studies could also present a conservative view of potential mitigation impact because they draw upon publicly reported mitigation actions and exclude subnational actions that are not reported (NewClimate Institute Data Driven Yale PBL German Development Institute Blavatnik School of Governement University of Oxford 2019).

Aside from direct mitigation contributions, an alternative perspective on subnational actors' performance derives from indirect effects that, while difficult to quantify, also catalyze action (Chan et al. 2015; Michaelowa and Michaelowa 2017). For instance, through experimentation and policy innovation, subnational actors establish best practices (Hoffmann 2011); set new norms for ambitious climate action, that help build coalitions (Chan et al. 2015; Bernstein and Hoffmann 2018); and translate into knowledge sharing or capacity building (Andonova et al. 2009; Acuto and Rayner 2016; Hakelberg 2014; Kern and Bulkeley 2009; Lee and Koski 2012; Purdon 2015; Toly 2008).

13.3.5 Inequality and justice

A growing body of literature examines environmental justice issues around the distribution of institutional capacities, and the benefits, costs and risks of climate action (distributive justice), and around the opportunities for participation and recognition for all, including subnational actors from the Global South and marginalized groups (procedural justice)(Reckien et al. 2018; Bulkeley et al. 2013; Bulkeley and Castán Broto 2013; Hughes 2013; Romero-Lankao and Gnatz 2019) **. What follows is a summary of their findings.**

The institutional capacities, including resources, legal frameworks, knowledge, political clout, and legitimate, democratic and inclusive institutions, vary widely within and among subnational governments globally (Jörgensen et al. 2015b; Joffe and Smith 2016; Genus and Theobald 2016; Reckien et al. 2018; Markkanen and Anger-Kraavi 2019; Klinsky 2018). For instance, membership in TMNs is skewed toward Europe and North America, while countries from the Global South are underrepresented (Hsu et al. 2018).

Frequently principles of justice are not incorporated in climate change framing and action. While multiple people have different views about what kind of mitigation action is desirable and how it can be implemented (Joffe and Smith 2016), dominant discourses tend to prioritize scientific and technical expertise as source knowledge, and to focus on infrastructural and economic concerns over the concerns and needs of marginalized populations (Sovacool and Dworkin 2015; Genus and Theobald 2016; Heikkinen et al. 2019; Romero-Lankao and Gnatz 2019). Potentially negative inequality effects of climate change mitigation policies also exist (Brugnach et al. 2017; Klinsky 2018; Ramos-Castillo et al. 2017) , which in the presence of poverty, inequality and corruption have been found to aggravate inequalities in many countries (Reckien et al. 2018; Markkanen and Anger-Kraavi 2019).

To overcome these injustices, scholarship suggests participatory planning, often overlooked in subnational policies despite its benefits in managing complex environmental problems (Castán Broto and Westman 2017; UN-Habitat 2016). They also suggest to deliver climate justice by aligning climate policy with discourses about 'just sustainabilities', which connect environmental planning and management with the needs of citizens and communities (Agyeman 2013; Rydin 2013; UN-Habitat 2016). In practice, these tools organise climate and sustainability action by addressing its democratic deficit and facilitating the recognition of multiple perspectives in environmental planning alongside material limits of development (Agyeman 2013).

13.4 The climate governance process

13.4.1 Introduction

Climate governance (see IPCC Glossary) is constrained and enabled by countries' political systems, material endowments, culture and traditions, but these factors do not determine domestic climate targets, strategies and measures (Unruh 2000; Ross 2015; Lachapelle and Paterson 2013; Bang et al. 2015; Smil 2017; Boasson et al. 2020). (*medium evidence, medium agreement,*). A broad range of actors may harness the opportunities that the differing domestic conditions give for climate governance (Stokes and Breetz 2018; Aamodt and Stensdal 2017).

A broad range of actors may be involved in climate governance processes, but their role and importance differs across countries, sectors and issue areas (Boasson et al. 2020; Aamodt and Stensdal 2017) (*medium evidence, medium agreement,*). To a certain extent, the importance of varying actors depends on their control of material endowments, their access to the political system and whether they challenge deeply entrenched cultural-institutional patterns and traditions (Boasson 2015).

13.4.2 Material and institutional context

Climate governance may change countries' material endowments, culture and traditions over time in a way that can enable acceleration of climate action (Meckling et al. 2015; Boasson et al. 2020). (*limited evidence, medium agreement,*). Political systems will probably not change in the same vein, but it is important to understand how differing political systems influence the room for climate governance development (Pierson 2004).

13.4.2.1 Material endowments

Natural resources, such as fossil fuel and renewable energy resources, forests and land, influence energy mix and economic structure, which in turn affect climate policy choices (*limited evidence, high agreement*) (Bang et al. 2015; Friedrichs and Inderwildi 2013; Hughes and Lipscy 2013; Lachapelle and Paterson 2013). Due to technological change, industrial and economic developments, the interpretation of how the domestic natural resources should influence policy development may change over time (Fisher 2006). Moreover, differing material endowments have been interpreted differently across countries, for instance, some countries with rich fossil fuel endowments resist climate action altogether, while others aimed to reduce emissions abroad rather than at home (Eckersley 2013) (*limited evidence, medium agreement*).

The physical infrastructure, such as electricity grid infrastructure, gas pipelines and railroad capacity, may constrain climate transitions due to "carbon lock-in": a form of path-dependence, itself the result of policy, which entrenches technical and other systems so as to constrain policy choices and mitigation capacity (2016; Unruh 2000) (*limited evidence, medium agreement*). Carbon-intensive infrastructure, carbon-emitting power plants or energy-demanding infrastructure like roads and buildings with low energy performance, constrain climate policy by increasing abatement costs, (Bertram et al. 2015a; Erickson et al. 2015a) and entrenching "high-carbon lifestyles" (Urry 2011), and thus reduces the support for climate action. The existence of low-carbon infrastructure, such as renewables plants and buildings with high energy performance may enable introduction of more ambitious climate policy (Ürge-Vorsatz et al. 2018). However, studies of Germany, France and Sweden, indicate that neither fossil fuel infrastructure nor nuclear infrastructure create absolute hindrances for the emergence of new, and low-carbon energy infrastructure (Boasson et al. 2020).

Economic factors are also of relevance. While it has been shown that higher GDP per capita may be associated with a broader portfolio of climate measures (Schmidt and Fleig 2018), the relationship between GDP and mitigation policies is also affected by a number of other societal and political factors (Hess and Mai 2014). One study indicates that the financial downturn around 2010 did not reduce the adoption of climate-related legislation (Fankhauser et al. 2015). Concerning a country's industry structure, there are no clear patterns with respect to how a high share of fossil fuel production influences climate policy developments across counties. In some countries, it has undermined development of ambitious domestic climate policy (Friedrichs and Inderwildi 2013; Lachapelle and Paterson 2013). In Germany it underpinned a forceful renewable energy policy (Eckersley 2013), while in Norway it underpinned extensive use of flexible mechanisms and development of such as Carbon Capture and Storage (CCS) technologies (Boasson 2015; Røttereng 2018; Eckersley 2013). Further, reduced renewable energy costs can both underpin creation of more ambitious renewable energy policies and measures (Aklin and Urpelainen 2013; Meckling et al. 2015; Boasson et al. 2020) and lead to the removal of renewable energy support schemes (Boasson et al. 2020).

13.4.2.2 Political systems

Political systems have developed over generations, primarily created to handle and resolve r issues other than climate change; they are made up of varying formal institutions, such as laws, regulations as well as the established organizational structures of political executives, legislative assemblies and political parties (Pierson 2004; Egeberg 2003; Scott 2008, p. 58). Political systems vary with respect to the degree of democracy, electoral rules, political party structure, ways of organizing the legislature and the executive government, the degree to which decision-making is centralized or decentralized, the role of the courts and the level of corruption.

Democracy is favourable for the adoption of climate policies and reaching climate goals (*medium evidence, high agreement*). Democratic countries tend to have lower CO_2 emissions (Li and Reuveny 2006; Bättig and Bernauer 2009), lower deforestation rates (Buitenzorgy and Mol 2011), be more successful in decoupling economic growth from CO_2 emissions (Lægreid and Povitkina 2018) and be more active in international climate mitigation cooperation (Bättig and Bernauer 2009; Böhmelt et al. 2016). One study indicates that older democracies tend to develop stricter climate policies (Fredriksson and Neumayer 2013).

For the global south, the literature on the role of democracy for climate governance has provided less clear results. Spilker (2013) finds that democracy does not matter for CO_2 emissions while Arvin and Lew (2011) specify that it is only true for the poorest income group, while democracy is associated with lower CO_2 emissions in lower- and upper-middle income groups. Bhattarai and Hammig (2001) find that democracy is associated with lower deforestation rates in Latin America and Africa but with higher deforestation rates in Asia. Several case studies on Singapore and China document that authoritarian countries may also succeed in environmental protection and climate mitigation (Han 2017; Gilley 2012; Beeson 2010; Green and Stern 2015; Engels 2018).

Proportional representation rules have been found to be more beneficial to climate policymaking (Finnegan 2019; Lachapelle and Paterson 2013; Fredriksson and Millimet 2004) (*medium evidence, high agreement*), because they open up possibilities for parties with more ambitious climate positions to win parliamentary seats and influence policymaking (Harrison and Sundstrom 2010). There is less political risk related to imposing climate related costs on voters in countries with proportional electoral systems (Finnegan 2018, 2019). Thus, proportional electoral systems underpin the emergence of parties with strong climate agendas. Party structure has some importance for domestic climate policy development (*medium evidence, medium agreement*). Similar parties in differing countries may have varying climate policy positions (Boasson et al. 2020). Statistical comparisons show that higher share of green parties is associated with lower GHG emissions (Neumayer 2003; Mourao 2019; Jensen and Spoon 2011), and left-wing parties tend to adopt more pro-climate policy positions than the rest (Farstad 2018; Carter 2013; Tobin 2017). Still, we need more research on the relationship between differing party families and climate policy development. There remains a limited literature on green parties in the global South (Haynes 1999; Kernecker and Wagner 2019), despite the fact that African green parties have provided government ministers in a handful of states (Death and Tobin 2017).

The structure of the legislature and the executive government, and the division of powers between them, may also influence the conditions for climate policy development (*limited evidence, medium agreement*). Madden (2014) finds that systems where the president, and/or other legislative champers, can veto decisions, tend to have lower rates of climate policy, while Schulze (2014) finds that if veto players have pro-environmental orientation, it positively influences ratification of international environmental agreements. Due to the limited number of studies, and the low number of cases, we cannot draw strong conclusions about the role of such political contexts for climate policy.

While some political systems have strong regional and local units with responsibility over many climate related policy areas, for instance federal systems, like Germany, Belgium, Brazil and the US (Fisher 2013), the political systems in other countries are highly centralized, with much authority concentrated at the domestic level, for instance France, UK and China (Webb et al. 2017).. There are few studies on the difference in climate governance across centralized and decentralized political systems, but increasing scientific attention is given to governments at state and local level. Studies show that local and state level governments are sites for new decarbonisation visions and policy ideas (Hodson and Marvin 2009; Nevens et al. 2013; Fenton and Gustafsson 2017), often have responsibility (shared with other levels) for many mitigation and adaptation policies areas (such as land use planning, waste management, health care services, infrastructure) and are close to where the impacts of climate change as well as potential negative consequences of mitigation efforts, such as unemployment related to low-carbon transition, are felt (Bulkeley and Betsill 2005; Bai et al. 2010; Burch et al. 2013; Pasquini and Shearing 2014; Ryan 2015; Amundsen et al. 2018). Hence, we can conclude that state and local level governments are crucial performers of climate governance across differing political systems (*medium evidence, high agreement*), although we know less about variance across differing political systems, countries and issue areas (see 13.3 for more details).

Courts play differing roles across varying political systems and law traditions (La Porta et al. 1998). Climate litigation has become increasingly important for domestic climate governance since the mid-2000s, but there are major variations across countries (Peel and Osofsky 2015; Wilensky 2015; Setzer and Byrnes 2019; Bouwer 2018) (*medium evidence, high agreement*). The vast majority of climate cases have emerged in United States, but climate litigation has also had importance in Australia and the United Kingdom. All of these are western countries with common-law juridical systems, built on the English law tradition. Overall, courts have also played a more active role for climate governance in democratic, than in authoritarian countries (Peel and Osofsky 2015; Setzer and Byrnes 2019), but recent reforms to environmental public interest laws in authoritarian systems, such as that in China, allow individuals and groups to initiate environmental litigation (Zhao et al. 2019b). Whether and to what extend differing law traditions and political systems influence the role and importance of climate litigation has however not been examined significantly.

Climate litigation has primarily influenced climate policy in developed countries (Fisher et al 2017), but more recently also in developing countries (Peel and Lin 2019; Setzer and Benjamin 2019) Less than 3% of the climate change cases that have emerged globally have been heard by courts in countries of the Global South, with the majority of these cases in countries with democratic or semi-democratic political systems (Peel and Lin 2019). Courts tend to be more important for climate governance in Global South countries that have constitutional environmental rights and/or civil rights protections (Peel and Osofsky 2018). See Section 13.9 for a more detailed discussion of climate litigation.

Corruption, commonly understood as 'abuse of entrusted power for private gain' (Treisman 2000), hampers the adoption and implementation of public policies, including policies aimed at combatting climate change (*robust evidence, high agreement*). For example, Damania, Fredriksson, and List (2003), Fredriksson and Svensson (2003), and Pellegrini (2011) report that more corrupt countries have weaker stringency of environmental policies. In his global statistical investigation, Welsch (2004) shows that CO_2 emissions increase with corruption, either through the direct effect of corruption on law enforcement or through the effect of corruption on countries' income. These findings are echoed by Cole (2007) in the global sample; by Bae, Li, and Rishi (2017) in the sample of post-Soviet countries; by Wang et al. (2018b) in the sample of BRICS (Brazil, Russia, India, China, and South Africa) economies; by Sahli and Rejeb (2015) in MENA-region; by Ridzuan et al.(2019) in Malaysia, Indonesia and the Philippines; and by Habib, Abdelmonen, and Khaled (2018) in African countries that already have relatively low CO_2 emission levels, but not countries that have relatively high CO_2 emissions. Sundström (2016), in his summary of the existing case studies on corruption and deforestation, describes how corruption undermine deforestation efforts. Povitkina (2018) further suggests that corruption disrupts the positive effect of democracy on CO_2 emissions and shows that democracies only emit less if their corruption levels are low. If corruption is high, no statistically significant difference between CO_2 emissions in democracies and authoritarian regimes is found.

13.4.2.3 Cultural-institutional features

Cultural institutions are values and morals and the shared conceptions that constitute the nature of social reality and the frames through which meaning is created (Scott 2008, p. 58). Cultural-institutional features, such as norms, world views, traditions, frames and institutional logics, contribute to shape which climate actions that are regarded as good and appropriate (Boasson et al. 2020) (*limited evidence, medium agreement*). For instance, climate governance may be influenced by sector-specific regulatory traditions (Boasson and Wettestad 2013; Boasson et al. 2020), traditional approaches to application of scientific information in policy making (Jasanoff 2011), cultural understandings of climate science (Hoffmann 2015), approaches to international climate cooperation, domestic political cultures (Harring et al. 2019), national identities (Eckersley 2016), media discourses (Schifeling and Hoffman 2019) and corporate cultures (Boasson 2009) (*limited evidence, medium agreement*).

Cultural differences can contribute to explain why similar policy elements have differing characteristics in differing countries and regions, such as emission trading systems (Knox-Hayes 2016; Wettestad and Gulbrandsen 2017) and feed-in schemes for renewable energy (Boasson et al. 2020). Cultural-institutional element tend to change slowly, but they are malleable, and cultural change can create shifts in how actors perceive their own interests (Boasson 2015; Boasson et al. 2020) and the attractiveness of differing policy solutions (Schifeling and Hoffman 2019) (*limited evidence, medium agreement*). Climate governance tends to emerge through a complex interplay between cultural elements and other factors (Tellmann 2012; Boasson et al. 2020; Boasson and Wettestad 2013). (*medium evidence, high agreement*).

13.4.3 Key Actors: governance influencers, adopters and implementers

Differing actors take part in climate governance, but their roles and importance vary across countries (Kukkonen et al. 2018; Longhofer et al. 2016), across sectors (Boasson 2015) and issue areas (Boasson and Wettestad 2013). (*medium evidence, medium agreement,*). This section will review the literature on the actor groups that have gained the most scientific attention: corporations, environmental groups, indigenous peoples' organizations, international organizations and politicians.

Table 13.1 The roles of differing actor groups for climate governance

The importance of varying actors in climate governance	Corporate actors	Environ-mental org.	Indigenous Peoples groups	Politicians	International organizations
Influence	HIGH	MEDIUM	MEDIUM/ LOW	HIGH	MEDIUM/HIGH
Adoption	MEDIUM	*	*	HIGH	MEDIUM
Implementation	HIGH	*	*	*	*

Note: We have not enough research at this stage to make conclusions about this, but we hope to get access to more research during 2020, enabling us to make more concluding statements.

Assessment of existing literature enables us to draw the conclusions presented in Table 13.1 The roles of differing actor groups for climate governance. Corporate actors, are for-profit enterprises—be they publicly traded, privately help or state-owned—and the business and industry associations that aggregate and represent their interests in politics, have been given particularly much attention in the literature (Meckling 2011; Mildenberger 2020). This term includes every commercial actor from the world's largest corporations to business with only one or two employees. Because corporate actors often have good access to political systems, control material resources and are favoured by domestic cultures and traditions, they play key roles when it comes to influencing, adopting and implementing climate governance (Mildenberger 2020; Pulver and Benney 2013). (*limited evidence, medium agreement*,). Still, corporate actors' positions and ability to influence climate policy vary across differing groups of corporate actors, countries, sectors and climate issue-areas (Skjærseth and Skodvin 2010; Boasson and Wettestad 2013; Boasson 2015; Boasson et al. 2020) (*medium evidence, medium agreement*).

Environmental organizations are non-governmental organizations that aim to mitigate environmental problems, but they may have differing origin stories (Longhofer et al. 2016), varying financial models (Bloodgood and Tremblay-Boire 2017) and differ with respect to how much priority they give to climate issues. Environmental organizations influence climate policy and governance discussions to a certain extent, but with the exception of a few big international organizations (such as WWF), we do not have much literature on their role as adopters and implementers of climate policy (Forsyth 2010; Comi et al. 2015; Longhofer et al. 2016; Aamodt and Stensdal 2017; Dentoni et al. 2018).

Indigenous peoples organizations represent the communities, peoples, and nations that 'have a historical continuity with pre-invasion and pre-colonial societies that developed on their territories and 'consider themselves distinct from other sectors of the societies now prevailing on those territories' (Schroeder 2010). Indigenous groups have had medium to low importance for the climate discussions relating to certain types of climate action, such as forest management, and creation of renewable energy plants, but we lack scientific assessments of their roles with respect to adopting and implementing climate measures, with the exception of the REDD+ literature (Jodoin 2017; Claeys and Delgado Pugley 2017; Thornton and Comberti 2017).

A broad range of international organizations may be involved in domestic climate governance, including intergovernmental organizations (a range of UN-bodies, but also others such as G20), regional intergovernmental actors (such as the EU and the African Union). International and regional financial institutions (such as the World Bank and AfDB), non-governmental and international think-tanks and knowledge institutions (such as the WRI and Climate Analytics). International organizations are especially important when it comes to framing of climate governance in public discourse, but in some countries, particularly in the Global South and within the EU, international organizations are also important for the adoption of climate measures (Urpelainen and Van de Graaf 2015; Delina 2017; Falkner 2018; Tosun and Peters 2018). There is less research about the role of such actors in the implementation phase.

Fifth, political actors are as political party organizations, legislative assemblies and committees, governmental executives and the political leaders of the governmental ministries (Boasson 2015, 38–46). Politicians have high importance for climate governance discourses and adoption of public policies, but we know less about their roles in relation to implementation of domestic climate governance (Guber 2013, 2017; Bang et al. 2015; Linde 2018; Boasson et al. 2020; Aamodt and Stensdal 2017).

13.4.3.1 Influencing climate governance

In the period before a policy idea or proposal is adopted (or rejected), actors may aim to influence the policy agenda, how the issue is framed, how issues are linked and how a particular measure is designed (Knill and Tosun 2012). Hence, in this section we assess state of the art knowledge on the importance of varying actors in influencing policy discussions in the discourses, in the media, in parliaments and elsewhere.

Corporate actors' positions and ability to influence climate policy vary across differing groups of corporate actors, countries and climate issue-areas (Skjærseth and Skodvin 2010; Boasson and Wettestad 2013; Boasson 2015; Boasson et al. 2020) (*medium evidence, medium agreement*). Corporations may gain influence their control of material endowments they control (Moe 2012), having superior access to the domestic political system (Mildenberger 2020) or their success in shaping cultural-institutional features (Boasson 2015). The fossil fuel industries have been important agenda-setters, for instance in the USA (Supran and Oreskes 2017; Downie 2018; Dunlap and McCright 2015) in the EU (Boasson and Wettestad 2013; Skjærseth and Skodvin 2010), in Australia (Ayling 2017), China and India (Blondeel and Van de Graaf 2018), and in Mexico (Pulver 2007), but they have had differing positions across countries (Kim et al. 2016; Nasiritousi 2017). In the US, the oil industry has underpinned emergence of climate scepticism (Farrell 2016a; Supran and Oreskes 2017; Dunlap and McCright 2015), and its spread abroad (Dunlap and Jacques 2013; Engels et al. 2013; Painter and Gavin 2016). Smaller corporate actors providing climate solutions, such as renewable energy industries, have sometimes succeeded in influencing public policy more than large fossil fuel actors, for instance in the EU (Boasson 2019), Germany (Leiren and Reimer 2018), the US (Stokes and Breetz 2018), the Nordic countries (Kooij et al. 2018) and Japan (Li et al. 2019). Corporate actors tend to change their climate policy preferences over time, particularly in Europe and in relation to energy issues (Boasson and Wettestad 2013; Boasson 2015). More studies are needed on how the positions of corporate actors changes over time.

Environmental groups have marginal control of material endowments, limited access to the political system, but often take part in larger coalitions or network that aim to shape cultural-institutional frames and understanding (Tjernshaugen 2011; Boasson and Wettestad 2013; Aamodt and Stensdal 2017). The salience of a climate issues may drop if different environmental groups have contrasting agendas, but organizations calling for more radical climate measures may also strengthened the climate agenda altogether (Schifeling and Hoffman 2019). Domestic environmental organizations influence environmental governance in democracies more, while international environmental organizations have a positive effect in all countries, although it is less strong in developing countries (Longhofer et al. 2016). The influence of environmental organizations may be enhanced when they succeed in: framing of low carbon measures as appropriate (Boasson 2015), makinging decission-makers compensate major climate losses with smaller climate victories (Boasson 2015) or decission-makers under-estimate challenger technologies (Leiren and Reimer 2018; Stokes and Breetz 2018). In addition to aiming to influence public climate policy, environmental groups also engage to influence private climate governance initiatives, such as partnerships between corporate actors and other environmental organizations (Dentoni et al. 2018).

Indigenous Peoples groups, they tend to have limited control of material endowments, and limited access to regular political processes, but often aim to shape cultural-institutional frames relating to broad variety of climate governance issues, such as opposing extraction and transportation of fossil fuels, on their traditional lands (especially in the Americas) (Claeys and Delgado Pugley 2017; Coryat 2015; Wood and Rossiter 2017; Hindery 2013; Bebbington and Bury 2013), deployment of small-scale renewable energy initiatives (Thornton and Comberti 2017), opposition to large-scale climate mitigation projects that may affect their traditional rights and lands (Brannstrom et al. 2017; Zárate-Toledo et al. 2019; Moreira et al. 2019), seeking to influence the development of REDD+ policies through opposition (Reed 2011) and participation in consultation processes and multi-stakeholder bodies (Jodoin 2017; Bushley 2014; Astuti and McGregor 2015; Gebara et al. 2014; Kashwan 2015). However, Indigenous Peoples have been excluded from national REDD+ readiness processes in some countries (Jodoin 2017; Pham et al. 2014).

Concerning international organizations, financial institutions and donors control key material endowments, in the shape of potential climate-related funding, few other international organizations possess significant material resources (Delina 2017). The World Bank, regional development banks and climate-related investment funds have adopted comprehensive environmental objectives for their lending activities, and in addition they support countries in strengthening their sector specific and domestic policies aimed at low carbon transformations (Delina 2017; Falkner 2018). International organizations tend to have less direct access to the political system in the Global North (with the exception of the EU for EU member states) then the Global South (Delina 2017; Kukkonen et al. 2018; Longhofer et al. 2016; Overland and Reischl 2018). Many organizations aim to shape cultural-institutional understanding of appropriate domestic climate governance in both the Global North and the South (Urpelainen and Van de Graaf 2015; Tosun and Peters 2018). Major UNFCCC summits and the launch of IPCC reports have contributed to increase the political attention to climate change, although European countries seems more easily affected than others (Andresen et al. 2012; Ogunbode et al. 2019).

Politicians have limited control of material endowments, but in democracies the politicians from majority coalitions have much formal authority in the political systems (Boasson et al. 2020). Politicians may play a key role in framing debates on climate change and their cues can shape public opinion both positively and negatively (Guber 2013, 2017; Linde 2018). Several political leaders have been successful in shaping how climate change is framed within their countries, for instance, Ethiopian Prime Ministers Zenawi and Desalegn largely succeeded in framing climate as a question of green industrialisation (Okereke et al. 2019), and President Lula and Minister for the Environment da Silva largely succeeded in framing deforestation in Brazil as a crucial climate measures (Hochstetler and Viola 2012; Nunes and Peña 2015). A key driver for political leaders to promote climate change is the prospect of portraying themselves as global climate leaders (Carter and Jacobs 2014a; Schmitz 2017; Boasson and Wettestad 2013). However, political leaders have also several times contributed to strengthen sentiments against domestic climate actions (Ferrante and Fearnside 2019; Selby 2019).

Politicians are more likely to pay much attention to climate issues when polling indicate high political salience in the public (Carter 2006, 2014). Fluctuations in the public's interests underpin instability in politicians' engagement (Willis 2017, 2018) Political parties payed much attention to climate issues in the high salient 2007–2009 period in Western Europe (Boasson et al. 2020). In this period, political parties in the UK competing on the climate issue, which environmental organizations were able to exploit to see the Climate Change Act adopted (Carter and Jacobs 2014b; Carter and Childs 2018).

13.4.3.2 Adopting climate governance

Climate governance adoption refers to actual decision-making, relating to targets, strategies, measures, instruments and long-term strategies (Knill and Tosun 2012). Governments are key decision-makers and adopters of climate policies and measures (Iacobuta et al. 2018), but an increasing number of non-governmental actors perform climate governance through partnerships (Forsyth 2010), voluntary agreements

(Krarup and Ramesohl 2002), GHG emissions disclosure (Hahn et al. 2015) other voluntary initiatives (*medium evidence, medium agreement*).

Emissions disclosure is the most prevalent form of corporate self-governance (Hahn et al. 2015) although reporting rates and practices vary across countries (Pulver and Benney 2013) and sectors (Backman et al. 2017), as well as between corporations within the same sector (Boasson et al. 2020). Disclosure may be accompanied by target setting, ranging from pledges to achieve carbon neutrality and source one hundred percent renewable energy to commitments to reduce carbon intensity per unit of product (Gouldson and Sullivan 2013; Walenta 2019).

Private climate governance initiatives can be collaborative partnerships between corporations, environmental organizations and other actors. For instance, environmental groups, many of which are international organizations, have been involved in partnerships that have developed forest management projects (Forsyth 2010), certification of certain more climate friendly products (Dentoni et al. 2018), corporate waste management policies (Van Huijstee et al. 2011), corporate GHG emission reducing strategies (Comi et al. 2015) and greening the supply chain (Van Huijstee et al. 2011). Overall, environmental organizations' collaboration with large corporate actors that contribute to significant GHG-emissions have increased, but some organizations engage more actively development governance initiatives that directly affect corporate practices then others (Van Huijstee et al. 2011; Comi et al. 2015). We know little about the overall performance of the private governance initiatives (Pattberg 2010), and the importance of environmental organizations in the internal decision-making processes (Forsyth 2010; Van Huijstee et al. 2011; Dentoni et al. 2018);. The partnerships provide environmental organizations with funding, but we know little about whether this reduces the clout of the environmental groups. For more information about sub-national partnerships please see 13.3.

International organizations play a leading role in many of the private governance initiatives discussed above (Pattberg 2010). Given that the EU carries the international climate commitment of its member states, it has played a key role when it comes to adoption of climate policies (Boasson and Wettestad 2013). No other regional organizations play a similar role, but one may argue that the some of the criteria and conditions of the international financial organizations are so strict that this in practice determine certain climate governance developments in developing countries (Somorin et al. 2014).

There is limited research on the role that Indigenous Peoples are playing in the performance of climate governance. One exception is a study that documents the climate adaptation policies and initiatives adopted by governments and communities in Nunavut, a territory governed and primarily inhabited by the Inuit (Labbé et al. 2017).

In most countries, important public climate policy decision are done by political leaders, although there may be radical variation in whether it is the legislative assembly, the executive government or the political leadership of certain ministries that have the last word (Boasson et al. 2020; Bang et al. 2015; Aamodt and Stensdal 2017). Although other governmental actors, such as agencies or the courts may have some authority over climate governance, politicians tend to be the most important decision-makes.

13.4.3.3 Implementing climate governance

Implementation is the carrying out of climate policy and governance decisions, denoting what happens after decisions are made (Hill and Hupe 2014). In general, we know far less about the role of organized actors in relation to implementation then the two other governance phases.

Corporate actors are crucial to implementation of public and private policies; this follows from their control of material endowments, their crucial role in the creation of climate change (as prominent emitters of the greenhouse gases and owners of carbon-intensive technologies) and in offering solutions (owning, developing and performing low emission practices and technologies) (Perrow and Pulver 2015). Measures that imply mandatory requirements for corporations rely on their compliance in order to succeed, such as carbon pricing covering 20 percent of global emissions(World Bank 2019), renewables support scheme requiring electricity providers to provide a certain share of renewable energy (Lyon 2016) building codes (Berardi 2017) and fuel-efficiency and emissions standards (Lipman 2017). The literature indicate that there are few implementation examples related to such requirements (Wettestad and Gulbrandsen 2017), although there is little systematic research. Measures creating economic advantages to corporate actors that perform certain practices, rely on businesses voluntary stepping up to exploit the economic opportunities, such as investment support or feed-in support for renewable energy or energy efficiency measures, voluntary set of programs like the Clean Development Mechanism (CDM) (Olsen 2007). Since corporations have to actively choose to exploit these measures, they have much leeway to influence the success of the measures (Boasson 2015), but there is little systematic research on this.

Environmental organizations and international organizations engage in 'naming and shaming' activities aimed at increasing countries' compliance with international climate obligations. The carbon tracker initiative is one example of is (Tracker 2019), but we have little systematic research on the effect of such initiatives.

There is an extensive literature (discussed in chapter 7 of AR6) that concerns the role of Indigenous Peoples in the implementation of REDD+ through community-based REDD+ programs and projects and community involved in measurement, reporting, and verification of carbon emissions from forest-based sources. In some cases, REDD+ programs and projects have supported Indigenous-led community forestry as a strategy for reducing carbon emissions, and contributed to strengthening the forest tenure rights of Indigenous Peoples, while in other cases, the pursuit of REDD+ has resulted in the exclusion of Indigenous Peoples, the neglect of their traditional knowledge, and led to violations of their forest tenure rights (Jodoin 2017).

It seems like politicians tend to play a less central role for implementation than they do with respect to influencing and adopting public climate policies. However, we have seen that when politicians intervene and change policies often, this may create uncertainty that again hampers implementation of climate policies (Boasson et al. 2020).

13.4.3.4 Other civil society groups

A broader range of civil society organizations play a role for climate governance, including labour unions, human rights groups, development and social justice groups, and religious communities (Cabré 2011; Jinnah 2011; Allan and Dauvergne 2013; Gulbrandsen and Andresen 2004; Wallbott 2014; Schroeder 2010; Glaab et al. 2018; Jamison 2010; Felli 2014). Research document that these are increasingly engaging in international climate politics, there is limited scholarship on the role that these actors play in the national level. A few scholars report that Labour Unions have developed positions and programmes on climate change (Snell and Fairbrother 2010; Stevins 2013; Räthzel et al. 2018), formed alliances with other actors in the field of climate policy (Stevis 2018), and participated in domestic policy networks on climate change (Jost and Jacob 2004). Little is known however about the impact that labour unions have had on the development climate policies through these activities. The one exception is Mildenberger's (2020) in-depth comparative analysis of the role that unions have played in influencing climate mitigation policies in Australia, Norway, and the United States. He concludes that labour unions tends to contribute to reduce the ambitiousness of domestic climate policies, but more research is needed. For more information on civic engagement, please see Section 13.9.

13.4.4 Conclusion

Domestic climate governance results from complex inter-relationships between political systems, material endowments, culture and traditions. A whole host of actors try to navigate these complexities. A broader array of actors are involved in the phase where policy and governance elements are discussed and decided upon. , Fewer are active adopters Implementation requires the active participation of a high number of actors, but there is less research on this crucial phase of climate governance. Overall, research is concentrated on the activities and actors that it is easier to map though public documents, media assessments and interviews, while we know less about actual decision-making and implementation phase. We also note that the scientific literature on the Global South primarily zoom in on the role of international and non-governmental actors, while the Global North literature captures a larger array of actors, and gives more weight to corporate actors and politicians. This may be more a result of biases in the literature than actual differences in the policy processes.

13.5 Policy instruments and evaluation

This section provides a taxonomy of policy instruments, presents a set of criteria for evaluation of the performance of policy instruments, and synthesizes the literature on policy instruments in the categories of economic or marked-based instruments; regulatory instruments; and other approaches. The emphasis in this concise treatment is on recent empirical experiences in the application of different policy instruments, and lessons that can be drawn from these experiences. AR5 provided a more in-depth theoretical treatment of policy instruments for mitigation.

13.5.1 Taxonomy of policy instruments

In Section 13.5., climate change mitigation instruments are organized into three categories: (1) economic or market-based instruments, (2) regulatory instruments, and (3) other instruments. Economic or market-based instruments include taxes, permit trading, offset systems, subsidies for mitigation, fossil fuel subsidies, and border tax adjustments. Regulatory instruments are divided into two sub-categories: performance standards and technology standards. The other instruments category includes a diverse range of policies and programmes including information programmes and policies, government provision of goods, services, and infrastructure, divestment strategies, and voluntary agreements between governments and private firms. Table 13.2 summarises the range of policy instruments applied across various sectors, drawing from the information in other chapters in this assessment.

13.5.1.1 Economic or market-based instruments

These policy instruments employ market forces to achieve emissions reductions by directly influencing prices through taxes or subsidies, or by establishing emissions quantity constraints along with trading mechanisms to determine a market price.

Taxes conventionally place a charge on fossil fuel-derived forms of energy based on their carbon content. Carbon taxes may be economy-wide or sector specific. Taxes may also be allocated based on energy or fuel use in sectors such as transportation, buildings and industry, or placed directly on specific technologies, products and processes, such as the case of vehicle or waste disposal taxes.

Permit trading, commonly referred to as ‘cap-and-trade’, is a quantity-based approach whereby an aggregate emissions limit is established and emission permits are issued among polluters that sum to the aggregate emissions limit. The trading of emissions permits among polluters produces a market permit price per unit of emission, giving the same price signal to consumers and firms as a carbon tax. The European Union’s Emissions Trading System is recognized as the world’s first and largest permit trading system.

Offset systems are an instrument related to permit trading, but credits are created when a source reduces its emissions below a baseline, measured as an estimate of what emissions would have been in the absence of the reduction. Offsets may be sourced domestically or internationally and have included projects that plant or preserve forested areas or develop new carbon-neutral energy generation installations.

Subsidies for mitigation represent financial instruments that support low-carbon technologies as well as the reduction or removal of mechanisms linked with technologies or actions that may encourage emissions. Examples include direct subsidies or tax credits that lower the price or investment costs of low-emission equipment purchases and retrofits. Government financial support for the development and procurement of low-emission technology may also be considered a subsidy for mitigation.

Fossil fuel subsidies either support the consumption or production of fossil fuels. Consumption subsidies alter the relative price of energy at the point of consumption thereby encouraging the purchase of low- or high-emissions energy depending on the carbon content and intensity of the energy system receiving the subsidy. Fossil fuel production subsidies reduce the investment or operation cost of fossil fuel extraction, processing and distribution.

Border tax adjustments are a system of levied import tariffs and export subsidies set according to the emissions intensity of traded products. Border tax adjustments have rarely been implemented.

13.5.1.2 Regulatory instruments

Regulatory instruments fall within one of two categories: technology standards and performance standards. *Technology standards*, often called direct, prescriptive, or command-and-control standards, typically feature one of three approaches: (1) requirements for specific pollution abatement technologies; (2) requirements for specific production methods; or (3) requirements for, or banishment of, specific goods such as energy efficient or inefficient appliances. Those whose operations fall under a standard must follow the rules and/or objectives established by the standard or face a financial penalty and/or legal sanction for non-compliance.

Instead of focusing on specific technologies, processes, or products, *performance standards* provide a more flexible approach by leaving it up to regulated entities to decide on the method or technology to be employed to achieve an objective. Thus, a performance standard might set a maximum carbon emissions per tonne of steel and allow steel-producing firms to decide how they might comply. Additional compliance flexibility can be incorporated through trading, where parties who over-perform on a target can earn credits to sell to those underperforming. Performance standards that include trading mechanisms are often referred to as market-oriented standards.

One example of a performance standard that includes trading is California's Low Carbon Fuel Standard. Under this regulation, transportation fuel providers must reduce the carbon intensity by a specified date. Providers can meet this emission intensity reduction themselves, buy credits from other producers who have overachieved yearly targets, or face a penalty for non-compliance (Yeh et al. 2016).

13.5.1.3 Other policies

Information programmes and policies aim to (1) correct for gaps or asymmetries in relevant information among firms and consumers and (2) influence preferences and behaviour towards low-emission technologies and lifestyles (Koos 2011). Examples include labelling requirements, which are commonly used to raise consumer awareness of household appliance energy efficiency and automobile fuel economy. Other mechanisms include third-party certification schemes for signalling sustainable product options and awareness campaigns extolling the merits of lower emission lifestyle choices such as carpooling, taking transit, cycling, or reducing home energy consumption.

Government provision of public goods, services, and infrastructure is a diverse set of instruments. Examples include physical infrastructure planning and development, such as public transportation services, district heating, and electricity systems. Forest conservation and afforestation programmes are also included in this instrument type, as is government-executed or government-funded research and development.

Divestment is defined as the reduction of an asset for financial, political, or ethical reasons. In the context of climate change mitigation, *divestment strategies* typically involve actions aiming to facilitate and encourage large institutional investors to remove their holdings from fossil fuel or other high-GHG industries (Ayling and Gunningham 2017).

Emerging from a negotiated process, *voluntary agreements between governments and private firms* are voluntary commitments that private firms make to achieve a government objective. These agreements may pertain to energy efficiency goals in industry, the introduction of consumer labelling for products or equipment, or carbon reduction or offset programs.

Table 13.2 Policy instruments in sectors

	Energy	Transport	Buildings	Industry	AFOLU	Urban systems	Demand	Cross-sectoral
Economic instruments								
Taxes	1) Carbon Taxes 2) Tax Incentives 3) Fossil Fuel Taxes	1) Carbon taxes (especially on heavy vehicles) 2) Congestion charges[a]	1) Energy/Carbon taxation	1) Energy/carbon taxation 2) waste disposal charges	1) Fertilizer or Nitrogen taxes	1) Sprawl taxes, impact fees, exactions, split-rate property taxes, tax increment finance, betterment taxes, congestion charges	1) Tax deduction for bioclimatic and zero carbon buildings	1) Taxes on Food Products according to GHG emissions/sustainability score
Permit trading	1) Emission Trading Schemes at national and sub-national scales	1) Fuel and vehicle standards	1) Incentives facilitating Third Party Financing / ESCOs; 2) Energy Efficiency Obligation Schemes (EEOSs) 3) White certificates 4) Technology deployment schemes 5) Personal Trading Schemes	1) Emissions trading 2) Tradeable green certificates		2) Urban-scale Cap and Trade	1) Charging according to how much food households throw away	

Offset systems					1) Emission credits under CDM 2) voluntary or compliance markets for land-based carbon offsets			
Subsidies for mitigation	1) Subsidies on Clean Energy Technology 2) Feed in Tariffs 3) Fiscal regulations to account for market failures in credit allocations by banks	1) Subsidies for Light Electric Vehicles	1) Feed in Tariffs 2) Grants in support of innovative technologies 3) Preferential loans 4) Tax incentives	1) Feed in tariffs	1) Payment for Ecosystem services 2) Financial instruments catered towards REDD+ policies and programs	1) Special improvement districts	1) Subsidies on EV and hybrid Vehicles 2) Subsidies for for bioclimatic and zero carbon buildings	
Fossil Fuel subsidies	1) Removal of Fossil Fuel Subsidies	1) Abolishing fossil fuel subsidies						
Border carbon adjustments				1) Border taxes on imports of emissions-intensive products (or rebates on exports)				
Regulatory instruments								

Technology standards	1) Technology and Produce Based Standards	1) Urban planning and zoning restrictions 2) Fuel standards	1) Building codes 2) Building renovation obligations 3)Phase-out of inefficient equipment 4) Mandatory energy labelling	1) Bans such as on single- use plastic	1) National REDD+ support policies including monitoring, reporting and verification	1) Building codes and street codes 2) Affordable housing mandates 3) Mixed use zoning		1) Food regulations (novel food laws, food waste regulations) 2) Trade restrictions on unsustainable/unhealthy food
Performance standards	1) Renewable Portfolio Standards (RPS) 2) Efficieny and Fuel Standards 3) Emission Standards	1) GHG emission performance standards	1) Minimum energy performance standards (MEPS) for new and existing buildings 2) Energy efficiency standards for appliances & equipment 3) Procurement regulations	1) Zero waste targets and recycling obligations 2) Extended producer responsibility programs 3) Public procurement regulations and standards	1) Regulation of supply chains for forest and agricultural products	1) site access controls 2) design codes	1) Incentivise building standards and energy certification schemes	
Other policies								
Information programs and policies	1) Promote Low-Carbon Infrastructure	1) Behaviour Change Programmes (to mainstream EVs)	1)Information and awareness campaigns 2) Information Centres and	1) Sharing best practices for new technologies	1) Forest certification programs		1) Nutritional guidelines 2) Narratives and public campaigns	1) Sustainable Food-Based Dietary Guidelines (sFBDGs)

		2) Life cycle cost assessments	information exchanges 3) Energy Audits 4) Energy consumption feedback 5) Energy labelling schemes	2) award schemes for recognizing clean production 3) Carbon labelling and reporting 4) Brokerage for industrial cooperation			3) Information & labelling policies promoting vegetarian or low carbon diet 4) Promote locally grown food	2) Food/nutrition/ environment education 3) Food labels 4) Improved best-before dates 5) Marketing regulations (advertising bans on unhealthy/unsustainable foods)
Government Provision of Public Services and Goods, Services and Infrastructure	1) Infrastructure expansion (e.g. district heating/cooling or common carrier) 2) R&D in new energy technologies	1) R&D programs on socio-economic structures impeding EV adoption 2) R&D programs and trials on fuel systems 3) R&D towards improved urban infrastructure and planning 4) Pilots and demonstrations for heavy vehicles	1) Training and education 2) Public procurement of efficient buildings and appliances	1) Transition planning including infrastructure planning and social transition planning 2) Conduct demonstrations and pilots in areas such as zero carbon production, building lightweighting etc. 3) Training and education programs	1) Establishment of parks and protected areas 2) National conservation programs aimed at forests or soil carbon sequestration 3) Satellite and ground based forest inventory measurements	1) Provision of utility infrastructure such as electricity distribution, district heating / cooling and wastewater connections 2) Urban rail	1) Direct Infrastructure Investment (railways, trams, compact cities, district heating) 2) R&D, demonstration projects 3) Compact urban Planning, investment in ICT infrastructure 4) Investment in Public transport,	1) Investment into R&I for emerging / still to emerge food technologies (e.g. alternative proteins) 2) CDR research, development, demonstration and targeted near-term deployment 3) Organizational procurement (standards, rules, for

		5) Education programs		4) Brokerage for industrial cooperation			Investment in cycling facilities 5) Number plate, parking restrictions 6) Improve education/awareness on food waste	schools, canteens)
Divestment strategies	1) Divestment from shares in fossil fuel companies							
Voluntary agreements			1) Voluntary certification and labelling programs 2) Voluntary and negotiated emission reduction agreements	1) Voluntary carbon neutrality or energy targets	1) sustainable timber harvesting 2) Voluntary adoption of REDD+ targets such as the New York Declaration of Forests 3) Moratoria on unsustainably sourced agricultural and animal product			1) voluntary sustainability schemes
Other					1) Efforts to expand property rights, especially			

					community forest management			

[a] *Light grey text represents entries from AR5 which may be updated for the final version of the table.*

13.5.2 Evaluation Criteria

Evaluation of policies can be defined as "careful, retrospective assessment of merit, worth, and value of the administration, output and outcome of government interventions" (Vedung 2005). The inherent complexity of climate change policies calls for the application of multiple criteria, and reflexiveness of the analysis with regard to governments' and societies' objectives for policies (Huitema et al. 2011).

In AR5 WGIII, objectives for mitigation policies were grouped into environmental effectiveness, economic effectiveness, distributional equity, and feasibility. More recently, two more sets of objectives have received increasing interest: to what extent policy instruments can facilitate transformational change, such as a shift towards zero-emissions systems; and achieving co-benefits in addition to primary mitigation objectives. For packages of policies, an additional criterion is the coordination, coherence and consistency of such combinations.

These seven evaluation criteria are applied in the assessment of different policy instruments and policy packages, both with regard to their in-principle features and ex-post evaluation of policies in operation. A range of indicators can be applied depending on the particular instrument and context. Not all criteria are applicable or relevant to all policy instruments. Their relative importance depends on overall objectives and context, and will often differ between jurisdictions.

The evaluation criteria applied in this chapter are elaborated on in Table 13.3.

Table 13.3 Evaluation criteria for policy instruments and packages

Criterion	Explanation
Environmental effectiveness	Effect of a policy (or package of policies) on greenhouse gas emissions Effectiveness in short-term and long-term (temporal dimension) Effectiveness within and beyond the specific sector/jurisdiction/region that policy instruments are applied in (spatial dimensions and spillovers)
Economic effectiveness	Direct costs (or benefits) of emissions reductions e.g. from extra investment or higher ongoing costs Economic costs (or benefits) e.g. from lower (or higher) productivity or distortions in economic allocation Dynamic economic effects, e.g. economic cost now might mean economic benefit later Transaction costs of policy implementation
Distributional effects	Distribution of costs (and benefits) of a policy (or package of policies) between different groups within a society, e.g. between industry, consumers, taxpayers; between poor/rich households Distribution of costs and benefits between different regions Assessment of effect of specific policy design features to affect distributive effects, e.g. compensation to some groups, businesses or households Broader social effects, including on particular communities or regions
Transformative potential	Potential of a policy instrument (or package) to fundamentally alter the trajectory of emissions, e.g. leading to deep reductions or towards (net) zero emissions in the particular sector/source of emissions that it targets Potential of policy instrument or package to work with other dimensions of an enabling environment to facilitate a step change etc in emissions reductions observed Potential of a policy instrument (or package) to shift technologies, practices or products to a new paradigm of production or consumption. Dynamic aspects – longer term potential for a policy to be transformative even if at early stages it does not yet have transformative effects.
Co-benefits, adverse side-effects and interaction with SDGs	Effects of a policy instrument that reduces GHG emissions on other objectives, or a policy aimed at other objectives that has the effect of reducing emissions. Special emphasis on interaction of policies with achievement of sustainable development goals.
Feasibility	The ability of governments to implement a policy instrument in practice. May include technical, institutional, political, economic or social constraints.
For policy packages – coordination, coherence and consistency	Interactions between different policy instruments that operate simultaneously (with positive and negative effects on the criteria listed above). The extent to which combinations of policies in operation in parallel are coordinated with each other; the coherence between different policy instruments that affect the same emissions sources; Consistency of goals and implementation between different policies that are implemented within one jurisdiction.

13.5.3 Economic or market-based instruments

Economic or market-based instruments are a class of policies that change the relative prices of different production processes and goods, depending on their emissions intensity. They thus create financial incentives for producers and consumers to switch form high- to low-emissions options. They include taxes, permit trading schemes, and subsidies or subsidy removal.

13.5.3.1 Taxes

Taxes have been implemented as economy-wide or sector specific instruments. In each case, taxing policies have been used to place a per-unit charge on GHGs emitted or on energy consumed. Economy-wide carbon taxes levy a GHG-intensity-based charge on carbon emitting sources to incentivise cost-minimizing changes in consumer behaviour, production processes and technology use which abate emissions. Sector-specific taxes have taken a wide variety of forms including excise taxes most commonly on fuels and to a lesser extent on electricity. Not all sector-specific energy taxes encourage decarbonization, especially when there is a lack of differentiation between the carbon intensity of different fuel sources, which may inadvertently disincentivise low emission energy alternatives (OECD 2019). When implementing a tax, governments have the advantage of utilizing existing revenue collection mechanisms with little or no additional administrative costs (Calder 2015).

To date, 26 carbon taxes have been implemented or are scheduled for implementation by national and sub-national governments around the globe (Ramstein et al. 2019). Several northern European countries have relatively high carbon taxes. Sweden currently has the highest at approximately 140 USD per tonne of CO_2e. There is evidence that the tax promoted a shift towards biomass-fuelled district energy in the country (Johansson 2000). More recent analysis suggests that the tax significantly reduced gasoline emissions, whereas separate energy taxes reduced coal and LPG emissions (Shmelev and Speck 2018). Industries covered by the EU ETS face lower tax levels, and natural gas is taxed at half the current rate. Denmark currently has a carbon tax of 17 USD per tonne of CO_2, with manufacturing sectors being exempt for up to 90% of the tax. Norway has applied a carbon tax to multiple sectors within its economy, albeit at different stringencies. Scant empirical evidence exists on the emissions impacts of these Scandinavian carbon taxes (Stavins 2019).

Some revenues from carbon tax policies have been used to reduce personal and corporate income taxes, and other taxes, or have been applied to government sponsored investments in zero-emission energy and technology innovations (Coste et al. 2018; Gavard et al. 2018; Murray and Rivers 2015). The first carbon tax in North America was implemented in the Canadian province of British Columbia (BC) and is mostly revenue neutral with a proportion supporting green initiatives in the province (Government of British Columbia 2019a). Special considerations for moderate- and low-income households are built into the policy through the Climate Action Tax Credit, which provides residents under a specified income threshold with lump-sum tax credits throughout the annual cycle (Government of British Columbia 2019b). Concerns about the equity effects of carbon taxes can be addressed by revenue-recycling programs that focus on low-income recipients, whether in developed or developing countries Saelim (2019).

Despite the growing use of taxes to address GHG emissions, the OECD has noted that in no jurisdiction are taxes set at levels to drive substantial decarbonization on their own (OECD 2019). Some research suggests that carbon taxes are less politically acceptable than regulatory policies, subsidies, and voluntary agreements (Drews and van den Bergh 2016; Rhodes et al. 2017). (Criqui et al. 2019) suggested that political opposition may be tied to the public's confidence in government to manage fiscal revenues in a transparent, just, and effective way. Moreover, excessive carbon taxes would cause "carbon leakage" among emission intensive and trade-exposed industries, whereby carbon emitting processes and production are moved to international jurisdictions with less stringent climate policy. To minimize competitiveness risks for emissions-intensive, trade-exposed industrial facilities, the Canadian government has developed an Output-Based Pricing System in which emitting industrial facilities are subject to a carbon price on the portion of emissions that exceed an annual emissions intensity (Government of Canada 2018).

13.5.3.2 Emission permit trading

Emissions permit trading, or Emissions Trading Schemes (ETS), are increasing in use. By April 2019, 28 ETS for greenhouse gas reductions had been implemented or scheduled across national and subnational jurisdictions (World Bank 2019). Together with 29 carbon tax schemes, these carbon pricing initiatives covered 11 $GtCO_2$-equivalent per year, or about 20 percent of total global emissions, an increase from around 5 percent in 2011. Coverage of sectors and sources differs between schemes, but usually includes fossil fuel combustion in electricity and industry, and in some cases transport and buildings, or process emissions in industry.

Carbon prices differ substantially between schemes and over time. During 2018, about three quarters of emissions covered under ETS globally were at average price levels between 15 and 25 USD/tCO2-e, and about one quarter at prices below 5 USD/tCO2-e (World Bank 2019). These prices are well below the price range that is estimated to be required for achieving the Paris Agreement goals (Boyce 2018). Where carbon taxes are applied, these have been typically at higher rates than the trading prices in ETS. Total revenue from carbon pricing was approximately USD 44 billion in 2018, with just under half of this from ETS.

Except for four ETSs that lack an emissions cap, emissions in all other ETSs have declined over time (Haites 2018). ETS schemes are usually deployed in parallel with other mitigation policies, such as renewable energy support schemes and energy efficiency subsidies, technology and product standards, and in some cases additional carbon price signals in sectors covered by ETS. There is evidence of positive impacts on the economic performance of the firms covered by the ETS in Germany (Löschel et al. 2019). Distributional impacts of emissions trading schemes are sometimes addressed by allocating free permits to some emitters, or by redistributing some of the revenue from governments' permit sales to particular groups such as low-income households.

Several ETS have been reformed over time, typically making them more effective. For example in the third phase of EU ETS, a mechanism to soak up excess liquidity in the permit market was introduced (Hepburn et al. 2016) that has increased market prices, the annual reduction in the allowance cap has been sped up and the amount of emissions permits allocated for free to emitters has been reduced (Perino 2018). Implementation of ETS in jurisdictions including California, Québec and South Korea indicates institutional learning from prior systems, especially the EU ETS (Narassimhan et al. 2018).

New ETS are implemented or planned in a number of industrializing and developing countries. A national ETS for China is in preparation, set to be by far the largest ETS (Pizer and Zhang 2018; Stoerk et al. 2019; Jotzo et al. 2018; Qian et al. 2018). It follows pilot ETS in five cities and two provinces in China in operation since 2013, which have been used as opportunities to experiment with policy design and to improve emissions reporting procedures (Zhang et al. 2019). Evidence on the effectiveness of the pilot schemes is mixed (Deng et al. 2018; Lin and Jia 2017). Effective carbon pricing in China could have substantial co-benefits through reduction in air pollution (Li et al. 2018).

Box 13.4 Fossil fuel supply-side policies

Policies to reduce emissions from fossil fuel use are typically envisaged and implemented as policies that reduce the demand for fossil fuels, such as carbon taxes, emissions trading schemes and technology standards. The goal could in theory equivalently be achieved by targeting the supply of fossil fuels (Hoel 1994). See also 13.7.2.

'Supply-side policy' has found renewed interest in recent years (Lazarus and van Asselt 2018), including as a potential option for internationally harmonized policy (Piggot et al. 2018). It could take the form of restrictions on the amount of fossil fuel that is made available, or taxes levied on fossil fuel supply at the source. Both could result in higher prices and lower use of fossil fuels.

The distribution of economic rents would differ from those under demand-side policies. Revenue from or taxes, and potentially from higher prices, would accrue to producers and governments in fossil fuel producing and exporting countries. With harmonized supply constraints, suppliers might potentially reap sizeable benefits from better terms-of-trade (Richter et al. 2018).

The effectiveness of supply-side constraints depends on the extent of global fossil fuel supplies covered, and the ease with which other jurisdictions can ramp up fossil fuels supply. Existing analyses typically assume there would be a coalition of fossil fuel supplying countries motivated by the prospect of higher resource prices (Asheim et al. 2019). Supply-side policies have been hypothesized to have the potential to induce, sustain and broaden international policy cooperation because of greater public support and relative ease of policy monitoring (Green and Denniss 2018).

13.5.3.3 Offset systems

Offset schemes are designed to incentivize emissions reductions in specific activities, typically on a project-by-project basis. The credits for emissions reduced may be purchased by companies to offset their liabilities under emissions trading schemes, governments to acquit against national emissions targets, or individuals or businesses as a voluntary measure.

The world's largest offset scheme is the Clean Development Mechanism (CDM), a mechanism under the Kyoto Protocol. From 2001 to August 2019, the CDM had produced about 2,000 MtCO_2-e of offsets from 3,260 projects (about 5,000 further projects are registered but had no credits issued) (UNFCCC 2019). Western European countries and Japan used some of the credits to use towards Kyoto Protocol emissions targets (Shishlov et al. 2016).

Offset schemes also exist as national instruments. An example is the Australian Emissions Reduction Fund (Climate Change Authority (Aus) 2017), where the government is the sole buyer of credits. China has established the 'Chinese Certified Emission Reduction' scheme, similar to the CDM but as a domestic offset mechanism (Lo and Cong 2017; Zhou et al. 2019).

Offset schemes require quantification of emissions savings compared to what would otherwise have been the case. Observed emissions levels under a project are compared to a baseline, which may over- or underestimate emissions savings. Regulators also need to consider whether a project claiming offset credits might have taken place anyway ('additionality'), and possible increases in emissions outside the project boundary ('leakage') (See Section 13.6.2). To safeguard environmental effectiveness, baselines need to be particularly stringent if uncertainty is high or the emissions price is low (Bento et al. 2016).

Available evidence suggests that many offset projects may have happened anyway or are over-credited, casting doubt about the extent of emissions reductions claimed (Cames et al. 2016; Burke 2016). Existing offset schemes provide important lessons for safeguarding the environmental integrity of possible future market mechanisms under the Paris Agreement (Michaelowa et al. 2019). Ex-post analysis further suggests that the CDM has affected international technology transfer in many instances (Murphy et al. 2015; Gandenberger et al. 2016), but that its contribution to sustainability objectives has generally been small (Dirix et al. 2016; Watts et al. 2015).

13.5.3.4 Subsidies for mitigation

Subsidies for mitigation encourage individuals and firms to invest in low-emissions assets or innovation. Governments routinely provide direct funding for basic research, subsidies for R&D to private companies, and co-funding of research and deployment with industry (Dzonzi-Undi and Li 2016). Research subsidies have been found to be positively correlated with green product innovation in a study in Germany, Switzerland and Austria (Stucki et al. 2018). Government subsidies for R&D have been found to greatly increase the green innovation performance of energy intensive firms in China (Yu et al. 2019).

Subsidies of different forms are often provided for emissions savings investments to businesses in energy, industry and agriculture, and also for the retrofit of buildings. Tax credits can be used to encourage firms to produce or invest in low-carbon emission energy and products with lower cost of low-emission equipment. Investment subsidies have been found to be more effective in reducing costs and uncertainties in solar energy technologies than production subsidies (Flowers et al. 2016).

Subsidies to households have been provided extensively and in many countries for the deployment of rooftop solar systems, typically using 'feed-in tariffs' that provide a payment for electricity generated above the market price (Pyrgou et al. 2016). Such schemes have proven effective in deploying household level renewable energy, but lock in subsidies for long periods of time and in some cases provide subsidies at higher levels than would be required to motivate deployment. Many governments have also provided subsidies for the purchase of electric vehicles, including with strong effect in China (Ma et al. 2017), sometimes at relatively high rates (Kong and Hardman 2019).

Box 13.5 Technology and R&D policy

Deep reductions in greenhouse gas emissions will require further technological innovations. Private businesses tend to under-invest in R&D because of market failures (Geroski 1995), hence there is a case for governments to support research and technology development. A range of different policy instruments are used, including government funding, preferential tax treatment, intellectual property rules, and policies to support the deployment and diffusion of new technologies. Chapter 16 treats innovation in-depth, including technology and R&D policy.

13.5.3.5 Fossil fuel subsidies

Governments have numerous ways of subsidizing fossil fuel consumption and production. They can affect prices through market intervention, assume production risks, give tax breaks, or provide government-supplied goods, services, and natural assets at reduced rates (Burniaux and Chateau 2014). Fossil fuel consumption subsidies are most prevalent in developing countries and are implemented by artificially lowering energy costs to end-users through direct wealth transfers from government revenues. Fossil fuel production subsidies reduce extraction and processing costs of petroleum products and coal, which can manifest as tax breaks or preferential loans to fossil fuel companies or, in some cases, direct financial support via state-owned energy corporations.

The existence and magnitude of production subsidies and their interaction with consumption subsidies are not always straightforward, as a subsidy can, for example, be defined to include the absence of taxes that would normally be levied. The IEA collectively estimates the value of all subsidies as the difference between fossil fuel end-use prices paid by consumers and reference supply prices representing full supply costs (i.e. price-gap approach). In 2017, it estimated total subsidies using this method at over 300 billion USD globally (IEA 2018).

A majority of studies indicate that the removal of fossil fuel subsidies worldwide should reduce global GHG emissions in the long term, although the magnitude of the expected emissions reduction is uncertain as measurements differ across studies. For example, IMF researchers calculate that if fuel prices were set at 'efficient levels' in 2015, estimated global GHGs would have been 28% lower that year (Coady et al. 2019), whereas researchers at the International Institute for Applied Systems Analysis (IIASA) estimates that subsidy removal would lead to a 1% - 4% GHG emission decrease by 2030 (Jewell et al. 2018) and OECD supported research estimates a 10% reduction by 2050 (Burniaux and Chateau 2011).

From a social perspective, fossil fuel consumption subsidies have been documented to be regressive and detrimental to economic stability and has promoted inequalities by providing disproportionate financial support to higher income households capable of consuming greater quantities of energy (Arze del Granado et al. 2012; Rentschler 2016).

However, despite the long term social and environmental benefits of subsidy reform, policies closely linked to the prevailing energy system may be subject to strong path-dependencies caused by the longevity of existing technological, infrastructural and institutional structures in any given economy. Opposition for reform is likely to come from a variety of constituencies that depend upon the existence of subsidies which can range from certain incumbent fossil fuel industries to farmers to lower income households reliant on fossil fuel subsidies for economic stimulus and poverty reduction (Fouquet 2016). Subsidy reforms can lead to short term energy price shocks that harm the most economically vulnerable (Rentschler and Bazilian 2017).

13.5.3.6 Border carbon adjustments

Import taxes on carbon-intensive goods could be used by countries with domestic mitigation policies to encourage or force other countries to likewise regulate their own industries (Anouliès 2015). The option of such strategic use of BCAs has seen increasing political interest, including as a complement or alternative to conventional trade tariffs in an age of rising protectionism (Mehling et al. 2018).

Traditionally, border carbon adjustments (BCAs) have been considered not as an instrument of strategic policy, but as a way to address international competitiveness effects of mitigation policies. Charges on imports of emissions intensive commodities and goods, or export rebates, would even out the effective carbon penalty. As a means to avoid 'carbon leakage' (see also 13.7.2), BCAs are an alternative to output-based free allocation of emissions allowances under permit trading, which is often used to compensate producers of emissions intensive traded products for carbon costs (Böhringer et al. 2017).

The size of the carbon tax levied on imports can be based either on the carbon content of the domestically produced goods, or the imported products and the effect of carbon policies that might apply to these imports. The latter is difficult to estimate, and the setting of product benchmarks would in either case be subject to many different economic interests (Cosbey et al. 2019).

The effect of BCAs on the economy and emissions in countries that apply them depends in large measure on how the revenue from import tariffs is used (McKibbin et al. 2018). In countries that have BCAs levied on their exports, domestic prices may fall. This may mean that the optimal rate for a BCA is lower than the domestic carbon tax (Balistreri et al. 2019).

While some forms of BCAs are likely to be legal under international trade rules, there remain legal uncertainties in particular with regard to export subsidies (Mehling et al. 2019; Weber 2015).

13.5.4 Regulatory instruments

Standards and regulations are used by governments to directly prescribe a process or outcome. Non-compliance will normally carry a penalty. Regulatory instruments can be classified as performance standards, which may allow flexibility including trading in markets, and the more prescriptive approach of technology standards.

13.5.4.1 Performance standards, including trading

Unlike technology standards, which regulate specific technologies, processes, or products, performance standards incorporate flexibility by granting regulated entities freedom to choose the technologies and methods they use for reaching an objective. Tradable performance standards (also called market-oriented standards) incorporate even greater flexibility by allowing trading between regulated entities, focusing on a market outcome where entities collectively achieve a sectoral target. Entities can trade compliance credits or permits amongst themselves, with under-performers buying from overperformers, thereby equating marginal abatement costs and reducing the aggregate cost of compliance relative to uniform (i.e. non-tradable) performance standards (Fischer 2008). Indeed, the line between regulatory approaches and economic instruments continues to blur with the ongoing development of market-oriented innovations in regulatory policy design.

Tradable performance standards have been applied to numerous sectors including electricity generation, transportation energy, personal vehicles, building energy efficiency, appliances, and large industry. A clean electricity standard (CES) is one such policy in the electricity sector. A CES requires that a minimum percentage of electricity is generated from specified 'clean' electricity generation sources each year. Each electricity provider is assigned the same minimum clean electricity generation requirement. However, in its most flexible policy design, providers can choose how they meet this minimum requirement—they can meet the minimum themselves, or they can underachieve and instead purchase credits from others who have exceeded the minimum.

Another prominent example of this policy mechanism is the low carbon fuel standard (LCFS), originally implemented by California in 2010. It requires the average life-cycle carbon intensity of energy sold for use in transportation to decline over time. The standard covers full-cycle emissions from liquid and gaseous fossil and bio- fuels, hydrogen, and electricity used in transportation. Like the CES, the LCFS allows providers to trade credits amongst themselves, with high carbon intensity providers cross-subsidizing low carbon intensity providers. Another transportation sector standard designed to incorporate flexibility is the vehicle emissions standard. One version of this standard, the zero-emission vehicle mandate, requires a growing average market share of zero-emission vehicles sold by retailers in a given jurisdiction.

While it is clear that incorporating trading and other flexibility mechanisms improves the economic efficiency of standards, research has found that tradable performance standards are less economically efficient than carbon pricing (Zhang et al. 2018; Fox et al. 2017; Chen et al. 2014; Holland et al. 2015; Quirion and Giraudet 2008), although efficiency appears to improve under high policy stringency scenarios and when technological flexibility is maximized (Vass and Jaccard 2017).

A major insight from real-world policy analysis is the importance of weighing multiple criteria, including political acceptability, in policy design. While carbon pricing has economic efficiency advantages, it appears to experience less political acceptability than regulatory and voluntary policy (Drews and van den Bergh 2016). In a survey of U.S. and Canadian citizens, Lachapelle et al. (2014) found that carbon taxes receive the highest levels of opposition while CESs receive the highest levels of support. Similarly, in a Canadian survey, Rhodes et al. (2017) found significantly higher support for tradable performance standards than for carbon taxes or cap-and-trade. Carbon pricing has also been found to have low levels of support in Switzerland (Tobler et al. 2012) and Taiwan (Lam 2015). Policy labelling (i.e. avoiding the term 'tax') and revenue recycling mechanisms appear to be important considerations for improving the public acceptability of carbon taxes (Amdur et al. 2014; Rabe and Borick 2012), as does incorporating pricing into a policy package approach (Wicki et al. 2019).

13.5.4.2 Technology standards

While performance standards establish a target for emissions intensity or category of technologies (e.g. low emission, renewables) that regulated entities must achieve (either individually or together as group), technology standards take a more prescriptive approach by specifically dictating the means of compliance. They typically feature one of three possible approaches: requirements for specific pollution abatement technologies; requirements for specific production methods; or requirements for (or banishment of) specific goods such as energy efficient (or inefficient) appliances. Technology standards are often referred to as command-and-control standards, prescriptive standards, or design standards.

Technology standards tend to score lower in economic efficiency than carbon pricing and their performance standard counterparts (Besanko 2018). By mandating specific compliance pathways, they risk locking in a high-cost pathway when lower cost pathways are available or may emerge through market incentives. Furthermore, because they do not incorporate credit or permit trading mechanisms, marginal abatement costs are inequal across regulated entities, diminishing economic efficiency. The technology lock-in created by technology standards also stifles product innovation compared to performance standards by 'choosing winners' and blocking alternative technologies from entering the market (Sachs 2012).

Benefits of technology standards include the speed with which they can change a market, and depending on their approach, their legislation can be straightforward to design, and their immediate results can be quite predictable—for example the ban of products under a specified performance threshold (Montgomery et al. 2019). And although technology standards rank poorly in terms of economic efficiency, they still can lead to long-term profitable gains in energy efficiency if applied to appropriate targets (Gillingham et al. 2006).

13.5.5 Other policies

While it is increasingly acknowledged by political leaders that wholesale decarbonization must involve the application of some combination of carbon pricing and regulations, less compulsory policies can also make a contribution. These "other policies" can help with accelerating and supporting the necessary socio-economic transformation implied by a dramatic reduction in GHG emissions.

13.5.5.1 Information programs

Information programs, including energy efficiency labels, energy audits, certification, carbon labelling and information disclosure, may reduce GHG emissions by promoting better informed choices by firms and households. A common feature of information programs is that they attempt to induce technology choices and behavioural changes that are voluntary; thus there is no financial penalty as with carbon pricing and no legal penalty as with regulations. Because of this, information programs can play a complementary role to stronger policies, but they are ineffective if employed as the lead policy for deep decarbonization.

Energy audits provide tailored information about potential energy savings through available technologies, and benchmarking of best practices through a network of peers. Typical examples include the United States Better Buildings Challenge that has provided energy audits to support US commercial and industrial building owners, energy savings have been estimated at 18% to 30% (Asensio and Delmas 2017); and Germany's energy audit scheme for SMEs achieving reductions in energy consumption of 5 to 70 percent (Kluczek and Olszewski 2017).

Carbon labelling is the practice of communicating directly to potential consumers the greenhouse gas emissions associated with a product or service. Typical applications include cars and appliances, but also food (Camilleri et al. 2019) and tourism products (Gössling and Buckley 2016).

13.5.5.2 Government provision

Public provision and planning can play an important role in climate change mitigation. Governments determine many aspects of infrastructure planning and decision making, fund investment in areas such as energy, transport and the built environment, and fund research. Public purchasing for governments' own use of goods, construction and services can also promote mitigation goals, through green public procurement initiatives. Such policy initiatives can be and are undertaken by regional, national, provincial and local governments.

Governments need to heed guidelines for public procurement which usually mandate cost effectiveness in public purchasing but may not spell out climate change as a factor in procurement decisions. In the

European Union, procurement law usually allows and on occasion mandates climate change consideration in public purchasing (Martinez Romera and Caranta 2017). In practice, awareness and knowledge of 'green' public procurement techniques and procedures is at the heart of uptake of climate-friendly procurement, and conversely the greatest barrier where it is absent (Testa et al. 2016).

Climate-friendly public procurement initiatives are not limited to developed countries. For example, green procurement for buildings has been undertaken in Malaysia (Bohari et al. 2017). Taiwan has had a green public procurement law in place since 1997, and its implementation has contributed to reduced emissions intensity of the economy (Tsai 2017).

Governments can also promote low-emissions investments through public-private partnerships and 'green banks' (David and Venkatachalam 2019). Green banks typically are government funded financial entities that provide loans on commercial or concessional basis for environmentally friendly private sector investments (Ziolo et al. 2019).

The literature on green public procurement has largely focused on implementation, and research of its effectiveness and performance according to other criteria compared to other climate change mitigation policy instruments is not yet extensive (Ziolo et al. 2019).

13.5.5.3 Divestment

Divestment refers to the dis-investment by large institutional investors and other financial entities from stocks in companies involved in fossil fuel extraction, and other financial investments in high emissions assets. Divestment is predominantly promoted by civil society organisations, using a range of strategies to shame, pressure, facilitate, and encourage investors to divest (Ayling and Gunningham 2017).

The divestment movement gained influence when the underlying moral arguments were combined with arguments about the financial risks inherent in fossil fuel investments (Blondeel et al. 2019). A prominent case of partial divestment is that of the Norwegian sovereign wealth fund, a large fund with longstanding ethical investment guidelines that were amended to include exclusions for fossil fuels (Nilsen et al. 2019).

Divestment can be understood as an 'anti fossil fuel norm', which has effect through political mobilization and peer pressure (Green 2018). Announcements by investors that they will divest have been shown to negatively affected the share price of listed companies, in a large sample of such announcements (Dordi and Weber 2019).

Efficient market theory would suggest that restricting portfolio choice would tend to negatively affect risk-adjusted returns. However, recent empirical studies indicate that portfolios without fossil fuel stocks on balance performed equally well or better than benchmark portfolios, in various settings. These findings hold for the US S&P500 in studies using data from 2005 onwards (Halcoussis and Lowenberg 2019) (Henriques and Sadorsky 2018), longer time periods for the broader US stock market (Trinks et al. 2018), for the Canadian stock market (Hunt and Weber 2019), for a comparison of Dutch pension funds with different carbon footprints (Boermans and Galema 2019), and for stocks excluded from the Norwegian and Swedish sovereign wealth funds (Hoepner and Schopohl 2018). Available evidence does not determine why exclusion of fossil fuel stocks improves portfolio performance or leaves it unchanged, and future relative performance is uncertain.

Box 13.6 Financial Disclosure of Carbon Exposure and Climate Risk

Financial accounting standards are increasingly used as frameworks to encourage or require companies to disclose how the transition risks from shifting to a low carbon economy and physical climate change impacts may affect their business or the value of their assets. The most prominent such standard was issued in 2017 by the Financial Stability Board's Task Force on Climate-related Financial Disclosures

(TCFD 2017). It aims for "voluntary, consistent climate-related financial risk disclosures for use by companies in providing information to investors, lenders, insurers, and other stakeholders".[1] The Financial Security Board is an international body that monitors and makes recommendations about the global financial system.

The goal of such financial disclosure is to reflect climate risk in financial asset pricing and investment decisions. Disclosure should result in investor pressure for better practices, less demand for financial investment in companies that are highly exposed, positive incentives for companies to improve their carbon and climate change exposure, and ultimately regulatory standards for climate risk (Eccles and Krzus 2018).

Traditionally, corporate reporting has treated climate risks in a highly varied and often minimal way (Foerster et al. 2017). Comprehensive reporting frameworks would be expected to yield an improved information base. However, financial disclosure alone may not be sufficient for an adequate financial market response to climate risk, because investment choices are also affected by behavioural practices and structural barriers to change (Ameli et al. 2019).

13.5.5.4 Voluntary agreements

Voluntary Agreements (VAs) result from negotiations between governments and industrial sectors that commit to achieve climate goals. VAs have been used as a means to attain reduction targets in GHG emissions, energy efficiency and renewable energy, and as a mechanism to coordinate carbon trading programs and technology certification (Mundaca and Markandya 2016). Historically VAs between industry and government to achieve environmental goals were introduced within OECD countries during the 1960s and the early 1970s. VAs are flexible instruments that reduce enforcement and administrative costs to government and allow individual businesses to innovate approaches to pollution abatement that are tailored to their specific needs (OECD 2000).

The two types of VAs involving both government and industry are: 1) Public voluntary programs **(**PVP) where a government regulator develops programs to which industries and firms may choose to participate on a voluntary basis (Lyon and Maxwell 2003, 2004; Macdonald et al. 2006) and 2) Negotiated Agreements (NA) where the regulator bargains with individual industries or firms to produce contracts that are ratified by both parties (Grepperud and Pedersen 2004; Macdonald et al. 2006). PVPs have been implemented in numerous countries, notably in the United States and the European Union. For example, the United States Environmental Protection Agency introduced numerous voluntary programmes with industry to offer technical support in promoting energy efficiency and emissions reductions, among other initiatives (United States Environmental Protection Agency 2017). A European example is the EU Ecolabel Award program, introduced in 1992, to label products with reduced adverse environmental impact for consumers to which manufactures may choose to apply (European Commission 2019). NAs have been historically used to the greatest extent in Japan and Europe, but more recently the practice as expanded globally. Most NAs are utilized to define emissions and waste abatement targets for different sectors on a case by case basis. (Glachant 2007; OECD 2000).

VAs are often implemented in conjunction with market-based or regulatory instruments. In some cases, industries are permitted to negotiate VAs as partial fulfilment of a regulation (Langpap 2015; Rezessy and Bertoldi 2011). For example, the Netherlands have permitted industries participating in VAs to be exempt from certain energy taxes and emissions regulations (Veum 2018). When used as part of a

[1] https://www.fsb-tcfd.org/about/, accessed 16 Dec 2019.

greater policy framework, VAs can enhance the cost effectiveness of individual firms in attaining pollution reductions while mandatory pricing and regulations act to incentivize industry participation in the agreement (Dawson and Segerson 2008).

13.6 Policy mixes and governance

13.6.1 Policy integration, interactions, mixes, and governance

Climate change is a complex problem that cuts across policy domains, governance levels and established jurisdictions (Adelle and Russel 2013; Dupont 2015; Candel and Biesbroek 2016) and requires consideration of multiple climate and non-climate objectives simultaneously (Bhardwaj et al. 2019). This understanding of the problem has led to a broader literature on 'climate policy integration' that seek to root policy action in conceptual clarity -- what is the framing of the objective sought and how does it interact with other objectives – and institutional clarity – what forms of coordination across policy domains and scales are available and best suited to addressing climate change (Adelle and Russel 2013)?

The starting point for consideration of cross-cutting problems like climate change lies upstream of policy formulation. Candel and Biesbrock (2016) suggest a four part framework for considering policy integration. First, the policy frame or problem statement can help shape understandings of the problem and therefore alternative solutions; for example, a greenhouse gas limitation framework versus a co-benefits framing would likely yield different approaches. Second, the range of actors and institutions involved in climate governance – the policy subsystem – and the density of interactions among them determines the scope and range of actions. Third, the goals articulated, the level at which it is articulated – system wide or individual sub-systems such as energy – and the coherence with other related policy goals such as energy security or energy access, are salient to integration. Fourth, the adoption of specific policy instruments is the final element in the framework.

The policy integration framework provides a heuristic to consider policy design processes. In practice, combinations of policies often occur through a layering process, driven by political circumstances and external drivers. Table 13.4 illustrates the prevalence of a range of different policies across various policy domains. The table illustrates different prevalence across domains; for example, renewable energy policies are widely adopted while agriculture and land-use policies are much less so.

Table 13.4. Percentage share of prevalence (number of countries) of policies in 30 major emitting countries

This table shows the prevalence of GHG reduction policies by the G20 countries (European Union considered as single country). Numbers in brackets indicate the prevalence of policies (i.e. number of countries having such policies) in respective focus areas (columns) and sectors (rows). The shading gradient from orange to green correlates with low to high prevalence respectively. Source: climatepolicydatabase.org.

Low coverage ---------------------- High coverage

0% 100%

	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
General	Climate strategy (53%)				
	GHG reduction target (87%)				
	Coordinating body for climate strategy (67%)				
	Support for low-emission RD&D (53%)				
		National energy efficiency target (57%)	Renewable energy target (67%)		
Electricity and heat		Support for highly efficiency power plants (including codes and standards and fiscal/financial incentives) (70%)	Renewable energy target for electricity sector (83%)	CCS support scheme, including fiscal/financial incentives and infrastructure investment (23%)	
		Reduction obligation schemes (10%)	Support scheme for renewables (including green certificates, fiscal/financial incentives, obligation schemes, net metering or direct investment) (87%)		
			Grid infrastructure development (60%)		
			Sustainability standards for biomass use (10%)		
	Overarching carbon pricing scheme or emissions limit (23%)				
	Energy and other taxes (10%)				
	No fossil fuel subsidies (33%)				
Industry	Strategy for material efficiency (including product standards and other requirements) (27%)	Support for energy efficiency in industrial production (including voluntary approaches, fiscal/financial incentives, obligation schemes or white certificates) (53%)	Support schemes for renewables (including fiscal/financial incentives, green certificates, obligation schemes) (27%)	CCS support scheme (including fiscal/financial incentives and infrastructure investment) (27%)	Landfill methane reduction (17%)
		Energy reporting and audits (57%)	Sustainability standards for biomass use (3%)		Incentives to reduce CH4 from oil and gas production (20%)
		Minimum energy performance and equipment standards (50%)			Incentives to reduce N2O from industrial processes (13%)
					Incentives to reduce fluorinated gases (20%)
	Overarching carbon pricing scheme or emissions limit (23%)				
	Energy and other taxes (30%)				
	No fossil fuel subsidies (3%)				
Buildings	Urban planning strategies (including infrastructure investments) (17%)	Building codes and standards and fiscal/financial incentives for low-emissions choices in heating, cooling, hot water, and cooking (60%)	Support scheme for heating and cooling (13%)		
		Minimum energy performance and equipment standards for appliances (60%)	Support scheme for hot water and cooking (10%)		
			Sustainability standards for biomass use		
	Energy and other taxes (10%)				
	No fossil fuel subsidies (10%)				
Transport	Urban planning and infrastructure investment to minimize transport needs (37%)	Minimum energy/emissions performance standards or support for energy efficient for light duty vehicles (40%)	Biofuel target (30%)	Support for modal share switch (30%)	
		Minimum energy/emissions performance standards or support for energy efficient for heavy duty vehicles (27%)	Support schemes for biofuels (including fiscal/financial incentives and obligation schemes) (53%)	E-mobility programme (17%)	
			Sustainability standards for biomass use (10%)		
	Tax on fuel and/or emissions (50%)				
	No fossil fuel subsidies (23%)				
Agriculture and forestry	Standards and support for sustainable agricultural practices and use of agricultural products (33%)				
	Incentives to reduce CO2 emissions from agriculture (23%)				
	Incentives to reduce CH4 emissions from agriculture (23%)				
	Incentives to reduce N2O emissions from agriculture (23%)				
	Incentives to reduce deforestation and support for afforestation/reforestation (63%)				

Note to reviewer: For the SOD, this table will reflect the share of emissions covered by each policy item rather than the prevalence in G20 countries.

This section explores different literatures that provide understanding of diverse and overlapping policies to address climate mitigation, and the empirical experience with these policies and policy mixes. The diversity of policies across domains and scales, and the reality of policy layering leads to a discussion, in Section 6.2, of the interaction effects when multiple policies operate simultaneously. Section 6.3 explores the emergent literature on policy mixes, which seeks to understand how combinations of policies can be intentionally made to work in an integrated fashion. Finally Section 6.4 examines the larger governance context within which policies and policy packages operate, and which can shape their effectiveness.

13.6.2 Empirical evidence on policy interactions

Climate policy packages can lead to policy interactions, where more than one policy applies to the same sector of the economy. These interactions can be problematic, where one policy hinders the success of another, ranging from marginal effects resulting in redundancies to cases where an additional policy actually results in an increase in emissions (IEA 2017). Interactions can also be positive, where the policy package achieves greater reductions than the sum of each policy individually. Thus, a real challenge for policymakers is deciding whether the emissions reduction potential of additional policies warrants the additional economic costs and administrative complexity they may confer. The challenge is heightened when multiple levels of government pursue policies that overlap and interact (Hood 2013).

The problem of leakage has been well explored in the context of cap and trade programs, and their interaction with standards. If a standard is binding and applies to a sector under the cap, the emissions reduction that results from the standard may be offset by increased emissions in other sectors under the cap (Schatzki and Stavins 2012). This emissions leakage is known as the "waterbed effect", a metaphor that relates the way water moves around in a waterbed to how emissions move around in different sectors under a cap-and-trade system—when a portion of a waterbed is depressed, the total amount of water doesn't decrease, it just moves and rises somewhere else (Perino 2018).

The problem is illustrated by California, which has taken a policy package approach. The state has introduced an economy-wide cap-and-trade program alongside a set of sector-specific tradable performance standards including a low carbon fuel standard, a vehicle emission standard, a zero-emission vehicle mandate, and a renewable portfolio standard. In addition to these, the state also implements a range of energy efficiency standards, technology standards, investments, and subsidies (Mazmanian et al. 2019).

California's cap-and-trade program – aimed at 40% reduction by 2030 relative to 1990 levels -- was introduced in 2012 and covers 85% of the state's emissions, including electricity generation, large industry, and most transportation fuels and building energy. In addition, California's low carbon fuel standard (LCFS) was implemented in 2010 with the target of reducing average life-cycle carbon intensity of energy used in transportation by 10% by 2020 and 20% by 2030 relative to 1990 levels The interaction between the state's cap and trade program and LCFS can result in cross-sector or "internal" emissions leakage from the LCFS to other sectors under the cap (Stavins 2019; Lade and Lin Lawell 2015). The state's renewable portfolio standard, adopted in 2002 with targets of 50% by 2030 and 100% by 2045, is another tradable performance standard that can interact with cap-and-trade, resulting in internal leakage (Thurber et al. 2015; Tsao et al. 2011).

China provides another set of examples. The ETS is expected to play a central role in China's climate action. However, the whole policy package of China's low carbon transformation needs coordination at both political and technical levels to achieve the full benefits of emissions trading (Duan et al. 2017). Some mandatory targets, such as the provincial carbon intensity reduction targets have affected marginal abatement costs and hence have influenced the optimal choice of price control or quantity control policies (Qian et al. 2017). In parallel with the pilot ETS, some entities in Shanghai are also regulated by another important policy, namely the 10,000 Enterprises Energy-Saving and Low-Carbon Actions (10,000 Programme). The ETS pilot achieved full compliance, whereas 15–17% of the 10,000 Programme's target entities fell short each year (Stensdal 2019). The interaction between government and companies are different in different institutional settings, which has led to the partial failure of the energy efficiency standards.

There are unfortunately few estimates of internal leakage in the literature. However, the available evidence indicates that reductions generated by a cap and trade programme are not fully offset by emissions elsewhere. Full offset would mean that emissions by participants in a cap and trade program are equal to the cap or that the cap is not binding and the allowance price is zero. Virtually all trading programs have accumulated allowance surpluses because emissions have been less than the cap (Haites et al. 2018). While allowance prices in a few systems have been very low at times, they have not been zero. For example, numerous assessments of the EU ETS have concluded that it has reduced emissions (see (Haites et al. 2018)for a review), although virtually none estimate the shares of the reductions due to the ETS versus other policies and exogenous developments such as fossil fuel price changes and economic recessions.

Internal leakage effects can be partially remediated by the incorporation of a well-designed market stability reserve, a mechanism that enables the regulator of the cap-and-trade policy to remove surplus allowances(Edenhofer et al. 2017). If designed and implemented properly, market stability reserves have the potential to "puncture the waterbed" and help eliminate the emissions reduction redundancy effect of policy packages involving emissions trading schemes and standards (Perino 2018). Careful attention to initial cap setting is also critical, as is the ability to alter the cap over time (Hood 2013). There is limited understanding as to how reserves have corrected for leakage in cap-and-trade systems in various jurisdictions, warranting further study for optimal policy package design (Perino et al. 2019).

It is important to note that this policy package leakage phenomenon is not a concern when standards are implemented alongside a carbon tax. However, as with cap-and-trade policy packages, this approach scores lower in economic efficiency for a given level of emissions reduction due to differences in the marginal abatement costs imposed by standards in one sector of the economy versus another (Goulder and Stavins 2011). Even with these considerations, jurisdictions may wish to pursue a policy package approach to account for well-documented political acceptability drawbacks of carbon taxes (Rabe and Borick 2012; Rhodes et al. 2017). Another perspective is that the cost of leakage with cap and trade systems is a premium to ensure that target reductions will be achieved. From this perspective, California implemented various regulatory policies to deliver most of the target emission reductions and implemented its ETS as an insurance policy to help ensure the reductions would be achieved (Bang et al. 2017).

In addition to leakage across sectors, emission leakage can also result in a cross-jurisdictional fashion. For example, California's LCFS interacts with the federal Renewable Fuel Standard (RFS), a tradable performance standard that specifies quantities of biofuels that must be used each year in the US (Schatzki and Stavins 2012). As the LCFS increases the sale of biofuels in California, the demand for biofuels to comply with the nation-wide RFS is relaxed elsewhere in the country, preventing the California LCFS from causing additional demand for biofuels at the national level. However, because the LCFS regulates the life-cycle emissions intensity of fuels, an aspect the RFS ignores, the LCFS may result in reduced overall emissions by favouring low-emission biofuels over high-emission biofuels, resulting in cross-jurisdictional emissions leakage less than 100% (Whistance et al. 2017).

Similarly, due to jurisdictional issues, estimated leakage rates for electricity generation for the California and Regional Greenhouse Gas Initiative (RGGI) ETSs are close to 50%. Neither system is able to effectively regulate the sources of imported electricity. California tries to do so, but the rules can be circumvented by ``resource shuffling`` leading to a leakage estimate of 45% (Caron et al. 2015). For RGGI about half of the reductions can be attributed to the trading program, implying leakage of roughly 50% (Murray and Maniloff 2015; Fell and Maniloff 2018).

13.6.3 Policy mixes: comprehensiveness, balance and consistency

The literature on policy interaction (Sec 13.6.2) is motivated by the objective of most efficiently addressing market failures, such as the negative externalities of greenhouse gas emissions (Edenhofer et al. 2013; Lehmann et al. 2019; Jacobsson et al. 2017). In addition, however, decarbonisation also requires an awareness of structural as well as transformational system failures (Weber and Rohracher 2012). Structural changes associated with low-carbon innovation and investment include building low-carbon infrastructure, such as aligning electricity grids and storage with the requirements of new low-carbon technology, and adjusting existing institutions to low-carbon solutions, for example, by reforming electricity market design (Bak et al. 2017; Patt and Lilliestam 2018). Transformation requires signalling a clear direction (e.g. through the elaboration of shared visions, unambiguous guidance for low-carbon solutions, and coordination of actors involved in the transformation process) and to overcome policy silos through better coordination across policy arenas (e.g. climate policy and industrial policy) and governance levels (e.g. national and regional level) (Uyarra et al. 2016; Nemet et al. 2017). While carbon pricing may be salient to these transitions, it is unlikely in isolation to able to address all of these failures (Tvinnereim and Mehling 2018; del Rio 2017).

An emergent multi-disciplinary literature on policy mixes – also referred to as policy packages or policy portfolios – seeks to examine this broader framing of sustainable low-carbon transitions that encompass market failures, structural change and transformation, in various sectors. These include energy (Rogge et al. 2017), transport (Givoni et al. 2013), industry (Scordato et al. 2018), agri-food (Kalfagianni and Kuik 2017) and forestry (Scullion et al. 2016).

In many of these sectors, governments typically pursue multiple policy objectives beyond GHG mitigation alone; for example, climate mitigation in energy is also associated with other objectives such as energy security, air quality, and energy access (Bhardwaj et al. 2019). Integrated model studies suggest that well designed transformative climate policy mixes paying attention to the co-benefits of climate mitigation for non-climate policy objectives can reduce the overall cost of achieving multiple sustainability objectives (von Stechow et al. 2015). The existence of such multiple policy objectives provides another rationale for coordination in policy mix design, as it allows policy makers to strive for synergies and to minimize trade-offs (Howlett and del Rio 2015; Obersteiner et al. 2016).

Clear goal setting, including long-term targets, are an important element of climate policy mixes as they provide credibility and guidance to strategic investments and innovation (Schmidt et al. 2012). However, to be credible and effective they need to be backed up by stringent and consistent policy instruments (Rogge and Schleich 2018). Several attributes have been identified in the literature to assess the extent to which policy mixes are believable and reliable (Jakob 2017; Nemet et al. 2017): the design of rules (e.g. are targets reviewed periodically?); transparency and trust (e.g. does an independent authority oversee target achievement?); political economy and distribution (e.g. are policies compensating losers of stringent climate policy?); and robustness (e.g. are multiple policy instruments in place, potentially also at different governance levels?). Empirical evidence for Germany demonstrates that companies' perceptions of the credibility of a climate policy mix can be linked not only to the existence of well aligned instruments but also to the coherence of climate policy making processes and the existence of ambitious phase-out policies for societally undesirable energy technologies (Rogge and Dütschke 2018).

Policy mixes may be evaluated based on a broad set of design criteria, including comprehensiveness, balance and consistency. Comprehensiveness assesses the extensiveness of policy mixes, including the breadth of system and market failures it addresses. For example, for OECD countries it has been shown that a comprehensive instrument mix which balances technology push instruments (such as public R&D) and demand pull instruments (such as energy tax) is beneficial for innovation in energy efficiency (Costantini et al. 2017). For example, instrument mixes that include carbon pricing, policies supporting new low-carbon technologies and a moratorium on coal-fired power plants may not only be politically more feasible than stringent carbon pricing, but may also limit efficiency losses and lower distributional impacts (Bertram et al. 2015b). Balance captures whether policy support is balanced across different instrument purposes, combining for example technology push approaches such as public R&D and demand pull approaches such as an energy tax. Consistency addresses the alignment of policy instruments and the policy strategy, which may have multiple objectives (Rogge 2019). Consistency has been identified as an important driver of low-carbon transformative change, particularly for renewable energy (Lieu et al. 2018; Rogge and Schleich 2018).

Design of policy mixes should consider not only policies supporting low carbon supporting low-carbon niches but also those destabilizing existing carbon-intensive regimes. Feed-in tariffs for renewable energy are an example of the former; reduction of subsidies for fossil fuels are an example of the latter. Policies that combine incentives for innovation with those aimed at 'exnovation' -- capturing the termination of fossil-based technological trajectories in a deliberate fashion -- stand greater chances of accelerating low-carbon transitions (Kivimaa and Kern 2016; David 2017). Such destabilization policies include stringent carbon pricing; changes in regime rules such as reform of electricity market design; reduced support for dominant regime technologies, for example removing tax deductions for private motor transport; and changes in social networks and representation, for example relative representation of incumbents and new entrants in policy advisory councils. Analysis has so far been done through the perspective of technological innovation systems and their functions, such as for Norway's transport and energy sector (Ćetković and Skjærseth 2019), Sweden's pulp and paper industry (Scordato et al. 2018), and Finland's building sector (Kivimaa et al. 2017b). In addition, CGE modelling for China's fossil fuel subsidy reform found that integrating both creation and destabilization policies is able to reduce rebound effects and make the policy mix more effective (Li et al. 2017).

Methodological approaches for developing real world policy mixes emphasize the importance of combining top down and bottom up mapping of policy mixes. A top down approach traces the governing entities, their strategies and corresponding policy instruments pertaining to an overarching strategic intent, such as promoting certain low-carbon technologies (Quitzow 2015; Schmidt and Sewerin 2019). A bottom up policy mix analysis starts from a specific geography and policy domain such as energy efficiency and renewable energies in the United States (Sovacool 2009), and helps identify multiple relevant governing levels and policy fields, and enables the consideration of both intentional and unintentional policy effects. When combined, the two approaches can yield a comprehensive coverage of governing entities, policy strategies and instrument mixes providing a thorough starting point for the analysis and design of climate policy mixes (Reichardt et al. 2016; Kivimaa and Kern 2016; Huang 2019; Ossenbrink et al. 2019).

13.6.4 The governance context for policy mixes

The effectiveness of a policy mix depends on conditions beyond design considerations, as discussed in the preceding section, and also rest on the larger governance context within which they operate. These include, for example, the political environment for decision-making, questions of coordination across scales, enforcement capabilities, bureaucratic traditions, and judicial functioning. As this list indicates, many of these factors are deeply context specific, suggesting the need for policy mixes to be tailored to national context. This section briefly discusses some of these governance factors in order to emphasize the importance of local context for effective design and implementation of policy mixes.

Design of policy mixes must account for the creation of winners and losers (Kern and Rogge 2018; Roberts et al. 2018). Winners include low-carbon entrepreneurs and future generations while potential losers include incumbents with vested interests, and neighbours of low-carbon infrastructure projects (Geels 2014; Rosenbloom 2018). The likelihood of losers and the need to win political acceptability justifies supplementing carbon pricing with other policies to ameliorate impact on incumbents while supporting new entrants (Passey et al. 2012). Building coalitions for climate mitigation action can help manage the politics of the transition, for example through green industrial policy (e.g. supporting renewable energies through feed-in tariffs) and introducing carbon pricing (Meckling et al. 2015). In addition, low-carbon technological innovation can play a key role in enabling a ratchet up of climate policy over time by reducing costs and creating jobs (Schmidt and Sewerin 2017). Negative policy feedback can act as a drag on policy, through ineffective policy instruments, competing policy objectives, and exogenous factors such as financial crises. This dynamic may have been at play in understanding why the UK zero-carbon homes target introduced in 2006 was eventually scrapped in 2016 (Edmondson et al. 2019). This calls for dedicated attention to the co-evolution of policy mixes and socio-technical systems occurring through resource, interpretative and institutional effects (e.g. increase of public R&D support for low-carbon solutions, information provision at climate policy conferences, expanding state capacities for policy evaluation and/or enforcement), and their socio-political, administrative and fiscal feedbacks (e.g. mobilisation of supporters vs opponents, avoiding or causing budgetary strains, and strengthening vs weakening of implementing agencies' reputation).

The process of designing and implementing low-carbon transitions is an important factor in building support and public acceptance. Low-carbon transitions cannot only be slowed down through resistance from vested interests, but also through a lack of public acceptance (Bicket and Vanner 2016). Therefore, several interdisciplinary studies have incorporated stakeholder views, for example by applying Q methodology in the case of building-integrated photovoltaics in Singapore (Chang et al. 2019) or transport backcasting scenarios with multi-criteria analysis in Spain (Soria-Lara and Banister 2018). Similarly, the public acceptance of climate policy has been increasingly investigated, for example through choice experiments for sustainable passenger transport in China, Germany and the USA (Wicki et al. 2019) or for climate change mitigation policies in the Czech Republic, Poland and UK (Ščasný et al. 2017). In addition, the emerging energy democracy literature argues for policy mixes that resist currently dominant energy technologies by ending subsidies for fossil fuels and supporting those dependent from jobs in fossil fuel industries, that reclaim the energy sector (e.g. by normalizing public control of energy production and consumption) and that restructure the energy sector (e.g. by governing energy systems as a commons) (Burke and Stephens 2017).

Coordination across scales is an important part of the governance conditions for policy packages. Accelerating low-carbon transitions can be supported by policy mixes spanning multiple governance levels (e.g. local, regional, national, supranational and international) and policy fields (e.g. climate, energy, industry, economy, innovation, and environment). Siloed rather than integrated policy mixes have been identified as bottleneck to low-carbon transitions, such as in the case of South Korea's renewable energy policy (Yoon and Sim 2015). Policy coordination provides an avenue to manage trade-offs between different policy objectives and to seek policy synergies, although coordination is no panacea and may require institutional remedies, given the complexity, uncertainty and cross-cutting character of transition processes (Matti et al. 2017; Gebara et al. 2019). An example includes urban planning where local planning authorities can use a variety of planning instruments that assist in implementing both planning and energy policy targets (Petersen and Heurkens 2018) and where mainstreaming climate policy with urban planning can lead to an identification of win-win strategies (Viguié and Hallegatte 2012). Another example includes empowering to climate-relevant bureaucracies as a result of international and domestic climate policies, which can impact the direction and practical policy limits for climate change policy (Rahman and Giessen 2017).

Governance conditions are typically country and sector specific, requiring careful attention to local context in the design and implementation of policy mixes. Table 13.5 illustrates this point with reference to several examples of efforts at low carbon transition built around a range of policy mixes. The examples illustrate the need for attention to local context, and to a wide enablers and barriers that arise from the governance context of a country and sector.

Table 13.5 Enablers and barriers for policy led sector transitions

Representative case of transition	**Policy objectives**	**Policy mix**	**Governance context**	
			Critical enablers	*Critical barriers*
Japan Top Runner program (Nordqvist 2006; Kimura 2010)	Efficiency for home appliances and motor vehicles	Performance standards which turned into mandatory standards after the compliance period; Energy Labelling (e-Mark programme); Commendation scheme for retailers; Integration with the green vehicle tax-relief scheme (one of the criteria)	Limited number of domestic players; Japanese business culture of high voluntary compliance and cooperation with the regulator and each other; Extensive consultative process of target setting	Challenges from non-Japanese actors at the WTO Standard setting procedural issues leading to over-compliance Prioritization of incremental development at the cost of innovations
Powering past coal alliance (PPCA) (Jewell et al. 2019)	Phasing out existing unabated coal power generation and a moratorium on new coal power generation without operational carbon capture and storage	Carbon taxes; fuel switching policies; divestment by institutional investors such as pension funds; re-training programs for workers;	High fiscal capacity to bear coal phase out costs; presence of cheap alternatives such as renewables;	Institutional lock in to carbon;
Brazilian Soy Moratorium (Gibbs et al. 2015; Dou et al. 2018)	Reduce deforestation caused by soy farming expansion	Coordinated Moratorium by major soy traders (under pressure from NGOs and retailers); Satellite based monitoring; supply chain management efforts	Concentration of buying power; the simplicity of compliance requirements; the transparency of monitoring, collaboration between government, industry and NGOs; Extensive pressure from civil society	Leakage and spillover effects beyond the embargoed regions; Weak enforcement of the national Rural Environmental Registry of private properties (Portuguese acronym CAR); Inconsistent producer information between the embargoed list and the CAR;

The German Coal Commission (Reitzenste and Popp 2019)	Coal phase out and Just Transition	Compensation (up to €2 billion p.y.) for energy users (private and industry) in case of rising prices; Compensation for operators of coal plants; Investment package (~40 mn euros over 20 years) in lignite mining regions; Transition plan including innovation, training, reskilling and social support schemes	Multi-stakeholder policy development process, especially including youth and regional stakeholders; Explicit legal mandate and political backing to create a phase out plan in conjunction with a transition plan	Strong politicization and emotionalization of the process; Large fiscal burden on the federal level; Risk of mandating the commission with too many conflictual political tasks

NOTE: For future drafts this table will be populated by detailed case studies from Chs 5-12. The current examples are illustrative.

13.7 International interactions of national actions, including spillovers

Actions taken in a national context can have implications for economic outcomes and mitigation efforts in other countries, and in the aggregate, globally. This section assesses the literature for these spillover effects organised around three areas: the effect of climate policies on fossil fuel prices and demand; leakage effects; and technology based spillovers.

13.7.1 Climate Policies and Fossil Fuel Prices and Demand

Policies to reduce emissions will often change relative prices for different goods and services, including energy. Where goods are traded internationally, the market effects are international also. For example, reduced demand for fossil fuels due to carbon pricing in one country will tend to lower the price for fossil fuels globally. These impacts of climate policies on fossil fuel prices and trading is under-studied and often examined with theoretical models (van der Ploeg 2016). Among the few quantitative empirical efforts, Dike (2014) found that over the period 1980 to 2011, a 1% decrease in change in carbon intensity (proxy for ambition of climate mitigation) has reduced crude oil prices by 1.6% in short run and by 8.4% in the long run.

Mitigation policies can also have implications for the distribution of resource rents between fossil-fuel importers and exporters. Several studies find that the large group of oil importers (e.g. OECD countries) can extract significant share of resource rents from oil producing nations through domestic demand-side climate policies, such as excise or carbon taxes (Bergstrom 1982; Liski and Tahvonen 2004; Johansson et al. 2009; Dong and Whalley 2009; Franks et al. 2017; Edenhofer and Ockenfels 2017; Bauer et al. 2016; van der Ploeg 2016; Peszko 2020). Some studies suggest that a carbon tax may capture higher share of rents from exporters than a cap-and-trade system (Strand 2008; Karp et al. 2016).

Several authors note that a global climate agreement could make countries that export a significant amount of fossil fuels worse off, and hence unwilling to voluntarily cooperate in the absence of additional incentives(Elliott et al. 2010; Erickson et al. 2015b). Simulations of incentives for fossil fuel dependent countries to cooperate on global climate action suggest that without border carbon taxes, cooperative wellhead taxes or some transfers, a stringent plurilateral climate policies initiated by the “club” of fossil fuel importers reduce exporters revenues beyond BAU, but also the opportunity cost of using these fuels domestically, thus tilting their diversification towards emission-intensive industries (Peszko 2020).

Fossil fuel exporters could revert to supply-side policies or to pre-empt importers' consumption-based carbon taxes, by for example applying production quota or taxes to reduce extraction, retain a part of the "climate rent" and reverse the leakage (Wirl 1995; Dullieux et al. 2011; Böhringer et al. 2012). The size of the coalition or cartel critically affects the scale of rent transfer and leakage reduction (Böhringer et al. 2018).

Another effect of climate policy is the 'Green Paradox' -- announced but gradually tightened or delayed climate policies can create expectations that future fossil fuel prices and rents will be lower than current ones, prompting their owners to accelerate extraction (Sinn 2008; Gerlagh 2011; Sinn 2012). This situation may occur when producers expect declining rates of capital gains on fossil fuel reserves, and try to extract them more quickly and reinvest the sales revenue in the capital markets, which offers higher yields (van der Meijden et al. 2014). The Green Paradox can remain 'weak' and temporary if policy and technology shifts lock up most of fossil fuel reserves in the ground, and thus limits cumulative carbon emissions, or it can become 'strong' and lead to higher cumulative GHG emissions, which ultimately increase warming (van der Ploeg 2013). The strong GP is less likely if climate policy is unexpected, ramps-up level of ambition very quickly, when extraction costs increase fast, when carbon price rises at lower rate than the market rate of interest, or if reserves are more responsive to oil and gas prices than demand (more likely in the long than in short run (van der Ploeg 2015). Green Paradox can be also avoided by levying an asset holding tax on oil and gas producers(Sinn 2012; van der Ploeg 2015), although it is not likely to be feasible.

The Green Paradox argument has brought attention to the supply side of the fossil fuel market in addition to the demand side (van der Ploeg 2013). Supply-side climate policies for the major fossil fuel producers (mainly coal) are often proposed to address the Green Paradox challenge (Sinn 2008, 2012; Eichner and Pethig 2011; Harstad 2012; Asheim 2013; Collier and Venables 2014; Muttitt 2016; Day and Day 2017; Piggot et al. 2018; Asheim et al. 2019) (see also Box 13.5). Political economy issues and supply competition are likely to prevent supply side policies of fossil fuel exporters unless they are implemented as part of the broader trade agreements with fossil fuel importers who commit to discriminate against exporters who do not implement such policies (Peszko et al. 2019).

The literature on the impact of climate mitigation goals and fossil fuel reserves originally focused on the quantitative mismatch between the carbon embedded in the size of proven reserves of fossil fuels and the "carbon budget" consistent with different global temperature increase constraints (Carbon Tracker Initiative and Grantham Research Institute 2013). Estimates of whose reserves are "unburnable" are usually based on the calculations using global extraction cost curves and break-even prices. McGlade and Ekins (2015) used a large assemble of models to estimate that about a third of global oil reserves, half of global gas reserves and over four fifths of global coal reserves are "unburnable" for 66 percent probability of achieving the 2°C goal, mostly in China, Russia and the United States in the Arctic, and Canadian tar sands. This suggests the risk of stranded fossil fuel assets.

13.7.2 Leakage Effects

A mitigation policy implemented unilaterally by a country induces numerous adjustments to production, consumption and investment domestically and elsewhere. These adjustments may affect the use of resources and emissions; the change in greenhouse gas emissions is labelled "leakage".

Leakage can occur via various channels, which, while conceptually distinct, can interact in practice (Zhang and Zhang 2016). (See Box 13.7.)

Box 13.7 Channels of Leakage

Competitiveness: Mitigation policy raises the costs and product prices of regulated sources which causes production to shift to unregulated sources, increasing their emissions.

Fossil fuel channel: Regulated sources reduce their fossil fuel use, which lowers fossil fuel prices and increases consumption and associated emissions by unregulated sources.

Terms of trade effect: Price increases for the products of regulated sources shift consumption to other goods, which raises emissions due to the higher output of those goods.

Technology channel: Mitigation policy induces low carbon innovation, which reduces emissions by sources that adopt the innovations that may include unregulated sources.

Abatement resource effect: Regulated sources increase use of clean inputs, which reduces inputs available to unregulated sources and so limits their output and emissions.

Scale channel: Changes to the output of regulated and unregulated sources affect their emissions intensities so emissions changes are not proportional to output changes.

Intertemporal channel: Capital stocks of all sources are fixed initially but change over time affecting the costs, prices, output and emissions of regulated and unregulated products.

Modelling results suggests that leakage resulting from mitigation policies is positive, thus lowering the emission reductions, but equally that via some channels it can be negative and change over time . So while emissions leakage is a real phenomenon, the sign and scale of the leakage in any given context is an empirical question. Among channels, most studies find that leakage via the fossil fuel channel exceeds that via the competitiveness channel, when models include both channels (Zhang 2012; Branger and Quirion 2014). However, policymakers tend to focus on the competitiveness channel because adverse economic impacts, such as loss of employment, are more consequential domestically than emissions leakage that has global aggregate consequences.

Adverse economic impacts and associated leakage can be reduced through mitigation policy design or adoption of complementary policies (Fischer and Fox 2012; Rajagopal 2017) although it cannot be precisely mitigated (Fowlie and Reguant 2018). These policies usually target emissions-intensive, trade-exposed (EITE) sources because they tend to be large emitters vulnerable to foreign competition for whom compliance may be costly (Martin et al. 2014a; European Commission 2015). One approach is to distribute free allowances to EITE sources based on historic emissions or in proportion to output, which maintains an incentive to reduce emissions while reducing the financial burden of the policy (Demailly and Quirion 2006). Another approach is a border tax adjustment that exempts exports and imposes costs on imports equivalent to those borne by domestic firms (Böhringer et al. 2012; Fischer and Fox 2012; Zhang 2012). Although extensively discussed in the literature, border adjustments are rarely implemented (Antimiani et al. 2013; Lanzi et al. 2013).

Estimates of leakage rely on both *ex ante* modelling studies, which tend to focus on potential for emissions leakage as a result of unilateral mitigation policies with no compensating measures. *Ex post* empirical studies that typically examine competitiveness effects. Because they focus on different questions, these two approaches are not directly comparable.

Ex ante studies reinforce the findings of AR5, and show model-based estimates of emissions leakage at around 5–20%, assuming the mitigation policy is not designed to limit leakage. However, the accuracy of such *ex ante* estimates has been questioned on the grounds that the policies modelled do not reflect those actually implemented and that the models cannot accurately estimate actual leakage, as they cannot realistically characterize the operation of actual production facilities and real-world investment decisions (Zhang 2012; Branger and Quirion 2014; Fowlie and Reguant 2018). Those characteristics include assumptions such as perfect competition in all markets, sectoral definitions that do not match those of the mitigation policy, and the suitability of the data (especially fossil fuel supply elasticities and Armington elasticities for traded goods) used to estimate the model.

Ex post analyses have focused on the possible adverse economic impacts of the policy and ignore its leakage effects on emissions via other channels. *Ex post* analyses usually compare the performance of sources subject to the mitigation policy with that of a control group, with differences in performance assumed to be impacts of the policy.

Three *ex post* studies analyse the competitiveness impacts of energy and carbon taxes and find limited or no competitiveness effects. Comparing German firms included and excluded (because of size) from reduced tax rates after 1999, Flues and Lutz (2015) found that firms subject to the full tax performed no worse than those that benefitted from reduced rates in terms of turnover, exports, value added, investment and employment through 2006. The UK Climate Change Levy, introduced in 2001, offered an 80% discount to plants in energy intensive industries with an agreed energy or emissions reduction target. The tax significantly reduced energy intensity and electricity use but until 2004 had no statistically significant effects on employment, revenue or plant exit(Martin et al. 2014b). An analysis of the impact of energy (including CO_2) taxes on a large number of firms in Europe between 1996 and 2007 found the taxes increased total factor productivity and returns to capital but decreased employment and had a mixed effect on investment, with varied impacts across sectors (Commins et al. 2011).

Ex post analyses of the competitiveness impacts of the EU emissions trading scheme (ETS) finds it has reduced emissions and increased innovation of low-carbon technologies with no statistically significant negative impacts on employment, output, value added, unit material costs, revenue, profits, exports or investment(Martin et al. 2016). The studies cover different time periods for individual countries (Jaraite-Kažukauske and Di Maria 2016; Petrick and Wagner 2014; Wagner et al. 2014; Klemetsen et al. 2016) as well as multiple countries (Abrell et al. 2011; Commins et al. 2011; Chan et al. 2013; Dechezleprêtre et al. 2018). Reviews of the environmental and economic performance of the EU ETS have drawn on those results and other evidence (Venmans 2012; Laing et al. 2013; Branger and Quirion 2014; Arlinghaus 2015; Martin et al. 2016; Dechezleprêtre and Kruse 2018).

Analyses of EITE sectors likely to be vulnerable to competitiveness impacts also find no adverse impacts. For example, the electricity and heat sector experienced statistically significant increases in revenue, assets, employment and return on assets due to the windfall profits stemming from the free allocations received and ability to pass through the value of those allowances(Chan et al. 2013; Dechezleprêtre et al. 2018). No adverse impacts were found for the cement and iron and steel industries, energy intensive industries considered to be vulnerable to international competition (Chan et al. 2013). In sectors considered at risk of relocation by the European Commission, the relocation rate was lower for ETS participants (Dechezleprêtre et al. 2018).

The absence of negative impacts on the competitiveness of participants during the first two phases (2005–2012) of the EU ETS is attributed to a large over-allocation of allowances leading to low prices, the ability of firms in some sectors to pass costs on to consumers, energy's relatively low share (5%) of production costs, and small but significant stimulating effects on innovation (Joltreau and Sommerfeld 2019).

13.7.3 Technology Spillover Effects

Knowledge about technology that transfers from one entity to another without compensation—known as knowledge spillovers—both retards and accelerates innovation in low-carbon technology. Spillovers can occur between firms (Hoppmann 2018), between countries (Baudry and Bonnet 2019), and between technologies (Nemet 2012a).

Spillovers reduce incentives for investment in innovation because firms and countries will not be able to fully appropriate the returns on those investments, e.g. because other firms can observe their activities and reverse engineer their products (Teece 1986). This results in an under-supply of innovation and provides an economic rationale for government intervention (Sandén 2005; Nemet 2012b). On the other hand, spillovers can also accelerate innovation by enhancing the process of technology diffusion and spreading new technology to other firms with complementary capabilities and to other countries, for example with lower ability to pay (Glachant and Dechezleprêtre 2017; Zhang and Gallagher 2016).

Some policy remedies create a trade-off between these two effects. For example, by granting patent holders a monopoly and thus raising prices, stringent intellectual property regulation enhances incentives for investment but limits technology diffusion by excluding technology adopters from the market (Dosi et al. 2006). Other policies such as government R&D funding, enhance both investment and diffusion but can be politically difficult to sustain if much of the benefits are seen to accrue to the rest of the world (Chan et al. 2017).

13.7.3.1 Technological Spillovers

Social rates of return on R&D exceed private returns (Goto and Suzuki 1989) due to knowledge spillovers and thus policy is needed to encourage sufficient R&D investment. Knowledge spillovers are generally largest early in the process of innovation, when innovators establish basic designs, which others can easily observe in scientific publications and which mobile employees can transfer as tacit knowledge. Recent data shows this market failure has grown (Lucking et al. 2018).

Knowledge spillovers also occur in the later learning-by-doing stages of the innovation process providing a strong justification for subsidizing demand (Nemet 2012b), for example via feed-in tariffs and auctions (Kitzing et al. 2018) These spillovers occur as both firms and users adapt technologies during the process of learning by doing, providing improvements for other firms and other adopters (Ghemawat and Spence 1985). Empirical work has found evidence of spillovers during adoption in solar thermal electricity (Cohen Gilbert E. et al. 1999), wind turbine operation (Tang and Popp 2016), and solar panel installations (Gillingham et al. 2016).

Empirical work also finds strong positive interactions between R&D and adoption (Jacobsson et al. 2004). For example, experience in producing technologies for consumers, and how they use them, can point to areas for improvement, which R&D activity can then target. Moreover, the expansion of a market can justify further private R&D investment (Watanabe et al. 2000). Since spillovers can exist in both R&D and adoption, the new knowledge that results from the positive feedback between R&D and adoption can increase the social benefits of technology development. This implies that policies that target both technology push (e.g. R&D) and demand pull (e.g. by subsidizing demand) can have very large social benefits as this "virtuous cycle" can amplify them (Watanabe et al. 2000).

Perhaps the most intentional and consequential policy example of targeting these interactions are Denmark's support for wind technology (Hendry and Harborne 2011) and Japan's MITI support for PV (Watanabe et al. 2000). As described above, Japan's industrial policies also supported inter-technology spillovers (Cohen et al. 2002).

Another set of recent studies has found spillovers at the intermediate stage involving technology pilots and demonstrations (Frishammar et al. 2015; Hart 2018). Spillovers here contribute to what is sometimes known as the technology "valley of death" (Murphy and Edwards 2003), when investment needs become much higher, the technology is still risky, and, because the technology is meant to be demonstrated, outcomes can be easily observed by other entities (Nemet et al. 2018). Public funding of demonstration projects has proven effective in generating demonstration projects, especially with industry partners contributing some share of the cost and actively engaged in the projects (Hart 2018).

Given inherent technology risk, one should not expect all demonstrations to succeed, and indeed government demonstration programs have produced both high profile failures, such as synthetic fuels (Anadon and Nemet 2014), as well as large successes, as in wind (Wene 2018).

Spillovers across technologies also occur, with solar and storage especially important sources (Noailly and Shestalova 2017). Policy can play a role in supporting cross-cutting work, such as in general purpose technologies (Ruttan 2001) or enabling spillovers across sectors. For example, the Ministry of International Trade and Industry in Japan in the 1990s created industry consortia creating shared expectations about future technology pathways and taking advantage of the broad scope of Japanese conglomerates to intentionally cross-fertilize advances from one area to another (Watanabe et al. 2000).

13.7.3.2 International Knowledge Spillovers

Knowledge spillovers across international boundaries generate a similar combination of both positive and negative effects on innovation. Global value chains enhance the flow of knowledge across borders (Zhang and Gallagher 2016)—tacitly in people (Neij et al. 2017), embedded in machines services provided by suppliers, aided by finance, and as value in final products (Ball et al. 2017). Investments in innovation in one country can thus facilitate improvements in another, enabling broader access to technology and ultimately widespread technology adoption (Binz and Truffer 2017). Moreover, policy innovations also spill over and involve their own process of diffusion. For example, the most important solar PV policy, the German Feed-in Tariff adopted the policy innovations of a declining subsidy from Japan (Kimura and Suzuki 2006) and of guaranteed purchase prices from California (CPUC 1983). The German policy, the FiT has subsequently been adopted by 110 additional countries, including dozens in the global south (REN21 2019), in what appears to exhibit the same s-curve shape as technology adoption (Rogers 2003). Efforts to coordinate and accelerate policy spillovers have had some success, including U.S.-China Clean Energy Center, IRENA's efforts to standardize and promote FiTs in the 2010s (Van de Graaf 2013), and a plethora of informal visits (Maycock et al. 1983).

The same downside exists for policy—weak incentives to invest and strong incentives to free-ride on the policy experimentation and public funds of others. In this case, international spillovers introduce political economy considerations (Meckling and Nahm 2018). Germany's >$200b of subsidies for the PV industry (Unnerstal 2017) was portrayed as its "gift to the world" (Gillis 2014)once it became clear that almost all manufacturing occurred elsewhere (Binz et al. 2017). Danish subsidies for wind in the 1980s led to cheap wind for the world (Hendry and Harborne 2011). The Brazil ethanol program of the 1980s reduced the cost of ethanol for all (Meyer et al. 2013). China's domestic quota for EV adoption are enabling scale and global adoption of EVs at much lower prices (Helveston et al. 2019). A pernicious outcome of these cases is the rise of what is becoming known as "innovation nationalism" (Kumar 2018), efforts to confine innovative activities within national borders.

A more constructive outcome of the accumulation of these successful cases of technology adoption are emerging efforts to provide coordination. For example, concurrently with the Paris Agreement in December 2015, 24 countries agreed to double their energy R&D budgets within 5 years, a plan known as Mission Innovation (Mission Innovation 2015). This coordination effort reflected both the public good aspect of knowledge spillovers as well as the need to complement the demand pull efforts of the NDCs with a coordinated technology push effort for longer term mitigation (Sanchez and Sivaram 2017), although progress in meeting the doubling goal has been weak (Cunliff 2019). If innovation nationalism continues then efforts at coordination (Schultes et al. 2018) become even more socially valuable even if challenging in the near term.

13.8 Mitigation and adaptation

13.8.1 Mitigation and adaptation policies across scales

One of the key messages of the IPCC AR5 was that "effective implementation depends on policies and cooperation at all scales and can be enhanced through integrated responses that link adaptation and mitigation with other societal objectives". Moreover, the Paris Agreement 2015 for climate change, the Sendai Framework 2015 for disaster risk reduction, and the New Urban Agenda for sustainable urban systems, all contribute to the Sustainable Development Goals. These international policy frameworks provide an integrated approach for both adaptation and mitigation, while promoting sustainable development and climate resilience across scales (from global, regional, to local government actions (Di Gregorio et al. 2017; Locatelli et al. 2017; Nachmany and Setzer 2018; Heidrich et al. 2016; Mills-Novoa and Liverman 2019; Duguma et al. 2014b).

Assessment of these integrated policies is just emerging. This section assesses the current status of policy implementation of mitigation and adaptation efforts from different perspectives and in different contexts.

13.8.1.1 Adaptation policy at the interface of mitigation and adaptation

Adaptation has been defined as how human and natural systems adjust to climate variability and change by reducing their vulnerability and increasing their resilience (Duguma et al. 2014b; Denton et al. 2015; Di Gregorio et al. 2017; Zhao et al. 2018). While mitigation is defined as human interventions to reduce the sources or enhance the sinks of greenhouse gases (GHGs) targeting to hold the increase in average global temperature well below 2ºC above preindustrial levels (IPCC 2018; Boräng et al. 2019). There is growing consensus that current mitigation efforts are inadequate to bridge the emissions gap in 2030; and isolated mitigation policy is not enough to face climate change impacts globally, leaving an urgent need for a more integrated framework for mitigation and adaptation (Wang and Chen 2019; UNEP 2018; Mills-Novoa and Liverman 2019; Nachmany and Setzer 2018).

Recent research in climate change assessment has evolved, with an emerging major focus on climate impacts and response experiences with adaptation in all sectors. For example, becoming more integrative with co-production of stakeholders; and focusing on climatic risks and solutions (Bank 2008; Solecki et al. 2011; Taylor et al. 2014; Bhave et al. 2016). Moreover, climate change adaptation has been aligned with the process of building climate-resilient systems, overlapping with sustainable development goals and disaster risk reduction (Bank 2008; Romero Lankao and Tribbia 2009; Solecki et al. 2019; Lewison et al. 2015; Fankhauser and McDermott 2016) .

Synergies between adaptation and mitigation are included in many of the NDCs submitted to the UNFCCC as part of overall low-emission climate-resilient development strategies, including economic diversification efforts with synergies being sought at project and sector levels; in planning or institutional frameworks at various scales ranging from national to local levels; and with adaptation measures that offer significant co-benefits being prioritised (UNFCCC Secretariat 2016). Sectors which offer adaptation and mitigation synergies (frequently highlighted in the adaptation component of NDCs) include the following sectors: agriculture, forestry and other land-use, including livestock; human settlements and infrastructure; water; energy; ecosystems; and tourism (UNFCCC Secretariat 2016). Knowledge gaps and uncertainties discussed in SR 1.5, Chapter 4, highlighted the need for evidence on synergies and tradeoffs in various sectors (de Coninck et al. 2018). Examples include the need for evidence on synergies with adaptation of carbon dioxide capture and storage (CSS) in the power sector; trade-offs with adaptation of low- and zero-energy buildings; trade-offs with mitigation and the built environment; and trade-offs with adaptation options for industrial energy and climate services.

Assessing the results of adaptation has been challenging because of the lack of clarity of goals and sparse data with the appropriate indicators (Tompkins 2018). In addition, there is neither classification of adaptation options, nor systematization of measures at the global or regional levels. The IPCC WGII considers the concepts of an “adaptation gap” which is related to the adaptation measures which are implemented but constrained in their extent by their resources and other priorities (e.g. political)(UNEP 2018); and the “adaptation deficit” which occurs when a country is unable to respond to the current impacts of climate variability (Millman and Arsano, 2014). Developing and emerging countries with such deficits will suffer more impacts of extreme events than developed countries. Those countries usually produce marginal impact of emissions, and therefore climate adaptation and mitigation need to be considered in broader political, economic and development goals(Fankhauser and McDermott 2016). There is a growing body of literature which assesses joint mitigation and adaptation, planning and implementation, and emphasizes the need for multi-objective frameworks able to identify synergies as well tradeoffs at multiple scales (from local to global) and across sectors (agriculture, forest, energy, water, urban, health) (Berrang-Ford et al. 2015; Berry et al. 2015; Denton et al. 2015; Grafakos et al. 2019)

13.8.2 Mitigation and adaptation integrated policies in different contexts and scales

There is a growing consensus that integration of adaptation and mitigation will advance sustainable development goals and lower emissions of GHGs and that ambitious mitigation efforts would reduce the need for adaptation efforts in the long term (IPCC 2014a). A better understanding of the synergies between both adaptation and mitigation policy implementation, to enhance/accelerate the reduction of GHGs while strengthening resilience and reducing vulnerability to climate variability and change, is needed (Klein et al. 2005; IPCC 2007; Mills-Novoa and Liverman 2019; Solecki et al. 2019).

The 5th Assessment report of the IPCC discussed climate-resilient pathways in terms of how to address climate change and current and future threats to development. Climate resilient pathways are development trajectories that combine adaptation and mitigation to realize the goal of sustainable development (IPCC 2014b; Denton et al. 2015) While mitigation measures may be successful, some degree of climate change is inevitable, therefore countries have started to focus on adaptation alongside mitigation (Keskitalo 2010a,b)

Synergies between adaptation and mitigation are included in many of the NDCs submitted to the UNFCCC as part of the overall low-emission climate-resilient development strategies, including economic diversification efforts with synergies being sought at project and sector levels; in planning or institutional frameworks at various scales ranging from national to local levels; and with adaptation measures that offer significant co-benefits when being prioritised (UNFCCC Secretariat 2016).

Integrated approaches to adaptation and mitigation planning and implementation lead to more efficient and cost-effective policies (Locatelli et al. 2011; Klein et al. 2005; Mills-Novoa and Liverman 2019). However unintended trade-offs between them need to be identified and avoided. (Di Gregorio et al. 2017; Locatelli et al. 2011).

An example of co-benefits is the Climate Change Action Plan of Wellington City, which includes enhancing forest sinks to increase carbon sequestration while at the same time protecting biodiversity and reducing groundwater runoff as rainfall increases (Grafakos et al. 2019).

The REDD initiative focus on mitigation by carbon sequestration, also generates some co- benefits such as: nature protection, political inclusion, monetary income, economic opportunities. However, some unintended trade-offs may have occurred such as physical displacement, loss of livelihoods, increased human–wildlife conflicts, unequal distribution of benefits to local population groups. (Duguma et al. 2014a; Di Gregorio et al. 2016; Anderson et al. 2016; Gebara et al. 2014; Bushley 2014; Di Gregorio et al. 2017)

Adaptation and mitigation include technological, institutional and behavioural options; the introduction of economic and policy instruments to encourage the use of these options; and research and development to reduce uncertainty and to enhance the options' effectiveness and efficiency (Klein et al. 2007).

Sectors which offer adaptation and mitigation synergies (frequently highlighted in the adaptation component of NDCs) include agriculture; forestry livestock among other land uses; human settlements and infrastructure; water; energy; ecosystems (blue and green); human health; and tourism (Klein et al. 2005; Di Gregorio et al. 2016; Mehling et al. 2019; UNFCCC 2018).

13.8.2.1 Policies approaches to mitigation and adaptation across scales

Fleig et al. (2017) found that all EU states, with the exception of Hungary, have adopted a framework of laws tackling mitigation and adaptation to climate change. In addition, 14 countries targeting both mitigation and adaptation approaches with framework legislation (Nachmany et al. 2014, p. 25; Boasson and Wettestad 2014). However, an assessment of climate legislation in Europe pointed out that there has been no coordination between mitigation and adaptation, and that implementation varies according to different national conditions (Nachmany et al. 2015). EU mitigation has been focused on techno-centric solutions towards a low-carbon society; while adaptation policies have focused on knowledge production and sharing, and financial tools (Fleig et al. 2017; Pietrapertosa et al. 2018).

EU climate change policy has also influenced the development and implementation of Climate Change Action Plans (CCAPs) at the subnational level (Heidrich et al. 2016; Díaz et al. 2013; Reckien et al. 2018; Villarroel Walker et al. 2017). However, the implementation of adaptation and mitigation by EU states is less homogeneous considering their leadership aspiration (Fleig et al. 2017). Adaptation is gaining prominence and countries are including these climate actions in their National Determined Contributions (NDCs) on a regular five-year basis (Fleig et al. 2017).

In the Global South, climate change policies are established in the context of sustainable development. National climate policy is given prominence to adaptation based on country vulnerability, climatic risk, and in particular the inclusion of gender, local/traditional and indigenous knowledge (Beg et al., 2002, Duguma et al., 2014). Despite the evidence that mitigation and adaptation can be effective and efficient (Klein et al. 2005) and can potentially reduce trade-off among their interactions, there is still limited evidence of how climate adaptation and emission reduction policies would contribute to SDGs (Antwi-Agyei et al. 2018; Campagnolo and Davide 2019; Di Gregorio et al. 2017) .

Local governments and cities are increasingly emerging as global climate governors (Gordon and Acuto 2015). Cities have played a critical role in the climate change agenda because urban areas are responsible for 76% of CO_2 emissions of the final global energy budget, while at the same time are socially, economically and technically vulnerable to climate change impacts (Rosenzweig et al. 2010; Romero-Lankao 2012; Goepfert and Dietrich 2014; Seto et al. 2015; Reckien et al. 2018). Cities and local governments are developing Climate Change Action Plans (CCAPs). However, joint plans of adaptation and mitigation are a minor percentage, with few cities establishing inter-relationships between them (Nordic Council of Ministers 2017; Grafakos et al. 2018) Moreover, few integrated policies have considered the culture and values of the stakeholders involved, focusing mostly on a technocratic solution. More inclusion of studies about social issues are necessary across sectors and levels of government.

While national climate governance may focus on mitigation efforts, local governments are more likely to develop and advance climate policies, generating socio-economic or environmental co-benefits, and improve communities' quality of life (Bowen et al. 2014; Duguma et al. 2014b; Gill et al. 2007; Mayrhofer and Gupta 2016; Hennessey et al. 2017; Deng et al. 2017)

Inter-relations between mitigation and adaptation need a cross-sectoral framework which allows for broader synergies and the identification of trade-offs in implemented climate actions (See Table 13.6).

Table 13.6 Examples of synergies and tradeoffs

Policy/action	Interrelation explained	Reference
Synergies *Adaptation & mitigation*		
Habitat restoration in coastal ecosystems.	Mangroves, tidal marshes, and seagrasses have high rates of carbon sequestration, act as long-term carbon sinks, and are contained within clear national jurisdictions;	(Howard et al. 2017)
Promoted the Ecosystems base Adaptation (EBA)	Protect vulnerable population from floods and coastal erosion	(Duarte et al. 2013)
"Greening" Construction of green walls and rooftops, Green Infrastructure - Indonesia	Green walls and rooftops increase energy efficiency of buildings and decrease water runoff	(Anderson et al. 2016)
Carbon reduction to support climate mitigation. Melaka, Indonesia	Cities' responses to the challenge of climate change includes urban spatial planning and capacity-building initiatives	(Zen et al. 2019)
Co-benefit 2 *Mitigation → Adaptation*		
REDD mechanism: an incentive for developing countries to protect their forest resources and coastal wetlands	Sustainable REDD+ increases the carbon sinks and consequently reduces GHGs emitted into the atmosphere Reduce destruction of forest resources and biodiversity Protecting natural forest also conserves soil and water by reducing erosion	(Busch et al., 2011; Kapos et al., 2012)
Integrate climate change adaptation and mitigation into energy sectors in Canada.	Integration is an effective means of generating benefits that contribute positively to the results of M&A.	(Hennessey et al. 2017)
Trade-offs *Mitigation U Adaptation*		
Case study and investigation of land use in a coastal city.	GHG reductions could increase climate stress or vice versa.	(Xu et al. 2019)

Energy: Energy is a complex sector with a range of potential synergies and trade-offs with other sectors. Mitigation strategies include increasing the use of renewable energy sources, as well as energy efficiency in end-user, transmission, and conversion perspectives (Klein et al. 2007). Adaptation with water sector focus includes hydrological monitoring and developing early warning system, surface storage, groundwater management, water efficiency and ecosystems restoration (Pittock 2011). Other strategies include investment in climate resilience assets and technology, and strategic diversification, micro-generation to improve access to electricity, and the increase in energy efficiency in households which may reduce negative health impacts, for example improved stoves and lighting (Duguma et al. 2014a; Nordic Council of Ministers 2017). There are potential trade-offs linked to the agricultural and forestry sectors, more empirical research is needed to identify trade-offs and measures needed to avoid them (Locatelli et al. 2011, 2017).

Land use change and Forest: There are synergies in climate actions, such as conservation of forests ecosystems, REDD, ecosystems restoration, nature-based solutions, and green and blue carbon, however, there may also be potential trade-offs related to food security, and conflicts over resource use (Locatelli et al. 2017; Berry et al. 2015). While integrated M&A forest policies can help societies adapt to climate change, there is the need to strengthen capacities at different government levels as well as to enhance the governance around ecosystems services.

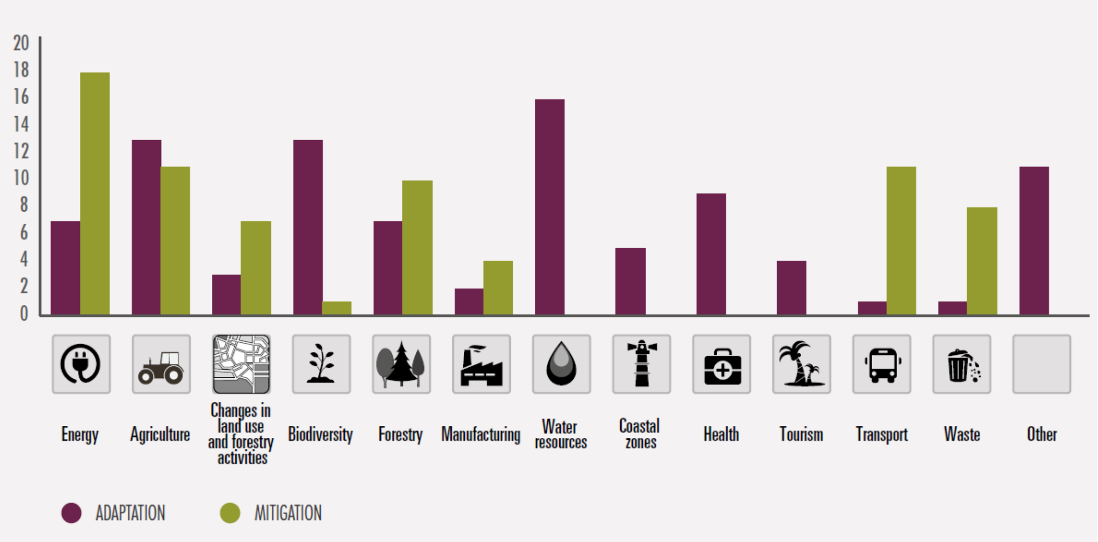
Cities: Climate actions and policies promoting green infrastructure to increase energy efficiency of buildings have various adaptation co-benefits such as reducing urban heat island effect, reducing urban runoff and improving air quality, as well protection of human health (Bowen et al. 2014; Gill et al. 2007; Pasimeni et al. 2019; Anderson et al. 2016). However, some trade-offs of climate proof houses are being more expensive and they can increase the vulnerability of poorer groups in society who cannot afford them (Juhola et al. 2013; Anguelovski et al. 2014). Nature-based solutions to increase carbon storage in wetlands and urban forests have co-benefits related to flood protection, enhancing urban biodiversity and supporting pollinating species (Villarroel Walker et al. 2017; Damsø et al. 2016; Bulkeley and Castán Broto 2013; Puppim de Oliveira 2013; Anguelovski and Carmin 2011; Aklin and Urpelainen 2014).

Trade-offs are related to issues of social justice, with adaptation and mitigation having potential negative impacts on the marginalized and most deprived urban populations or escalate socio conflict (Hughes and Romero-Lankao 2014; Romero-Lankao et al. 2018a; Chu 2016; Anguelovski et al. 2014). For example, a densely built environment, in lower income areas, can lead lower quality of life and can cause health impacts (Juhola et al. 2013).

Cross- sectors and Climate Nexus: The term 'nexus' is used to describe the linkages between water, energy, food, health and other socio-economic factors in some integrated assessment approaches. The Food-Energy-Water (FEW) nexus for example considers how water is required for energy production and supply, how energy is needed to treat and transport water, and how both are critical to food production (Biggs et al. 2015). Climate change impacts all these dimensions in the form of multi-hazard risk (Froese and Schilling 2019). Although integrative, the FEW nexus faces many challenges including: limited knowledge integration; coordination between different institutions and levels of government; politics and power; cultural values; and ways of managing climate risk (Leck and Roberts 2015; Romero-Lankao, P., McPhearson, T. & Davidson 2017). More empirical assessment is needed to identify potential overlaps between sectoral portfolios, as this could help to delineate resources allocation for synergies and to avoid trade-offs.

Box 13.8 Latin American and Caribbean Region Adaptation linking Mitigation

In the Latin American and the Caribbean region, national governments are moving towards adaptation as a priority to reduce their vulnerability to climate change while looking for opportunities for mitigation. The most relevant sectors to integrate mitigation and adaption measures in the region are: energy, agriculture, land use change and forestry, biodiversity, and water resources (Box 13.8 Figure 1) (Sánchez 2018). Climate change policies have often been approached as a natural resource management, but recently vulnerability and development goals are part of the regional policy agenda. Adaptation and mitigation strategies can produce co-benefits, but are mostly disconnected across sectors resulting in some social conflicts (Locatelli et al. 2015). For example, the Reducing Emissions from Deforestation and Forest Degradation (REDD+) initiative aims to reduce GHGs by capturing carbon in forests and wetlands, while at the same time providing ecosystems services to the most vulnerable population in the LAC region. Although this initiative has been active in the region for years, there has not yet been any national assessment of co-benefits and potential trade-offs between sectors, or with local communities(Locatelli et al. 2017). Conflicts have emerged over political views, government priorities of resources (oil, bioenergy, hydropower), and weak governance among national and local authorities, indigenous groups and other stakeholders such as NGOs which play a critical role in the technological and financial support for the REDD initiative (Gebara et al. 2014; Reed 2011; Kashwan 2015; Locatelli et al. 2017).



Box13.8 Figure 1 Latin America and the Caribbean: high-priority sectors for mitigation and adaptation, June 2016. Number of countries that name the following sector in their national climate change plans and/or national communications (Sánchez 2018).

Box 13.9 Adaptation and mitigation synergies in Africa

Synergies between mitigation and adaptation actions and sustainable development exist at both sectoral and national levels that can enhance the quality and pace of development in Africa. Available data on NDCs show a clear pattern of climate change priorities across African countries where the top mitigation priorities include energy, forestry transport and agriculture and waste, and adaptation priorities focus on agriculture, water, energy and forestry. The energy sector dominates in mitigation actions and the agricultural sector is the main focus of adaptation measures, with the latter sector being a slightly larger source of greenhouse gases than the former (Mbeva 2015; Nyiwul 2019; AfDB 2019).

Renewable energy development can support synergies between mitigation and adaptation through stimulating local and national economies through microenterprise development; providing off-grid solutions, especially in rural areas where electricity provision is expensive; and contributing to poverty reduction through increased locally available resource use and employment and increased technical skills (Nyiwul 2019). Close to $123 billion in climate-smart investments in Africa are in clean energy (IFC 2016). The technology transfer and funding mechanisms embedded in the Paris Agreement could support renewable energy production in Africa by helping reduce costs and providing scale economics to local economies.

Barriers to achieving the maximum benefits from these synergies include the absence of suitable macro- and micro- level policy environments for desirable adaptation and mitigation actions; institutional and capacity deficiencies in climate and policy research; and the high financial needs associated with the cost of mitigation and adaptation (Nyiwul 2019; AfDB 2019).

National institutions and policies will need strengthening to maximise synergies and co-benefits between adaptation and mitigation, to increase synergies between sectors; to reduce silos and redundant overlaps; to increase knowledge exchange at the country and regional levels through coordination mechanisms, strategic partnerships and the establishment of platforms for engagement and planning; and to utilise all available means of support and climate finance through engaging bilateral and multilateral partners and mobilising finance through the mechanisms available, e.g. the Green Climate Fund, thus creating opportunities to leverage additional resources for mitigation (AfDB 2019).

13.8.3 Barriers to joint M&A implementation and enablers and solutions

13.8.3.1 Governance barriers and challenges to adaptation and mitigation integrations

Current research assessing M&A interlinkages concludes that integrating both requires understanding of equity, synergies, trade-offs in a systemic and polycentric approach (Grafakos et al. 2019; Denton et al. 2015; Brugnach et al. 2017; Nachmany et al. 2015; Di Gregorio et al. 2017; Locatelli et al. 2017). For example, analysis of energy and water resources policies implementation and their trade-off with agriculture is just emerging (Huggel et al. 2015; Antwi-Agyei et al. 2018). In addition, policy integration needs to be considered iteratively along the process of development, implementation, and evaluation of climate policies. Applying the framework for assessing adaptation challenges and opportunities (Moser and Dilling 2011), the following barriers have been identified in each phase:

Understanding interlinkages between A&M policies: Policy frameworks for assessment mitigation and adaptation in the context of sustainable development are just emerging. Challenges are related with the limited evidence-base policy on synergies, co-benefits, and trade-offs across sectors and jurisdictions (Di Gregorio et al. 2016; Locatelli et al. 2017; Zen et al. 2019). Given sparse data and information gathered on A&M policies, integration across sectors is not easily available, accessible, or salient, because of different objectives and priorities of policy actors (Nordic Council of Ministers 2017; Grafakos et al. 2019; Edenhofer et al. 2017). Although some NDC describe inter-relationships between A&M, some are not explicitly recognized by their countries, indicating the need of capacity building on those interlinkages (Nordic Council of Ministers 2017).

There is not information on determining the thresholds or limits to avoid trade-offs among M&A. Limits to adaptation (WGII- Chap. 16) can be exacerbated by the mitigation policies implemented.

Establishing integrated A&M policies across sectors and multilevel of government: National policies mostly focus either on mitigation or on adaptation, with interest and willingness to integrate both across sectors, but don’t know how what policies to design and how to implement them (Di Gregorio et al. 2017; Shaw et al. 2014b). For example, interlinkages in the water, energy and food nexus, require coordination among sectoral institutions and capacity building in innovative framework for linking science, practice and policy at multiple levels (Shaw et al. 2014b; Cook and Chu 2018; Nakano et al. 2017). Empirical research suggests a limited coordination among sectors and across jurisdiction – e.g., between national and subnational governments.

Implementing and managing integrated A&M policies: Another challenge is given by the fact that limited financial, technical and human resources exist for implementing joint A&M (Kedia 2016; Chu 2018; Antwi-Agyei et al. 2018; David and Venkatachalam 2019; Satterthwaite 2017).

Monitoring and Evaluation: Monitoring and evaluation systems address M&A separately, broadly considered learning (lessons learned) and accountability (expected outcomes). A big challenge is to attempt to design a framework for the monitoring and evaluation of integrated M&A policies, which have different objectives and mostly are tailored to their specific context priorities and capacities. Moreover, adaptation policies mostly lack measurable targets or expected outcomes making even tougher to design an integrated framework (OECD 2017).

13.9 Building agreement and action

Societal engagement is a crucial component of achieving necessary policy targets for greenhouse gas (GHG) reduction. Chapter 5 is the primary home of the 'people and behaviour' discussion in this assessment report. This section explores people's perception of climate change; their attitudes to mitigation policies and how that interacts with building agreement for action. It assesses behavioural action – citizen engagement and climate litigation – and its potential for climate change mitigation; and it explores the importance of the media in building agreement and encouraging action.

13.9.1 Engaging people

13.9.1.1 Public perceptions of climate change

The general public in western contexts agree that anthropogenic global warming is happening (Shwom et al. 2015) (*high evidence, high agreement*), there are high levels of climate change concern across nations, and the concern is increasing (Shwom et al. 2015) (*high evidence, high agreement*). Levels of concern, perceptions of risk, urgency and causes of global warming vary in these contexts with political orientation (left leaning), gender (female) and geographic (urban) factors(Shwom et al. 2015; McCright et al. 2016). Income, race, religiosity and place of residence are less consistent predictors of climate concern as are age and education (Shwom et al. 2015).

A few studies pool data across multiple cross- national surveys conducted by many organizations to examine the variety in the intensity of public concerns about climate change, and find that citizens in developed nations report higher awareness of climate change than in developing nations and mixed results regarding concern and risk perceptions (Kim and Wolinsky-Nahmias 2014; Lee et al. 2015; Knight 2016). Lee et al. (2015) report higher concern among those in developing countries who have heard about climate change (than those in developed countries who have heard about climate change). Kim and Wolinsky-Nahmias (2014) report similarly higher concern about climate change and support for mitigation policies in developing nations, whereas Knight (2016) find the opposite regarding concern. Lewis (2019) finds in his cross-country study that in non-western countries, climate concern is only weakly correlated with gender, rises with age and religiosity, and is more strongly correlated with education.

Although the detailed knowledge about specific behavior and consumption and other sources of emissions vary in the public, there is a widespread and well established general public perception in western studies that the link between lifestyle and climate change is considerable (Ehrhardt-Martinez et al. 2015) (*high evidence, high agreement*).

13.9.1.2 Attitudes to mitigation policies and solutions

Within the literature exploring people's attitudes towards policies aimed at changing behavior, individual level studies typically dominate. A number of factors have been shown to influence an individual's attitudes to climate policy measures, including values (egalitarian values, self-transcending values, environmental values), political orientation/ideology (left-oriented), personal norms, social norms, climate concerns and beliefs, as well as the person's trust in politicians, the institutional system and trust in people in general (Drews and van den Bergh 2016; Harring et al. 2019).

Generally, this literature finds that carrots are more popular than sticks. For example, CO_2 taxes targeting industry and producers receive more support than CO_2 taxes directed towards consumers (Drews and van den Bergh 2016; Harring 2016). Further, it is a robust finding that earmarking (designating income from taxes to sustainable alternatives to the taxed behavior, e.g. developing public transport) of taxes targeted at behavior increases support for such taxes (Drews and van den Bergh 2016; Carattini et al. 2019). Awareness of co-benefits for the public, when these exist, such as health benefits from reduced emissions, increases support for climate policies (Drews and van den Bergh 2016; Bain et al. 2016) (*high evidence, high agreement*). Perceived fairness of a policy instrument or transition policy, that policies do not restrict the behaviour of those with limited resouces more than they affect the affluent, is also important for the public acceptance (Drews and van den Bergh 2016; Harring 2016; Harring et al. 2019) (*high evidence, high agreement*).

A few recent studies find that the belief that global warming generally can be mitigated is associated with increased policy support and political engagement on climate change (Bostrom et al. 2018; Dubois et al. 2019; Marlon et al. 2019; Aasen et al. 2019; Schleich et al. 2018). Policy support is expected to be greater if people believe effective measures are being taken in other countries and on the international level (Schleich et al. 2018; Aasen et al. 2019). Similarly, policy support is expected to be greater when there is the belief that there are mitigation efforts targeted at other emission sources than household behavior (Bostrom et al. 2018; Marlon et al. 2019). However, we tend to underestimate people's willingness to support mitigation policies warming (Mildenberger and Tingley 2019; Hurlstone et al. 2014).

13.9.1.3 Enabling behavioural change

Scholars across disciplines highlight that a combination of tools are necessary in order for the public to support and respond to policies aimed at influencing behavior (Creutzig et al. 2018; Nisa et al. 2019; Geels et al. 2017a; Drews and van den Bergh 2016; Carattini et al. 2019; Stern et al. 2016; Capstick et al. 2014). Interventions that combine appeals, information, financial incentives, informal social influences, and efforts to reduce the transaction costs of taking the desired actions have demonstrated synergistic effects beyond the additive effects of single policy tools (Stern et al. 2016; Nisa et al. 2019) (*high evidence*, *high agreement*). Positive attiudes among the targeted public towards a policy instrument aimed at influencing their behaviour is important for the acceptance of the policy, but also for the behavioral effect of it (Allen et al. 2015; Stern et al. 2016; Nisa et al. 2019).

Achieving the potential from consumption and behavioral changes requires recognizing that households are embedded within larger socioeconomic, sociotechnical, sociocultural and natural systems that affect human dimensions of carbon emissions and possibilities for mitigation (Ehrhardt-Martinez et al. 2015; Geels et al. 2017a) and that it is important to pay attention to cultural and structural factors – such as the expectations and practices of people (Geels et al. 2017a; Capstick et al. 2014).

Scholarly papers across disciplines suggests the need for a dynamic partnership between the state and stakeholders (economics actors, non-governmental organizations and citizen organizations) to enable acceptable and effective societal transformations (Fazey et al. 2018; Dryzek and Niemeyer 2019; Stern et al. 2016; Chilvers and Longhurst 2016; Aaen et al. 2016).

13.9.2 Citizen Engagement

One specific type of behaviour that has both direct and indirect effects on greenhouse gas emissions is civic engagement. Civic Engagement combines the manifold ways that citizens participate in their societies with the intention of influencing communities, politics, and the economy (Skocpol and Fiorina 1999; Barrett and Zani 2014).

One civic engagement tactic involves citizens working collectively to change their individual behaviors. For example, environmental movements that involve various forms of collective efforts encourage their members to make personal lifestyle changes that reduce their individual carbon footprints (Ergas 2010; Middlemiss 2011; Haenfler et al. 2012; Cronin et al. 2014; Saunders et al. 2014; Büchs et al. 2015; Wynes et al. 2018). These efforts focus on trying to change the individual members' consumer behaviours by reducing car-use, flying, shifting to non-fossil fuel sources for individual sources of electricity, and eating less dairy or meat (Salt and Layzell 1985; Cherry 2006; Stuart et al. 2013; Ergas 2010; Middlemiss 2011; Haenfler et al. 2012; Cronin et al. 2014; Saunders et al. 2014; Büchs et al. 2015; Wynes et al. 2018; Wynes and Nicholas 2017). To date, there are only a limited number of case studies that measure the direct effect of participation in these types of movements as it relates to climate outcomes (Vestergren et al. 2018, 2019; Saunders et al. 2014).

There is expansive research on the ways citizens with less access to resources and power participate by challenging the political and economic system. These forms of engagement target nodes of power—policymakers, regulators, and businesses—to change their behaviours and/or accelerate their efforts. One method is through lobbying, legal challenges, shareholder activism, coop board stewardship (Snow and Soule 2010; McAdam 2017). They provide the labour and political will needed to pressure political and economic actors to enact emission-reducing policies, as well as providing resistance to them as well (McAdam 2017; Conway and Oreskes 2012; Fox and Brown 1998; Boli and Thomas 1999).

Oher Citizen Engagement, involves a range of more confrontational tactics, such as boycotting, striking, protesting, and direct action that target politics, policymakers, and businesses that employ data collected from specific types of engagement with the issue of climate change (Fisher et al. 2005; Fisher 2010; Walgrave et al. 2012; Saunders et al. 2012; Wahlström et al. 2013; Hadden 2014, 2015; Hadden and Jasny 2019; Fisher et al. 2018; Cock 2019; Fisher 2019; Swim et al. 2019; Meyer and Tarrow 1997; Tarrow 2005). Very few studies look specifically at the effect of these tactics on actual climate-related outcomes , This type of engagement has received attention recently as climate strikes and other confrontational forms of climate activism led by groups like Extinction Rebellion have become more common (Evensen 2019; Fisher 2019).

A good deal of research has found that activism, including the tactics of protest and strikes played a large role in pressuring governments to create environmental laws and environmental agencies tasked with enforcing environmental laws that aimed to maintain clean air and water in countries around the world (McCloskey 1991; Schreurs 1997; Rucht 1999; Brulle 2000; Christoph Steinhardt and Wu 2016; Longhofer et al. 2016; Wong 2018). In addition, there are a number of studies which compare across countries to understand the relationship between NGOs in country and the country's environmental impact (Schofer and Hironaka 2005; Jorgenson et al. 2011; Shwom 2011; Dietz et al. 2015; Grant and Vasi 2017; Longhofer and Jorgenson 2017; Grant et al. 2018; Frank et al. 2000; Mildenberger et al. 2019; Baxter et al. 2013). They also find that environmental NGOs have a positive effect on reductions in carbon emissions.

At the same time, other research has documented various forms of backlash against climate policies, both in terms of voting behaviour, as well as other collective efforts (Hill and Knott 2010; Walker et al. 2014; Krause et al. 2016; Fast et al. 2016; Lyon 2016; Stokes 2016; Stokes and Warshaw 2017; Muradian and Pascual 2020; Mayer 2016; Williamson et al. 2011; Boudet et al. 2016; McAdam and Boudet 2012; Wright and Boudet 2012).

Box 13. 10 Civic Engagement: The School Strike Movement

On August 20th 2018, Greta Thunberg participated in the first climate strike ever. Inspired by the national school walkout against gun violence in the US that was organized after the Parkland School Shooting in Florida, the 15 year-old decided to spend her Fridays sitting with a hand written sign in front of the Swedish parliament. Since that Friday in August, Fridays for Future—the name of the group coordinating this tactic of skipping school on Fridays to protest inaction on climate change—has spread across the seas and around the world.

In March 2019, the first *global* climate strike took place, turning out more than 1 million people around the world.[2] Six months later in September 2019, young people and adults responded to a call by young activists to participate in climate strikes as part of the 'Global Week for Future' surrounding the UN Climate Action Summit,[3] and the number of participants globally jumped to an estimated 7.6 million people.[4] Research on this movement and its consequences in terms of political outcomes and emissions reductions have yet to be published (Evensen 2019; Fisher 2019; Wahlström et al. 2019). However, there is no indication that this wave of activism is dying down. This scale of globally coordinated protest is unprecedented and organizers are continuing to schedule more climate strikes at least through mid-2021.

13.9.3 Climate change litigation

Another type of behaviour intending to deliver more action on climate change is climate litigation. The first climate legal action is generally recognised to have been brought in the United States in 1990 (Preston 2011a). Over the last 20 years it has been used by a wide variety of litigants to affect climate policy outcomes at all scales (McCormick et al. 2018; Lin 2012b; Peel and Osofsky 2015; Preston 2016; Keele 2017). Climate change litigation has been concentrated in developed countries, but is growing into a transnational movement (Peel and Lin 2019) that involves a range of actors (governments, private actors, civil society and individuals) at multiple scales (local, regional, national and international) (Osofsky 2007; Peel and Osofsky 2015; Setzer and Vanhala 2019).

There is a need for caution in predicting the impacts of ongoing cases and of potential new cases (Bouwer 2018). Assessing the significance of climate change litigation involves questions of how to define impact; which evidence sources to consider; and the relevant timeframe for assessment (Setzer and Vanhala 2019). Individual cases often progress slowly through the court systems, and judgments might not be easily enforced (Setzer and Benjamin 2019).

As of November 2019, more than 1,400 climate change litigation cases have been identified the Sabin Center for Climate Change Law (2019a). This identification process has treated climate change litigation cases as being cases brought before administrative, judicial and other investigatory bodies that raise issues of law or fact regarding the science of climate change and climate change mitigation and adaptation efforts (Markell and Ruhl 2012; Burger et al. 2017).

Climate change litigation is 'regulatory' in that it can be seen as an intentional activity attempting to control, order or influence the behaviour of others (Peel and Osofsky 2015, 2018). The regulatory

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[2] https://www.theguardian.com/environment/2019/mar/19/school-climate-strikes-more-than-1-million-took-part-say-campaigners-greta-thunberg (Accessed 23 October 2019).

[3] https://www.theguardian.com/commentisfree/2019/may/23/greta-thunberg-young-people-climate-strikes-20-september (Accessed 29 October 2019).

[4] https://350.org/7-million-people-demand-action-after-week-of-climate-strikes/ (Accessed 17 October 2019)

function of climate litigation has mostly been observed in developed countries, (1,110 have taken place in the United States (Ghaleigh 2010; Preston 2011b; McAllister 2007; Peel and Osofsky 2015; Fisher et al. 2017; Wilensky 2015; 2019a) but more recently also in developing countries (Peel and Lin 2019; Setzer and Benjamin 2019; Humby 2018; Kotze and du Plessis 2019; Zhao et al. 2019a). Thirty-four cases of climate litigation have been identified in the Global South docket, which over half are in Asia (eighteen cases), six are in Africa, and ten in Latin America. Fourteen of these cases were brought between 2005 and the end of 2014, and twenty were brought between 2015 and 2019 (Peel and Lin 2019; 2019b).

Cases have also been brought to supranational tribunals such as the UN Human Rights Committee, the Inter-American Commission on Human Rights and the Inter-American Court on Human Rights(2019b). Some scholars see a potential role for climate change litigation in international courts and tribunals, including the International Court of Justice (Bodansky 2017; Sands 2016).

The majority of climate change litigation cases are brought by citizens, corporations and non-governmental organisations (NGOs) against governments (Wilensky 2015; Markell and Ruhl 2012; Eisenstat 2011; Fisher et al. 2017) with 85 per cent of cases in the US; 81 per cent of cases in the rest of the world (Setzer and Byrnes 2019).

Climate change litigation has also been brought against corporations by governmental (regional and local governments) as well as non-governmental actors (civil society organisations, individuals and commercial associations) (Wilensky 2015; Ganguly et al. 2018);. risk (Abate 2010, 2019; Hodas 2000; Ganguly et al. 2018; Hunter and Salzman 2007; Kysar 2011; Bouwer 2018). Private actors have also been defendants to climate change litigation (Wilensky 2015; Markell and Ruhl 2012). Analysis of climate change litigation in the United States shows NGOs have played a prominent role in climate protection before the courts (Adler 2019).

In the United States, an analysis of the outcomes of 873 cases between 1990 and 2016 found that outcomes favoured anti-regulatory litigants compared with pro-regulatory litigants with a ratio of about 1.4 to 1 (McCormick et al. 2018). Examined by climate topic, pro-regulation litigants tend to win renewable energy and energy efficiency cases, and more frequently lose coal-fired power plant cases (McCormick et al. 2018). Outside the United States, an analysis of 305 cases between 1994 and May 2019 found that outcomes favoured pro-regulatory litigants compared with anti-regulatory litigants with a ratio of about 1.6 to 1 (Setzer and Byrnes 2019).

More recently, a new generation of strategic private climate change litigation alleging climate change-related damage and seeking compensation from major carbon polluters has been identified (Ganguly et al. 2018). This litigation responded to studies suggesting that a group of multinational corporations (the so-called ‘Carbon Majors’) are historically responsible for a significant portion of global greenhouse gas emissions (Heede 2014; Frumhoff et al. 2015; Ekwurzel et al. 2017). Strategic climate change litigation against major emitters also relies on advancements in climate science, particularly climate attribution (Marjanac et al. 2017; Marjanac and Patton 2018; McCormick et al. 2018). Litigants have argued that major carbon emitters had knowledge and awareness of climate change and took actions to confound or mislead the public about climate science (Supran and Oreskes 2017).

Strategic climate change litigation has been used to argue against financial investments in the fossil fuel industry (Franta 2017). Shareholders have brought claims against banks, pension funds and investment funds for failing to incorporate climate risk into their decision-making, and for failing to disclose climate risk to their beneficiaries, as a way to force these institutions to make changes to their business and investment models in the face of altered risk (Solana 2019; Ganguly et al. 2018).

13.9.4 Media, Building Agreement and Action

The coverage of climate change by media (television, films, books, flyers, newspapers, magazines, radio, new and social media) has grown steadily from the 1980's (Boykoff et al. 2019). There is no one single climate-related event that has significantly transformed media coverage over time (Anderson 2015; Fazey et al. 2018).

Media coverage of climate change mitigation has influenced public discussions through political, economic, ecological/meteorological, scientific and cultural themes about climate change ('*high evidence' and high confidence*') (Irwin et al. 1996; Smith 2000; Boykoff 2011; O'Neill et al. 2015). Media representations of climate science and policy do not solely drive public opinion, individual action, culture or societal change, but they have proven to be a key contributor – among a number of factors – that have stitched together spaces of climate science, governance and daily life (Boykoff 2011). Research interrogating legacy/traditional (also known as print, radio and television, (Lester and Cottle 2009) as well as new/social media (O'Neill et al. 2015) and Models (the Issue-Attention Cycle (Downs 1972), the Public Arenas Model (Hilgartner and Bosk 1988) and Circuits of Communication (Carvalho and Burgess 2005)) have helped explain the production, movements and influences of media in the public sphere coverage of climate change. Importantly, peer-reviewed research has illustrated that more media coverage of climate change does not necessarily lead to more fair and accurate coverage of climate change mitigation (Boykoff and Yulsman 2013; van der Linden et al. 2015; Painter 2019; Whitmarsh and Corner 2017; Fahy 2018). Media therefore can have far-reaching consequences in terms of ongoing environmental scientific inquiry as well as policy maker perceptions, understanding and potential decision-making (Boykoff 2011; Hmielowski et al. 2014). Interpretation and consumption of media varies demographically (Engesser and Brüggemann 2016; Vu et al. 2019).

Media are intermediaries between science and people's everyday lives, and media representations influence understanding of climate science and policy decision-making (Nisbet 2009; Pezzullo and Cox 2017; Berglez et al. 2017; Luedecke and T. Boykoff 2017; Boykoff 2019; Boyce et al. 2009; Asayama and Ishii 2014). Media representations – from entertainment to news – play a critical role in shaping our perceptions and considerations and action (Boykoff and Goodman 2009; Carvalho 2010). Media can be a useful conduit to build public support to accelerate mitigation action as well as shine a light on individuals, groups and organizations that impede these decarbonisation endeavours (Boykoff 2011; Farrell 2016a; Carmichael et al. 2017; Carmichael and Brulle 2018; Boykoff 2019).

A trend towards increased media coverage of present and localized issues have helped connect climate change with what matters to their audiences, thereby increasing awareness and engagement (Leiserowitz 2006; Trope et al. 2007; Corner and Clarke 2017; Whitmarsh and Corner 2017; Doyle 2016; Markowitz and Guckian 2018).

There are numerous professional challenges associated with media representations of climate change mitigation (Carvalho 2007; Revkin 2007; Painter 2013; Zaval 2016; Luedecke and T. Boykoff 2017; Hoffmann 2015)

There has been important research undertaken over time to improve media communications about mitigation and other associated dimensions of climate change (Moser and Dilling 2011; van der Linden et al. 2015; Hansen 2015; Olausson et al. 2018; Markowitz and Guckian 2018). Research has examined creative approaches through media to engage segments of the public citizenry through endeavours such as climate fiction and films (Svoboda 2016); humour and entertainment media (Brewer and McKnight 2015; Boykoff and Osnes 2019; Skurka et al. 2018); and strategic communications campaigns (Hansen and Machin 2008; Hoewe and Ahern 2017). New/social media can be harnessed as powerful tools to accelerate civic action in the public sphere (Segerberg and Bennett 2011; Davies and Hara 2017).

There has been a great deal of social science analyses of how certain framings of climate change have influenced public understandings and policy action on climate change (Boykoff 2011; Wozniak et al. 2015) and how re-framing climate communications in print media (Rebich-Hespanha et al. 2015; Bernauer and McGrath 2016) through television media (Debrett 2017; Smith et al. 2018) and via new social media (Shapiro and Park 2018); can help boost engagement and (mitigation) policy action (Weingart et al. 2000).

There are also disruptive influences where misinformation can rapidly spread through new / social media (Walter et al. 2018). Clear transference of the science of climate change for segments of the global public citizenry has been undermined through contributions in part by climate change counter-movements which have significantly shaped media discussions (Farrell 2016a; Carmichael et al. 2017; Carmichael and Brulle 2018; Boykoff and Farrell 2019; McCright and Dunlap 2000, 2003; Jacques et al. 2008; Brulle et al. 2012; Boussalis and Coan 2016; Almiron et al. 2019)). Researchers have documented how contrarian individuals and groups have influenced both legacy and new/social media environments with misinformation and impeded awareness and engagement (van der Linden et al. 2017; Dunlap and McCright 2015, 316–318).

Climate change counter-movements have utilized media as a conduit to spread misinformation about the causes and consequences of climate change (Brulle 2014; Farrell 2016a,b; Supran and Oreskes 2017). Together with the proliferation of suspicions of 'fake news' and 'post-truth', media representations have fuelled polarization and partisan divides on climate change in contexts such as the United States (Feldman et al. 2015)*(citation missing)*, Australia, Canada and Brazil (Hornsey et al. 2018).

13.10 Enabling conditions and acceleration

13.10.1 Introduction

This section focuses on literature advice concerning an acceleration of the rate of climate mitigation. It provides a brief overview of the literature of enabling conditions for successful policy goal implementation; the self-reinforcing ability of some policies, and therefore the potential of the characteristic to speed up climate mitigation; and an introduction to a sub-transition literature theme of acceleration which suggests various necessary conditions for accelerating climate action and GHG reduction.

Multiple chapters and sections in AR6 focus on key individual enabling conditions such as people and behaviour (chapter 5 and 13.9); finance for investment (Chapter 15); innovation policy (Chapter 16); sustainable development, and its relationship with accelerated stringency (Chapter 1 and Chapter 17). This section does not repeat their messages. We hope that this section – framed as it is in enabling conditions – provides a way to combine the urgency of climate mitigation with a way forward in the context of sustainable development.

13.10.2 Enabling Conditions

Enabling conditions is a widely used term e.g. (UNFCCC 2001). The current IPCC AR6 glossary definition is:

> 'Conditions that affect the feasibility of adaptation and mitigation options, and can accelerate and scale-up systemic transitions that would limit temperature increase and enhance capacities of systems and societies to adapt to the associated climate change, while achieving sustainable development, eradicating poverty and reducing inequalities…..'

A multi-disciplined literature argues for ‘enabling conditions’ to be in place to deliver a successful policy. Analogous terms are also ‘enabling environment’ (Gomez Echeverri 2018); ‘enabling factors’ (Korhonen-Kurki et al. 2014) and ‘favourable conditions’ (Roberts et al. 2018). The enabling conditions body of literature views policy instruments and institutions as necessary, but insufficient, conditions for the most effective delivery of the context specific policy goals. The concept of enabling conditions has only recently been theorized with the intention to take it beyond its broad use as a phrase to encompass all necessary, context specific requirements to ensure a policy is successful in its implementation (Zabaloy et al. 2019); and to clarify the ‘more (or less) favourable conditions for deliberate acceleration’ (Roberts et al. 2018). These conditions are context specific, and include hard-to-tie-down aspects such as justice, coordination, inclusivity and engagement; and can be found in multiple literatures, including the acceleration literature below.

Multiple authors list (some of) a core set of enabling conditions such as institutions, policy and regulatory framework, economic issues, financial issues, laws, resources, information, knowledge and public awareness (Zabaloy et al. 2019; Duguma et al. 2014b; Mallett 2013; Haselip et al. 2011; Waisman et al. 2019; Recalde 2016). Because the enabling condition literature is context specific, authors may then specify additional conditions for specific policy goals and places. For example, Zabaloy (2019) includes International border conditions (energy price volatility, cooperation agreements, international funding opportunities) and National border conditions (institutional framework, political will, energy subsidies, human and capital capacities, natural conditions (energy resources, endowment) as important enabling conditions for the effectiveness in delivering energy efficiency policies in South America. Korhonen-Kurki et al. (2014) note national ownership of policy process, transformational coalitions, inclusiveness of the policy process as ‘enabling factors’ for establishing REDD+ in a context of weak governance. See also (Duguma et al. 2014b; Suzuki 2014; Haselip et al. 2011; Mallett 2013; D’Almeida Martins and Da Costa Ferreira 2011).

Enabling conditions are often described in tandem with the need to overcome barriers (D’Almeida Martins and Da Costa Ferreira 2011; Suzuki 2014; Boyd and Ghosh 2013). For example, current systems built around fossil fuels, lack of open access to infrastructure, with the corollary that enabling conditions are required to overcome them (Pekez et al. 2016).

13.10.3 Accelerating action over time: Designing effective policies and institutions

At the same time as ensuring the presence of the necessary enabling conditions for a policy goal, At the same time as ensuring the presence of the necessary enabling conditions for a policy goal, attention to the temporal aspects of policy processes helps to conceptualize, understand and improve policy responses to climate change and accelerate mitigation action . These temporal concepts include, inter alia: path dependence, policy feedback (Pierson 1993), policy stability (Rietig and Laing 2017), political sustainability (Lockwood 2013), path dependent policy (Yona et al. 2019), policy lock-in (Biber et al. 2017), policy stickiness (Rosenbloom et al. 2019), positive institutional lock-in(2016), tipping points (Roberts and Geels 2019; Strauch 2020), policy inertia (Munck af Rosenschöld et al. 2014), and planned policy removal through exnovation (David 2018).

13.10.3.1 Path dependence and climate mitigation

Path dependence is a situation where decisions, events, or outcomes at one point in time constrain actions or options at a later point in time (see Glossary). Institutional path dependence created by policies and institutions can constrain, slow, and otherwise act as a barrier to climate mitigation (Fleurbaey et al. 2014; Munck af Rosenschöld et al. 2014; 2016; Unruh 2000). For example, carbon-intensive modes of transportation and energy generation generate technological lock-in, which can be reinforced by the institutional lock-in created by supporting policies such as fossil fuel subsidies (Kotilainen et al. 2019; 2016; Skovgaard et al. 2018).

Climate mitigation policies themselves can also create path dependent processes that accelerate mitigation, for example by contributing to technological innovations and cost reductions (Schmidt and Sewerin 2017), mobilizing supportive coalitions (Bernstein and Hoffmann 2018; Jordan and Moore 2020; Meckling et al. 2015), and increasing the public acceptability of mitigation, for example by using revenues from carbon pricing to distribute per-capita dividends to the public (Klenert et al. 2018).

Ambition can be increased by changing policies in a gradual, incremental fashion (Mahoney et al. 2010) for example by the sequencing of progressively more stringent policy instruments (Meckling et al. 2017) or increasing the ambition of existing policies (Averchenkova et al. 2017b; Schaffrin et al. 2015). Change can also happen rapidly during critical junctures (or windows of opportunity) when constraints are reduced for relatively short periods of time (Capoccia and Kelemen 2007), for example during changes in government, or in the run-up to international climate negotiations such as the 2009 Copenhagen summit (Gravey and Moore 2018; Skjærseth et al. 2016).

In some cases, change is slow at first but then reaches a threshold or tipping point, after which mitigation accelerates (Roberts and Geels 2019; McMeekin et al. 2019). Some sectors will be further along the pathway on the low-carbon transition than others, and policy makers should design tailored policy mixes tailored to these different situations. For example, Victor et al. (2019) suggest sectors such as steel and aviation that have only started to transition should be supported by policies to support testing and deployment, while in more advanced sectors such as electricity generation governments should support an increase in market share for low-carbon technologies.

Policies can also influence their own development through policy feedback, the effects that a policy, once adopted, has on subsequent political processes and policy making (Edmondson et al. 2019; Jordan and Moore 2020; Lockwood 2013; Pierson 1993; Skocpol 1992). Self-reinforcing policy feedback strengthens a policy politically, for example by distributing concentrated benefits to industries which then defend the policy (Meckling et al. 2015); providing evidence of industry performance on emissions reductions which can be used by civil society actors to push for greater ambition (Jordan and Moore 2020) or being feedback friendly (Strauch 2020). Self-reinforcing policies can also lead to technological innovation, creating technology-related feedback effects that influence subsequent political processes (Schmidt and Sewerin 2017).

13.10.3.2 Temporal thinking to design policies and institutions to accelerate low-carbon transitions

A key challenge that policy makers face is to design mitigation policies and institutions that are simultaneously durable enough to create predictability and flexible enough to respond to changing circumstances (Jordan and Moore 2020; Patashnik 2003; 2016). To create durability, policies should seek to create self-reinforcing dynamics that build support for mitigation across a wide variety of actors (Müller and Slominski 2013; Wettestad and Jevnaker 2019), including the public (Klenert et al. 2018), businesses (Downie 2019; Meckling et al. 2015), and public authorities (Jordan and Moore 2020; Skjærseth 2018). Policy makers can, for example, include specific, binding emission targets in policies and place evaluation and enforcement authority in the hands of an independent agency (Jordan and Moore 2020).

Policies and institutions must also be flexible in order to adapt to changing conditions, for example to raise ambition in light of changes to scientific knowledge and technological innovation. For example, including revision clauses that require policy makers to update underlying legislation at regular intervals creates predictable windows of opportunity for further refinement (Carlson and Fri 2013; Haasnoot et al. 2013; Jordan and Moore 2020; Patashnik 2008; Rabe 2016; Seto et al. 2016).

Rosenbloom et al. (2019) argue for policy makers to focus on stability for “the overarching orientation of climate policy as a transition towards a low greenhouse gas emission economy” – meaning that the means of mitigation could change as became necessary but the overarching goal would remain durable.

More recent literature has begun to compile ‘lessons’ to operationalize the temporal aspects of policy making specifically for acceleration (Jordan and Moore 2020; Levin et al. 2012; Kotilainen et al. 2019; Strauch 2020).

13.10.4 Coordination and acceleration

The literature exploring how to accelerate GHG reduction has grown rapidly over the last few years (European Environment Agency 2019; Victor et al. 2019; Kotilainen et al. 2019; Strauch 2020; Roberts et al. 2018; Hess 2019; Gomez Echeverri 2018; Burger et al. 2020; O’Brien 2018) . A review of the state of transition research confirmed that ‘acceleration’ is now an important sub-theme (Köhler et al. 2019). Most of this literature argues for certain conditions to enable acceleration, although not necessarily calling them ‘enabling’ conditions.

At a national system level, Geels et al. (Geels et al. 2017b) argues that ‘acceleration depends heavily on country-specific dynamics in political coalitions, industry strategy, cultural discourses, and civil society pressures. There is no “one-size-fits-all” blueprint for accelerating low-carbon transitions’. Roberts et al. (2018) when exploring the politics of ‘deliberate acceleration’ note ‘the role of coalitions in supporting and hindering acceleration; the role of feedbacks, through which policies may shape actor preferences, which in turn create stronger policies; the role of broader contexts (political economies, institutions, cultural norms, and technical systems in creating more (or less) favourable conditions for deliberate acceleration’. Roberts and Geels (2019) argue that the conditions under which policy makers can accelerate policies are: a weak or destabilised ‘regime’ (which reduces opposition to acceleration policies); the presence of a stabilised niche (meaning that the new innovations are no longer niche such as wind or solar, even if not accepted as the ‘regime’); and a focusing event that galvanises reorientation of regime actors. McMeekin et al. (2019) argue for a whole system approach and greater attention of system architecture, its linkages and reshaping to enable acceleration. See also Hess (2019); Kotilainen (2019) and Victor et al. (2019) who set out means of action and conditions for acceleration in different sectors – the latter arguing that more targeted and coordinated action are the key conditions; and O’Brien (2018) argues for the bringing together what she calls the ‘three spheres of transformation’: the practical, political and personal as the basis of a deliberate, rapid transformation to deliver a 1.5 target.

Other authors focus on acceleration related to single policy goal issues rather than national level transitions. For example, analyzing how to tackle a coal sector transition and ‘stranded regions’ (Spencer et al. 2018) whilst ensuring justice; Dubois et al. (2019) illuminate that targeting household consumption and behavioural decisions are the key to low carbon futures; See also for example, Bodnar et al. (2018) and Goddard and Farrelly (2018). Deliberately phasing out unsustainable technologies and systems (European Environment Agency 2019) as a means to accelerate climate mitigation is a burgeoning literature. See ‘exnovation’(2018); ‘motors of creative destruction’ (Kivimaa and Kern 2016); regime destabilization (Rosenbloom 2018); and dealing with incumbent resistance (Roberts et al. 2018).

Literature alludes to the role that intermediary actors (individuals or a group of people within organisations and can undertake work at multiple geographical levels) play in facilitating knowledge sharing and pooling, building the wider networks needed to support change; and using their expertise to mediate between different interests and making connections (Hodson and Marvin 2010; Roberts and Geels 2019; Bush et al. 2017). Intermediary actors can be understood as ‘coordination agents’ (McMeekin et al. 2019).

13.11 Further research

- Research on climate policy and institutions does not uniformly cover world regions. Specifically, much of the work derives from studies of the global north; more research is needed for global south policies and institutions.
- Further work is required on strengths and weaknesses of different approaches to designing climate institutions that take account of local specificities.
- There is a limited body of *ex post* empirical studies of policy outcomes for both the global north and south. More empirical analysis is needed across the board for policy and institutions, at all scales and for all actors.
- Further work is required on the distributional and transformational impact of a range of climate policy instruments.
- Effective implementation depends on policies and cooperation at all scales and can be enhanced through integrated responses that link adaptation and mitigation. However, assessment of these integrated policies is just emerging and would benefit from greater understanding at all scales.
- There is limited empirical evidence available on the prevalence and extent of climate leakage across countries, and the relative impact of different channels of leakage.
- There is very little experience of accelerating emission reduction through behavioral changes. Empirical analysis in this area is needed but also some scholars argue for the benefits of research monitoring and alongside experimentation with policies to enable learning. There is, in general, too little research on understanding the conditions under which people will alter their behavior to the benefit of climate mitigation.
- To date, there are only a limited number of case studies that measure the direct effect of citizen participation in citizen engagement movements and actions, as it relates to climate outcomes.
- Most forms of civic engagement have indirect effects on greenhouse gas emissions—pressuring economic and political actors to change policies and behaviours in a way that will lead to reductions in emissions. Absolute levels are unknown and would benefit from more research.
- Beyond these studies that directly look at emissions, there is a small but growing literature that assesses the consequences of civic engagement and activism, which aims to pressure policymakers to take action. Again, this would benefit from more research.
- Most of the existing literature on the temporal aspects of climate policies, and institutions, including path dependence and policy feedback, focuses on North America and Europe Assuming mitigation is more rapid in developed parties under Common but Differentiated Responsibilities, lessons on this topic are even more crucial for developing parties, more attention to these issues is needed in research focused on the Global South.
- Further theoretical and empirical research on the necessary conditions to accelerate climate mitigation would also be welcome.

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