issues of justice in Adaptation Fund financing decisions to date. Further research into the distribution of adaptation finance across countries, sectors, and communities is required to assess the equity, efficiency, effectiveness, and environmental impacts of the operation of the Adaptation Fund (Persson, 2011).

The Conference of the Parties to the UNFCCC has decision-making power regarding the representation of country groups on the governing boards of the UNFCCC's funding vehicles, voting rules, the choice of secretariat and the choice of trustee (e. g., who oversees the finances and ensures funds go where they are supposed to go). Due to its complex structure, the GEF faces challenges coordinating with UNFCCC decisions (COWI and IIED, 2009; Ayers and Huq, 2009). Recipient countries have a majority on the board of the Adaptation Fund, while the decision-making bodies for the other UNFCCC financing institutions have equal representation for developing and industrialized countries. The Adaptation Fund has allowed the possibility of 'direct access' by host country institutions, which has been used sparingly to date (Ratajczak-Juszko, 2012). The GEF is also starting to experiment with this approach (GEF, 2011).

Funding per country eligible under the Adaptation Fund is limited to 10 million USD, essentially leading to a situation where each country gets financing for a single project. Stadelmann et al. (2013) show that this does not lead to projects ranking high on equity and efficiency criteria. The GEF operates funding floors and caps for each country (currently 2 million USD and 11 % of the total volume available, respectively) (GEF, 2010). Between these thresholds, a complex allocation formula is used whose variables consist of GDP, project portfolio performance, country environmental policy and institutional performance, GHG-emissions level, development of carbon intensity, forestry emissions, and changes in deforestation.

A step change with regards to the international coordination of public finance flows was the collective commitment by industrialized countries in the Copenhagen Accord of 2009 to provide resources approaching 30 billion USD as 'Fast Start Finance' (FSF) during the period 2010–2012 for mitigation and adaptation in developing countries (UNFCCC, 2009a). Fast Start Finance was to provide 'new and additional' resources, flowing through existing multilateral, regional, and bilateral channels. Although few countries disclose details of their FSF, studies show that FSF ranges from small grants to large loans for infrastructure development (Fransen et al., 2012; Nakhooda and Fransen, 2012; Kuramochi et al., 2012). While the FSF commitment for 2010–2012 has been exceeded, transparency regarding allocation criteria and actual disbursement is low (Ciplet et al., 2013). Official development assistance (ODA) made up a large share of total funding (Ballesteros et al., 2010) and several studies argue that the use of ODA as a substitute for new climate finance mechanisms could divert funding away from other important imperatives (Michaelowa and Michaelowa, 2007; Ayers and Huq, 2009; Gupta and van der Grijp, 2010). See also Section 16.2.1.1.

13.11.1.2 Multilateral development banks

Multilateral development banks (MDBs) have played a significant role in mobilizing, coordinating, and overseeing the growth of climate-related financial flows. The World Bank provides services as trustee or interim trustee for all the UNFCCC-related funds noted above. A group of MDBs manages and governs the Climate Investment Funds (CIFs), which were set up in 2008, are not supervised by the UNFCCC, and are financed through voluntary government contributions. The Clean Technology Fund supports investments in low-carbon technologies, and the Strategic Climate Fund is an umbrella for improving resilience against climate change, reducing deforestation and renewable energy support for low-income countries.

Tirpak and Adams (2008) see increases in MDBs' funding and shifts to low-GHG technologies being fragile owing to variability and low levels of funding. Bowen (2011) proposes expansion of the capital base of multilateral financial institutions in order to increase concessional financing (finance made available at lower than market costs) of mitigation and adaptation activities.

Over the last two decades, recipients have gained more decision-making power in the institutions under the UNFCCC, while multilateral financial institutions have not followed this trend. Financing is typically not given directly to the project recipients but provided through implementing agencies, mostly multilateral financial institutions or UN agencies that fulfil predefined fiduciary standards. Direct access, as implemented by the Adaptation Fund, is seen by some as the most appropriate model for climate finance (UNDP, 2011). However, peer-reviewed literature comparing the effectiveness of the two approaches is lacking. At the same time, national development banks (e. g., China Development Bank, Brazilian Development Bank (BNDES)), Bilateral Finance Institutions, and a planned multilateral fund of the Brazil, Russia, India, China, and South Africa (BRICS) countries have also provided or may provide substantial funding (Höhne et al., 2012a; Robles, 2012)

13.11.2 Mobilizing private investment and financial flows

Another emerging focus of international climate cooperation is on mobilizing private investment to finance mitigation and adaptation. As discussed in Sections 13.4.1.4 and 13.13.1.1, carbon credits from market mechanisms generate revenues for private sector players, thus leveraging potentially large investments in mitigation. Such leverage is seen as important by Urpelainen (2012), who presents a game-theoretical model where capacity building leverages private mitigation investment. A number of international initiatives have supported capacity building for market mechanisms (Okubo and Michaelowa, 2010). Also, the multilateral financing institutions discussed in Section 13.11.1 will 'leverage' private finance to complement their public funding.

The potential for leveraging to lead to double- and multiple-counting has led to suggestions that internationally agreed methodologies to account for leveraging are needed (Clapp et al., 2012), which would be of help in consistent reporting of finance against the goal agreed under the UNFCCC. Stadelmann et al. (2011a) find that the leverage factors, that is the ratio between mobilized private funding and mobilized public finance, for the Climate Technology Fund under the CIFs and the GEF reach self-reported levels of 8.4 and 6.2, respectively. However, an analysis of over 200 CDM and close to 400 GEF projects, Stadelmann et al. (2011a) find a leverage ratio of just 3.0–4.5. Moreover, high-leverage factors may mean that the underlying project is not additional, i.e., not contributing to mitigation. Finally, instead of leveraging in the private sector through capacity building, the World Bank engagement in the Kyoto mechanisms has at least partially crowded out private sector activities, as shown empirically by Michaelowa and Michaelowa (2011).

Besides market mechanisms, other instruments such as grants, loans at concessional rates, provision of equity through financial institutions, or guarantees can mobilize private funds. This can happen directly on the company level or be channelled through national governments (Neuhoff et al., 2010). While they can be implemented on any level of aggregation, the level of incentive provided could be coordinated internationally, e.g., by basing it on a previously agreed 'social cost of carbon' (Hourcade et al., 2012). The success of the Multilateral Investment Guarantee Agency shows that costs of guarantees are likely to be low if multilateral and bilateral financial institutions with strong financial ratings provide them (Brown et al., 2011; Buchner et al., 2011).

13.12 The role of public and private sectors and public-private partnerships

International responses to climate change ultimately depend on private sector action. Large multinational corporations produce about half of the global world product and global GHG emissions (Morgera, 2004). Hence, private companies will need to generate investment and innovation necessary to pursue a low-carbon economy (Forsyth, 2005). Given that damages from climate change are a (negative) externality, a gap remains between the need for GHG reduction and the commitments of the largest international companies (Knox-Hayes and Levy, 2011). While some business sectors may have an interest advancing policy to mitigate climate change (Pulver, 2007; Falkner, 2008; Pinkse and Kolk, 2009; Meckling, 2011), in practice the public sector typically guides, supports, and motivates private sectors to contribute to a low-carbon economy. These types of public sector interactions with the private sector can operate through government regulations (whether market-based or conventional), but may also be facilitated through public-private partnerships, the focus of this section.

13.12.1 Public-private partnerships

One channel for such guidance is through public-private partnerships focused on climate change, which have multiplied and grown in recent years (Bäckstrand, 2008; Pattberg, 2010; Andonova, 2010; Kolk et al., 2010). Public-private partnerships involve governments, businesses, and sometimes NGOs. Examples include the Renewable Energy and Energy Efficiency Partnership (REEEP) (Parthan et al., 2010); the Methane to Markets initiative (now renamed the Global Methane Initiative) (de Coninck et al., 2008); the former Asia Pacific Partnership on Climate and Energy (which was largely organized through sector-specific partnerships) (Karlsson-Vinkhuyzen and van Asselt, 2009; McGee and Taplin, 2009; Okazaki and Yamaguchi, 2011); the Global Superior Energy Performance Partnership (taking sector-specific activities from the regional scale to the global scale) (Fujiwara, 2012; Okazaki et al., 2012; see also Section 14.3.3); the CDM (where some projects can take the character of public-private partnerships) (Streck, 2004; Green, 2008; Newell, 2009); the World Bank Prototype Carbon Fund (Lecocq, 2003; Andonova, 2010); the UN Fund for International Partnerships (39% of whose environmental partnerships are in energy- or climate change-related projects) (Andonova, 2010); the UN Global Compact's 'Caring for Climate' initiative (Abbott, 2011); the Green Power Market Development Group (Andonova, 2009); and the Munich Climate Insurance Initiative (Pinkse and Kolk, 2011). These partnerships can facilitate development and commercial deployment of low-carbon technologies as governments remove barriers to the entry and provide stakeholders with new business frameworks. Industries also demonstrate leadership through active involvement with regards to their technologies, investments, and know-how (IEA, 2010).

Some international public-private partnerships concentrate on the development of specific technologies. Others focus on rural renewable energy or low-carbon energy development in general. Others center their attention on carbon market development. Few focus on adaptation, although the insurance sector is involved in such initiatives (Pinkse and Kolk, 2011). Effective partnerships are institutionalized with representatives of major stakeholders, a permanent secretariat, resources and a dedicated mission (Pattberg et al., 2012). Company willingness to engage in adaptation depends on their capacity, their past exposure to disasters, and the link between their business planning horizons and climate impact uncertainty (Agrawala et al., 2011). Some also need to ensure that they are able to adapt to changing climatic circumstances (Linnenluecke and Griffiths, 2010; Vine, 2012).

13.12.2 Private sector-led governance initiatives

Private sector actors have also engaged in direct attempts to govern aspects of climate change transnationally. First, some institutional investors now ask companies to report on their GHG emissions, strategies to reduce them, and more broadly on climate risk exposures (Kolk et al., 2008; Newell and Paterson, 2010; Harmes, 2011; MacLeod and

Park, 2011). The most important example of this is the Carbon Disclosure Project, whose signatories controlled 70 trillion USD in assets in 2011 (Carbon Disclosure Project, 2011). The private sector is playing a role in developing systems for carbon accounting (Lovell and MacKenzie, 2011).

Second, like NGOs (see Section 13.5.2), private-sector actors have developed initiatives to govern voluntary carbon markets, either through certification standards for offset markets or by developing trading exchanges, registries, and protocols for reporting GHGs (Green, 2010, 2013; Hoffmann, 2011). Many of the certification schemes are either developed by private-sector actors (such as the Voluntary Carbon Standard, developed by the International Emissions Trading Association, the Climate Group, and the World Business Council for Sustainable Development) or by such actors in collaboration with environmental NGOs (such as the Social Carbon standard).

13.12.3 Motivations for public-private sector collaboration and private sector governance

For private sector actors, partnerships with governments or NGOs on climate may create direct economic benefits through financial support, learning opportunities, risk sharing, or market access (Pinkse, 2007; Perusse et al., 2009). Since direct regulation of firms at the international level is unavailable, states have incentives to pursue partnerships to affect transnational private sector activities. International organizations pursue partnerships for similar reasons (Andonova, 2010). Partnerships or private governance may create club goods for participants (Andonova, 2009). Sometimes, firms are motivated more by concerns for public relations (Pinkse and Kolk, 2009). Private sector finance can be stimulated by a five-step approach: strategic goal setting and policy alignment, an enabling process and incentives for low-carbon and climate-resilient (LCR) investment, financial policies and instruments, harnessing resources and building capacity for a LCR economy, and promoting green business and consumer behaviour (Corfee-Morlot et al., 2012).

13.13 Performance assessment on policies and institutions including market mechanisms

This section surveys and synthesizes quantitative and qualitative assessments of existing and proposed forms of international cooperation to address climate change mitigation that have appeared in the literature since AR4. Adaptation is not treated here, as there have been few international cooperative initiatives focused on adaptation, although these are now starting to emerge (Section 13.5.1.1).

Existing cooperation is considered in Section 13.13.1 with reference to the UNFCCC, its Kyoto Protocol, the CDM, agreements under the UNFCCC pertaining to the post-2012 period, and agreements and other forms of international cooperation outside of the UNFCCC. Section 13.13.2 considers the literature that assesses various proposed forms of future international cooperation described in Section 13.4.3. Throughout, we synthesize assessments in terms of the four criteria discussed in Section 13.2: environmental effectiveness, aggregate economic performance, distributional impacts, and institutional feasibility. Table 13.3 summarizes the key findings of this section's performance assessment.

In applying the evaluation criteria to evaluate existing and proposed forms of international cooperation, five general caveats apply. First, an ex-ante evaluation of a policy may overestimate the costs and/or the benefits of that policy for several reasons, such as overestimating the extent of its implementation (Harrington et al., 2000; Harrington, 2006), failing to account for over-reporting by regulated parties (Bailey et al., 2002), and underestimating learning related to technological development (Norman et al, 2008). Second, ex-ante evaluation may over- or under-estimate the effectiveness of proposed cooperation, because interactions between proposed policies and other existing policies may be difficult to predict. These interactions can be counterproductive, inconsequential, or beneficial (Fankhauser et al., 2010; Goulder and Stavins, 2011; Levinson, 2012). Third, while evaluation of proposed policies can be informed by lessons learned from regime complexes in other contexts (see Section 13.5), such lessons may come with extrapolation bias, since it may not be appropriate to generalize to climate change findings from other contexts. Fourth, in comparing existing policies using these criteria, it can be helpful to keep in mind that as institutions evolve, the performance of particular policies may also change. Fifth and finally, the overall performance of the international regime depends also on national and regional policies (see Chapters 14 and 15, in particular Sections 14.4.2 and 15.5).

13.13.1 Performance assessment of existing cooperation

13.13.1.1 Assessment of the UNFCCC, the Kyoto Protocol, and its flexible mechanisms

The UNFCCC established a framework and a set of principles and goals for the international response to climate change. Under Article 2, the parties agreed to the objective of "prevent[ing] dangerous anthropogenic interference with the climate system," an objective which was not quantified and was subject to several caveats. Under Article 4(2)(a), the Annex I parties committed to adopt measures (which could be

Table 13.3 | Summary of performance assessments of existing cooperation of proposed cooperation on climate change.

	Mode of International Cooperation		**Assessment Criteria**			
			Environmental Effectiveness	**Aggregate Economic Performance**	**Distributional Impacts**	**Institutional Feasibility**
Existing Cooperation [13.13.1]	**UNFCCC**		Aggregate GHG emissions in Annex I countries declined by 6.0 to 9.2 % below 1990 levels by 2000, a larger reduction than the apparent 'aim' of returning to 1990 levels by 2000.	Authorized joint fulfilment of commitments, multi-gas approach, sources and sinks, and domestic policy choice. Cost and benefit estimates depend on baseline, discount rate, participation, leakage, co-benefits, adverse side-effects, and other factors.	Commitments distinguish between Annex I (developed) and non-Annex I countries. Principle of 'common but differentiated responsibility.' Commitment to 'equitable and appropriate contributions by each [party].'	Ratified (or equivalent) by 195 countries and regional organizations. Compliance depends on national communications.
	The Kyoto Protocol (KP)		Aggregate GHG emissions in Annex I countries were reduced by 8.5 to 13.6 % below 1990 levels by 2011, more than the first commitment period (CP1) collective reduction target of 5.2 %. Reductions occurred mainly in EITs; emissions increased in some others. Incomplete participation in CP1 (even lower in CP2).	Cost-effectiveness improved by flexible mechanisms (Joint Implementation (JI), CDM, International Emissions Trading (IET)) and domestic policy choice. Cost and benefit estimates depend on baseline, discount rate, participation, leakage, co-benefits, adverse side-effects, and other factors.	Commitments distinguish between developed and developing countries, but dichotomous distinction correlates only partly (and decreasingly) with historical emissions trends and with changing economic circumstances. Intertemporal equity affected by short-term actions.	Ratified (or equivalent) by 192 countries and regional organizations, but took 7 years to enter into force. Compliance depends on national communications, plus KP compliance system. Later added approaches to enhance measurement, reporting, and verification (MRV).
	The Kyoto Mechanisms		About 1.4 billion tCO_2eq credits under the CDM, 0.8 billion under JI, and 0.2 billion under IET (through October 2013). Additionality of CDM projects remains an issue but regulatory reform underway.	CDM mobilized low-cost options, particularly industrial gases, reducing costs. Underperformance of some project types. Some evidence that technology is transferred to non-Annex I countries.	Limited direct investment from Annex I countries. Domestic investment dominates, leading to concentration of CDM projects in few countries. Limited contributions to local sustainable development.	Helped enable political feasibility of Kyoto Protocol. Has multi-layered governance. Largest carbon markets to date. Has built institutional capacity in developing countries.
	Further Agreements under the UNFCCC		Pledges to limit GHG emissions made by all major emitters under Cancún Agreements. Unlikely sufficient to limit temperature change to 2°C cost-effectively. Depends on treatment of measures beyond current pledges for mitigation and finance. Durban Platform calls for new agreement by 2015, to take effect in 2020, engaging all parties.	Efficiency not assessed. Cost-effectiveness might be improved by market-based policy instruments, inclusion of forestry sector, commitments by more nations than Annex I countries (as envisioned in Durban Platform).	Depends on sources of financing, particularly for actions of developing countries.	Cancún Conference of the Parties (COP) decision; 97 countries made pledges of emission reduction targets or actions for 2020.
	Agreements outside the UNFCCC	**G8, G20, Major Economies Forum on Energy and Climate (MEF)**	G8 and MEF have recommended GHG emissions reductions by all major emitters. G20 may spur GHG emissions reductions by phasing out of fossil fuel subsidies.	Action by all major emitters may reduce leakage and improve cost-effectiveness, if implemented using flexible mechanisms. Potential efficiency gains through subsidy removal. Too early to assess economic performance empirically.	Has not mobilized climate finance. Removing fuel subsidies would be progressive but have negative effects on oil-exporting countries and on those with very low incomes unless other help for the poorest is provided.	Lower participation of countries than UNFCCC, yet covers 70 % of global emissions. Opens possibility for forum-shopping, based on issue preferences.
		Montreal Protocol on Ozone-Depleting Substances (ODS)	Spurred GHG emissions reductions through ODS phaseouts approximately 5 times the magnitude of Kyoto CP1 targets. Contribution may be negated by high-GWP substitutes, though efforts to phase out HFCs are growing.	Cost-effectiveness supported by multi-gas approach. Some countries used market-based mechanisms to implement domestically.	Later compliance period for phaseouts by developing countries. Montreal Protocol Fund provided finance to developing countries.	Universal participation. but the timing of required actions vary for developed and developing countries.
		Voluntary Carbon Market	Covers 0.13 billion tCO_2eq, but certification remains an issue.	Credit prices are heterogeneous, indicating market inefficiencies.	[No literature cited.]	Fragmented and non-transparent market.

	Mode of International Cooperation		Assessment Criteria			
			Environmental Effectiveness	Aggregate Economic Performance	Distributional Impacts	Institutional Feasibility
Proposed Cooperation [13.13.2]	**Proposed architectures**	**Strong multi-lateralism**	Tradeoff between ambition (deep) and participation (broad).	More cost-effective with greater reliance on market mechanisms.	Multilateralism facilitates integrating distributional impacts into negotiations and may apply equity-based criteria as outlined in Ch. 4	Depends on number of parties; degree of ambition.
		Harmonized national policies	Depends on net aggregate change in ambition across countries resulting from harmonization.	More cost-effective with greater reliance on market mechanisms.	Depends on specific national policies.	Depends on similarity of national policies; more similar may support harmonization but domestic circumstances may vary. National enforcement.
		Decentralized architectures, coordinated national policies	Effectiveness depends on quality of standards and credits across countries.	Often (though not necessarily) refers to linkage of national cap-and-trade systems, in which case cost-effective.	Depends on specific national policies.	Depends on similarity of national policies. National enforcement.
	Effort (burden) sharing arrangements		Refer to Sections 4.6.2 for discussion of the principles on which effort (burden) sharing arrangements may be based, and Section 6.3.6.6 for quantitative evaluation.			

implemented jointly) to limit net emissions (covering both sources and sinks of all GHGs not controlled by the Montreal Protocol), "recognizing that the return by the end of the present decade [the year 2000] to earlier levels" would contribute to modifying long-term trends consistent with the treaty's objective. Under Article 4(2)(b), Annex I parties committed to periodically communicate information on their emissions, "with the aim of returning individually or jointly to their 1990 levels."

According to UN data, aggregate GHG emissions in Annex I countries declined by 9.2 % from 1990–2000 (if land use and forestry are included; or by 6.0 % if they are not; the base year for some countries is in the mid- or late 1980s) (UNFCCC, 2013c, Profile for Annex I Parties). This is a larger reduction than the apparent two-step 'aim' implied in Article 4(2)(a) and (b) of the UNFCCC to return emissions to 1990 levels by the year 2000. Much of this reduction, however, was due to factors other than measures adopted under the UNFCCC, such as the economic downturn in Annex I 'economies in transition' (EITs)—Russia, former Soviet Republics, and Eastern Europe—during the 1990s.

The 1997 Kyoto Protocol adopted the first binding, quantitative mitigation commitments for developed countries. The 38 countries listed in its Annex B (industrialized countries, EITs, and the European Union separately from its member states) made aggregate commitments to collectively reduce their GHG emissions by 4.2 % relative to 1990 levels (5.2 % relative to the country-specific base years used for establishing national committments) by the Protocol's first commitment period, 2008–2012 (UNFCCC, 1998, 2012b). Other parties to the Kyoto Protocol are not constrained (but can participate in other ways; in particular, see discussion of CDM in Section 13.13.1.2). The Protocol also contained a number of new mechanisms, including IET, JI, and the CDM, that aimed to help reduce GHG emissions cost-effectively.

The aggregate emissions by Annex I countries have been reduced below the Kyoto Protocol's collective 5.2 % reduction target, but, as with the UNFCCC, much of the reduction was due to factors other than Kyoto Protocol. (The list of countries in the Protocol's Annex B is nearly identical to the list of countries in the Convention's Annex I during the historical periods referenced in this section, and the difference in aggregate emissions between the two does not affect the analysis here.) According to UNFCCC GHG inventories, aggregate GHG emissions from all Annex I countries were reduced by 13.6 % from 1990–2011 (if land use and forestry-sector changes are taken into account, and 8.5 % if they are not). Not counting the United States—because it was not a party to the Kyoto Protocol—the reduction from 1990–2011 in the remaining Annex I aggregate GHG emissions was 22.9 % if land use and forestry sectors changes are taken into account and 16.6 % if they are not. Not counting the EITs, the remaining Annex I countries' aggregate GHG emissions increased by 2.1 % and 3.2 % from 1990 to 2011 (with and without land use and forestry, respectively) (UNFCCC, 2012b).

Although emissions have decreased among Annex B parties, the environmental effectiveness of the Protocol's first commitment period has been less than it could have been, for several reasons. First, not all Annex B parties have participated. The United States, until recently the country with the largest share of global emissions (Gregg et al., 2008), did not ratify the Protocol (see also Section 13.3.1). Therefore, its target emissions reduction of 7 %, which would have amounted to over 40 % of the difference in total Annex B committed emissions commitments and base year emissions levels (UNFCCC, 2012b), was not binding. In addition, Canada withdrew from the Protocol in December 2011 (effective December 2012). Russia, Japan, and New Zealand opted not to participate in the second commitment period (2013–2020).

Second, the Annex B EITs were credited for emissions reductions that would have occurred without the Protocol due to their significant economic contraction during the 1990s. These loose targets may have been necessary to engage them as parties (Stewart and Wiener, 2003). In principle, these countries were allowed to sell resultant surplus emissions-reduction credits to other Annex B parties, which might have further reduced environmental effectiveness. However, in practice, other parties bought few AAUs relative to the stock available from EITs during the first commitment period (perhaps because the United States decision not to ratify reduced demand for such allowances), and thus environmental effectiveness was not affected as much as it could have been (Brandt and Svendsen, 2002; Böhringer, 2003; IPCC, 2007, p. 778; Crowley, 2007; Aldrich and Koerner, 2012).

Current model projections imply that emission reductions achieved by Annex B parties during the first and second commitment periods of the Kyoto Protocol are not likely to be sufficient to achieve environmental performance that limits global average temperature increases to 2 °C above pre-industrial levels (Rogelj et al., 2011; Höhne et al., 2012b) (see also Section 6.4 for a discussion of scenarios that relate short-term environmental performance to long-term GHG stabilization and tempterature change goals). A key reason is that, since 1990, the Annex B countries' share of global GHG emissions has declined significantly, from approximately 56 % of global emissions in 1990 to approximately 39 % in 2010. Simultaneously, overall global GHG emissions have risen significantly; global emissions in 2010 were approximately 31 % higher than in 1990 (JRC/PBL, 2013) (see Section 5.2).

The criterion of economic performance encompasses both efficiency and cost-effectiveness (see Sections 3.7.1 and 13.2.) Assessments of the efficiency of the Kyoto Protocol depend on respective estimates of the costs and benefits of mitigation and assumptions regarding the appropriate discount rate (see Sections 2.4.3.2 and 3.6.2 on discounting). Contrasting assumptions regarding these values are the key determinants in explaining the differences between assessments that have found the Protocol inefficient (e.g., Nordhaus, 2007), and those that find it cost-effective, but insufficient (e.g., Stern, 2007; Weitzman, 2007). These latter researchers also tend to emphasize the non-zero probability of catastrophic climate outcomes. The Kyoto Protocol also fostered monitoring and reporting of emissions, and capacity building in developing countries, which may facilitate further cost-effective action in the future (Hare et al., 2010).

With respect to cost-effectiveness, the Kyoto Protocol's three market-based instruments (the CDM, JI, and IET) intended to lower the cost of the global regime (see Section 13.4.2.3 for a description of these mechanisms). Most research on the Kyoto mechanisms has focused on the CDM, primarily because transaction volumes of CDM credits have been so much greater than JI credits or AAUs. Performance assessment of the CDM is discussed separately in Section 13.13.1.2.

International Emissions Trading could, in theory, reduce abatement costs by as much as 50 % if trades took place among Annex B countries (Blanford et al., 2010; Bosetti et al., 2010; Jacoby et al., 2010). However, in practice, trading under this mechanism has been limited, partly due to the surplus problem discussed above (Aldrich and Koerner, 2012) and the absence of the United States. As of July 2013, 0.2 billion tCO_2eq have been traded through IET (Point Carbon, 2013). The few trades that were made generally required reinvestment of the revenues into projects that reduce GHG emissions, under so-called 'Green Investment Schemes.' The economic performance of IET also depends on what type of actor is doing the trading. Early expectations were that the main traders would be states (national governments), and that states would not operate as efficient traders, because they are not cost-minimizers (e.g., Hahn and Stavins, 1999). In practice, increasing shares of trades have been made by private sector firms, which may increase cost-effectiveness (Aldrich and Koerner, 2012).

Joint Implementation also has the potential to improve the cost-effectiveness of Annex B countries' activities under the Protocol (Böhringer, 2003; Vlachou and Konstantinidis, 2010). A large majority of JI projects have been in the transition economies, especially Russia and Ukraine, given the low cost of emissions reductions there relative to other Annex B countries (Korppoo and Moe, 2008). From 2008 through July 2013, JI had led to the issuance of over 0.8 billion emission reduction unit (ERU) credits (UNFCCC, 2013d), each equivalent to one tCO_2eq of reported emission abatement. Over half of this volume was issued by Ukraine and Russia, especially in 2012 in response to the limitation on carrying over surplus AAUs to the second commitment period. The actual distribution of JI projects is not consistent with the theoretical potential, as some countries, such as Ukraine, proactively supported JI, while in others, including Russia, JI lacked political support, and efficient frameworks took several years to establish. In Western Europe, a number of companies in the chemical industry generated emission credits for their own use in the EU ETS, demonstrating the cost-reduction potential (Shishlov et al., 2012). Countries without a surplus of emission units usually applied strict rules to capture part of the emission reductions achieved by JI projects (Michaelowa and O'brien, 2006; Shishlov et al., 2012).

In addition to the three Kyoto flexibility mechanisms, the Protocol provides flexibility with regard to how Annex B parties may achieve their targets; they may employ domestic or regional policies of their own choice. One result has been the development of domestic emissions trading programmes in several countries and regions (Paterson et al., 2014). Regional and national emissions trading programmes include those in the EU (the EU ETS), Australia, and New Zealand, as well as subnational trading programmes in the United States Regional Greenhouse Gas Initiative (RGGI) and California/WCI) and in China (seven regional pilot programmes launched in 2013). See Figure 13.4 above and Sections 14.4.2 and 15.5; (Convery and Redmond, 2007; Ellerman and Buchner, 2007; Ellerman and Joskow, 2008; Ellerman, 2010; Ellerman et al., 2010; Olmstead and Stavins, 2012; Newell et al., 2013).

Distributional impacts of the Kyoto Protocol have been examined both cross-sectionally (mainly geographically) and temporally. Income patterns and trends as well as distribution of GHG emissions have changed significantly since the 1990s, when the UNFCCC and Kyoto Protocol listed Annex I/Annex B countries; some countries outside these lists have become wealthier and larger emitters than some countries on these lists (U.S. Department of Energy, 2012; WRI, 2012; Aldy and Stavins, 2012). For example, in 1990, China's total CO_2 emissions were about half of United States emissions, but by 2010, China emitted more than 50 % more CO_2 than the United States. Over this same time period, China's per capita CO_2 emissions experienced an almost three-fold increase, rising to nearly equal the level in the EU, but still about 36 % of the United States level (IEA, 2012; PBL, 2012, see Annex II.9; Olivier et al., 2012; JRC/PBL, 2013). Non-Annex I countries as a group have a share in the cumulative global greenhouse emissions for the period 1850 to 2010 close to 50 %, a share that is increasing (den Elzen et al., 2013b) (see Section 5.2.1 for more detail on historical emissions).

Meanwhile, income inequality and variations in capacity remain substantial both within and across countries. While GDP per capita in some non-Annex I countries has increased and some have joined the OECD, incomes of G8 countries remain higher than those of major emerging economies such as the BASIC countries (World Bank, 2013). Poverty is much more extensive and income at lower absolute levels in the latter, compared to the former (Milanovic, 2012). Inequality in income remains related to inequalities in emissions (Padilla and Serrano, 2006; Chakravarty et al., 2009).

More broadly, although the Kyoto Protocol's quantitative mitigation requirements are limited to Annex B countries, the economic impacts of these requirements may spill over to non-Annex B countries (Böhringer and Rutherford, 2004). In terms of intertemporal distributional equity, some have noted that climate change mitigation that requires emissions reductions in the short term for uncertain long-term benefits, also involves inter-generational distributional impacts (Schelling, 1997; Leach, 2009).

Among Annex B countries, the Kyoto Protocol's emissions-target allocation is generally progressive, one common measure of distributional equity, exhibiting positive correlation between gross domestic product per capita and the degree of targeted emissions reduction below business-as-usual levels. For a 10 % increase in per capita GDP, Annex B countries' emissions reduction targets are, on average, about 1.4 % more stringent (Frankel, 1999, 2005).

In terms of institutional feasibility, it is notable that the Kyoto Protocol has been ratified (or the equivalent) by 191 countries (plus the EU separately) (Falkner et al., 2010). As noted above, participation among Annex I countries in emissions-reduction commitments dropped significantly from the first (2008–2012) to the second (2013–2020) commitment periods, though the stringency of the emission-reduction commitments of those countries still participating increased for the second period. More broadly, the high rate of ratification is likely due in part to the lack of emissions-reduction commitments asked of non-Annex B countries (Lutter, 2000).

Allowing Annex B countries the flexibility to choose policies to meet their national emissions commitments may have contributed to institutional feasibility. However, compromises made during the negotiation of the Protocol that enabled its institutional and political viability may have reduced its environmental effectiveness (Victor, 2004; Helm, 2010; Falkner et al., 2010). This serves as an example of the tradeoff across ambition, participation, and compliance discussed in Section 13.2.2.5.

Additionally, obstacles for enforcement have hurt the Protocol's institutional feasibility. Despite the Kyoto Protocol's compliance system (Oberthür and Ott, 1999; Hare et al., 2010; Brunnée et al., 2012), it is difficult in practice to enforce the Kyoto Protocol's targets because of the lack of a legal authority with enforcement powers, and the weakness of possible sanctions relative to the costs of compliance. This is, of course, true of most international agreements (van Kooten, 2003; Böhringer, 2003; Barrett, 2008b) (see also Sections 13.3.2 and 13.4.2.1.).

13.13.1.2 Assessment of the Kyoto Protocol's Clean Development Mechanism

The CDM aims to reduce mitigation costs for Annex B countries and contribute to sustainable development in non-Annex B countries (UNFCCC, 1998) (Article 12). This mechanism led to the issuance of nearly 1.4 billion emission credits from over 7300 registered projects by October 2013 (see Section 13.7.2; UNFCCC, 2014). This performance was surprising, given that the CDM suffered from many disadvantages relative to the other flexibility mechanisms (Woerdman, 2000).

The environmental effectiveness of the CDM depends on three key factors: whether a credited project actually reduces more emissions than would have been reduced in its absence (which may depend on whether the project developers are indeed motivated primarily by expected revenue from the sale of the emission credits) ('additionality'); the validity of the baseline from which emission reductions are calculated; and indirect emissions impacts ('leakage') caused by the projects.

The issue of additionality (IPCC, 2007, pp. 779–780) continues to generate controversy, despite an increasing elaboration of additionality tests by CDM regulators (Michaelowa et al., 2009). On the one hand, (Schneider, 2009) found that key assumptions regarding additionality were often not substantiated with credible, documented evidence, in a sample of 93 projects. On the other hand, (Lewis, 2010) finds a clear contribution of the CDM to the rapid upswing of the renewable energy sector in China.

Clean Development Mechanism projects in energy efficiency, transport and buildings have faced challenges in baseline determination, monitoring, and transaction costs (Sirohi and Michaelowa, 2008; Michaelowa et al., 2009; Millard-Ball and Ortolano, 2010). Kollmuss et al. (2010) suggest that it may be possible to prevent baseline gaming through a clear regulatory framework. Heeding this advice, CDM regulators have increased the conservativeness of approved methodologies, after rejecting a significant share of baseline methodology proposals (Michaelowa et al., 2009; Millard-Ball and Ortolano, 2010). Recent attempts by CDM regulators to standardize baselines have triggered a debate regarding their impacts on environmental effectiveness and transaction costs. Making the choice between standardized and project-specific baselines voluntary (Spalding-Fecher and Michaelowa, 2013), as well as "simple, highly aggregated performance standards" (Hayashi and Michaelowa, 2013) could reduce environmental effectiveness.

With regard to leakage, (Vöhringer et al., 2006) argue that emission leakage due to market price effects is unavoidable (as it is for mitigation within Annex B countries), while Kallbekken et al. (2007) stress that regardless of the baseline used, the CDM will reduce carbon leakage through the reduction in the difference in marginal mitigation costs between countries. Schneider (2011) shows that for HFC-23 reduction projects, baseline gaming enabled production of the underlying commodity to shift from industrialized to developing countries (Wara, 2008).

With regard to cost-effectiveness, the CDM offers the potential for cost savings where abatement costs are lower in developing countries. The large volume of credits and projects in the CDM indicates its cost-saving potential. Still, Castro (2012) found that many low-cost opportunities had not been taken up by CDM projects.

The long-term contribution of the CDM to cost-effectiveness depends in part on its ability to promote technological change in developing countries either through technology transfer from industrialized to developing countries (see Section 16.8 for an overview of the technology transfer component of CDM), or by stimulating innovation within developing countries (Reichman et al. 2008). Roughly a third of CDM projects involve technology transfer (Haites et al., 2006). Dechezleprêtre et al. (2008) find that the likelihood of technology transfer is higher for CDM projects operated by subsidiaries of companies from industrialized countries. Seres et al. (2009) find that 36 % of 3296 registered and proposed projects accounting for 59 % of the annual emission reductions claim to involve technology transfer, confirming Dechezleprêtre et al.'s (2008) results. But all of these technology transfer studies limit themselves to assessment of project documents, which are not subject to rigorous and independent verification. Project developers have an incentive to overstate technology transfer. Wang (2010) is an exception, and underpins his analyses of many project documents with background interviews and assesses government policies. He finds that in all but one of the industrial gas projects in China, technology transfer occurred, but only in about a quarter of wind and coal mine methane projects. Okazaki and Yamaguchi (2011) fear that transactions costs, imposed by additionality criteria and Executive Board delays, can discourage technology transfer through the CDM.

Distributional impacts of the CDM relate to contributions to sustainable development, as well as the distribution of rents generated by the sale of emission credits. Olsen (2007) provides a summary of the early literature that did not find significant support for sustainable development induced by CDM projects. Several researchers (Sutter and Parreño, 2007; Gupta et al., 2008; Headon, 2009; Boyd et al., 2009; Alexeew et al., 2010) see the process of host country responsibility for sustainable development and competition between host countries for CDM investment as a reason for the lack of sustainability benefits of CDM projects in some countries, as Designated National Authorities (national CDM-management bodies) may not adequately scrutinize the environmental or social benefits of projects. Parnphhumeesup and Kerr (2011) find that experts and the local population weight sustainability criteria differently in the context of biopower projects in Thailand. Ellis et al. (2007) found wide variation in the contribution to local sustainable development by project type, with greater contributions in small-scale renewable energy and energy efficiency than in large-scale industrial CDM projects. Using a sample of 39 projects, Nussbaumer (2009) finds that CDM projects certified by 'The Gold Standard'—referring both to the organization and the certification scheme by that name—slightly outperform other CDM projects with respect to sustainable-development benefits. A similar result is found by Drupp (2011) for a sample of 18 Gold Standard projects compared with 30 projects certified through other means. Torvanger et al. (2013) propose dividing the CDM into two tracks, one for GHG offsets and one for sustainable development (though investors in the second track would need some new incentive).

The distribution of CDM projects has been concentrated in a relatively small number of developing countries (Yamada and Fujimori, 2012; see also Section 14.3.6.4). Given that companies in developing countries finance CDM projects out of their own resources and eventually sell the credits as a new export product, with the CDM consultant receiving a share (Michaelowa, 2007), a substantial amount of the rents remain in the host country. At the same time, the demand for CERs is evidence that it reduces costs compared to domestic reductions by developed countries. The fear, even if unfounded, of losing this export revenue may be a deterrent against taking up national emissions commitments (Castro, 2012), although in practice many such countries are developing policies aimed at emissions limitations. Therefore, it has been proposed to discount CDM credits to provide an incentive for taking up stricter national targets (Schneider, 2009).

In terms of institutional feasibility, baselines, additionality, and emissions-reductions are subject to third-party audit. However, due to the inadequate quality of many audits, regulators have been forced to introduce multi-layered procedures that have led to high transaction costs. Flues et al. (2010) show econometrically that regulatory decisions about project registration and baseline methodology approval have been influenced by political economy considerations.

There is ongoing debate in the literature about the efficacy of CDM governance (Green, 2008; Lund, 2010; Michaelowa, 2011; Okazaki and Yamaguchi, 2011; Böhm and Dhabi, 2011; Newell, 2012). The UNFCCC commissioned an evaluation of the CDM in the CDM Policy Dialogue, which issued a report in September 2012 recommending several reforms of CDM governance (CDM Policy Dialogue, 2012). Michaelowa (2009) and Schneider (2009) propose a shift from the current 1:1 offsetting system to a system that only credits part of the reductions. This would improve additionality on the aggregate level and provide an incentive for advanced developing countries to accept their own emission reduction commitments. Giving preferential treatment in procedures and methodology to certain project categories, certain sectors, notably forestry (Thomas et al., 2010; CDM Policy Dialogue, 2012), or certain regions (Nguyen et al., 2010; Bakker et al., 2011) might expand the reach of CDM.

The price of CDM credits has declined, due largely to decreased demand from the EU ETS and others, following the 2008 recession, as well as changes in EU ETS rules regarding the use of CDM credits (see Section 13.6.1). In response, the CDM Policy Dialogue (2012) proposed creation of a central bank for carbon markets to bolster credit prices, as well as further standardization of baseline and additionality determination to reduce transaction costs. The benefits of these two recommendations are disputed in the literature (Hayashi and Michaelowa, 2013; Spalding-Fecher and Michaelowa, 2013).

13.13.1.3 Assessment of further agreements under the UNFCCC

As discussed in 13.5.1.1, since AR4, negotiations under the UNFCCC have produced the system of pledges in the Copenhagen Accord and the Cancún Agreements, as well as the development of the GCF and an agreement to negotiate a new agreement by 2015. In terms of

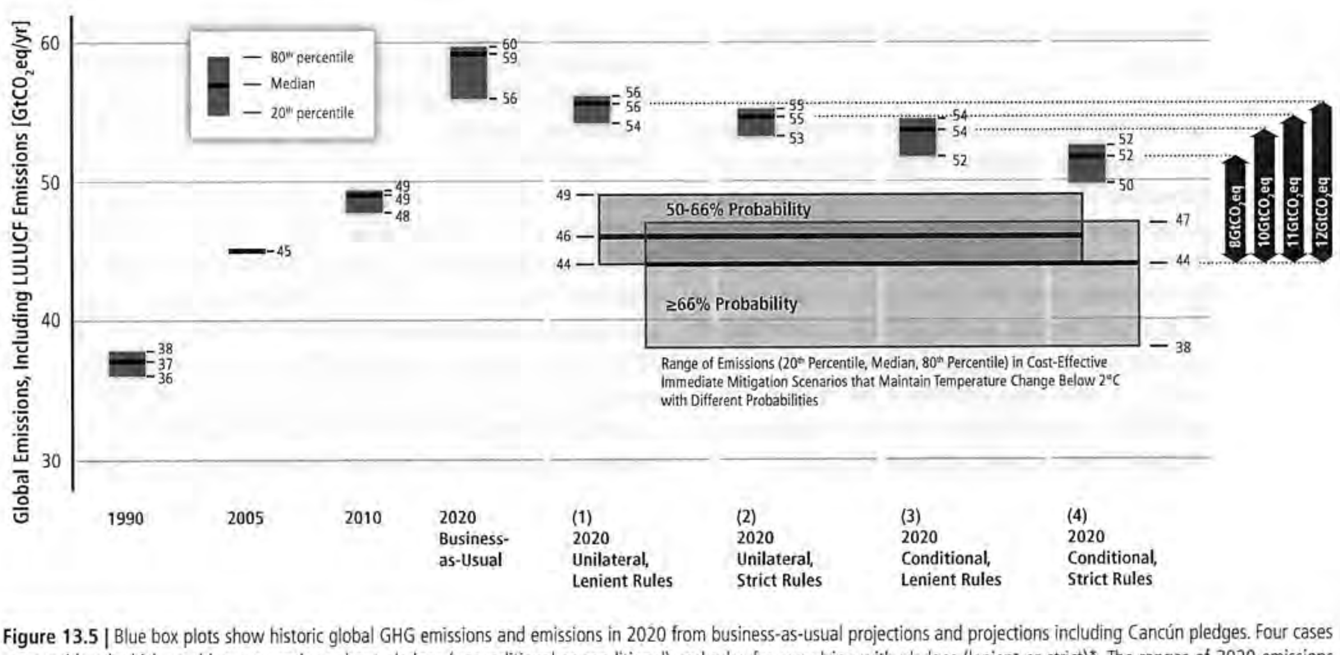

Figure 13.5 | Blue box plots show historic global GHG emissions and emissions in 2020 from business-as-usual projections and projections including Cancún pledges. Four cases are considered which combine assumptions about pledges (unconditional or conditional) and rules for complying with pledges (lenient or strict)*. The ranges of 2020 emissions (20th percentile, median, and 80th percentile) are taken directly from the UNEP Emissions Gap Report (UNEP, 2012) and represent findings from various modelling groups considering scenarios that begin mitigation immediately. The arrows indicate the difference between the median emissions projection in each case and the median emission level projected to maintain temperature change below 2 °C with a greater than 66 % probability. The ranges (20th to 80th percentiles) of 2020 emissions that maintain temperature change below 2 °C can be compared to those from cost-effective immediate mitigation scenarios from the WGIII AR5 Scenario Database: greater than 66 % probability: 36–47 $GtCO_2eq/yr$; 50–66 % probability: 43–47 $GtCO_2eq/yr$ (see Chapter 6 and Annex II.10 for details, including MAGICC calculations). Differences in these ranges depend, for example, on assumptions about the availability of negative emissions technologies (see, e.g, Figure 6.31). Note that the analysis reconciles pledges for all countries against a business-as-usual counterfactual based on what has been described in the literature, even though developed country pledges for 2020 are absolute (against a historical base year) and developing country pledges relative (with rare exceptions; see Section 13.5.1).

environmental performance, these agreements acknowledged that deep reductions in GHG emissions would be required to limit global average temperature increases to 2 °C above pre-industrial levels, and recognized the possibility strengthening this target to 1.5 °C (UNFCCC, 2010). Different goals will imply different reductions in climate change impacts (see WGII AR5) and different mitigation costs (see Section 6.3).

There is broad agreement in the literature that global emissions reductions through 2020 implied by the Cancún pledges are inconsistent with cost-effective mitigation scenarios, which are based on the immediate onset of mitigation that maintain temperature change below 2 °C with a greater than 50 % probability (see Section 6.4 for detail on these scenarios). The difference between the emissions in 2020 in immediate mitigation scenarios and the Cancún pledges has been referred to as the '2°C emissions gap' (Rogelj et al., 2010; Dellink et al., 2011; den Elzen et al., 2011b; Höhne et al., 2012b). However, there are a number of delayed mitigation scenarios that delay mitigation and still meet this temperature goal and have emissions in the range of the Cancún pledges in 2020 (see Section 6.4). Analyses that have quantified the Cancún pledges exhibit substantial differences in results, owing in part to uncertainties in current and projected emissions estimates and interpretations of reduction proposals, and in part to different methodologies (UNEP, 2010, 2011, 2012, 2013b; Höhne et al., 2012b) (Figure 13.5). For example, one source of differences in analyses is due to changing rules: At COP-17 in Durban in 2011, parties agreed to new rules for using land use credits for the Kyoto Protocol's Second Commitment Period (UNFCCC, 2012c; Grassi et al., 2012), and at COP-18 in Doha in 2012, for surplus Kyoto allowances (Chen et al., 2013; UNFCCC, 2012d).

Studies suggest that the emissions gap between current Cancún pledges and a an immediate mitigation trajectory consistent with maintaining temperature change below 2°C with a 50 % or greater chance could be narrowed by implementing more stringent pledges, applying stricter accounting rules for credits from forests (Grassi et al., 2012) and surplus emission units (den Elzen et al., 2012), avoiding double-counting of offsets for both developed-country commitments and developing countries' Cancún pledges (UNEP, 2013b), increasing support for action in developing countries (Winkler et al., 2009), and implementing measures beyond current pledges (den Elzen et al., 2011b; Blok et al., 2012; Weischer et al., 2012; UNEP, 2013b).

In terms of aggregate economic performance, some analyses have estimated the direct costs of the Cancún pledges (den Elzen et al., 2011a), as well as broader economic effects (Mckibbin et al., 2011; Dellink et al., 2011; Peterson et al., 2011). For example, Dellink et al. (2011) estimate costs of action at around 0.3 % of GDP for both Annex I and non-Annex I countries and 0.5–0.6 % of global real income. However, there have been no published comparisons of the benefits and costs of the Cancún pledges, and thus no quantitative assessments of economic efficiency.

In terms of cost-effectiveness, the Cancún Agreements endorsed an on-going role for domestic and international market-based mechanisms, among various approaches, to improve cost-effectiveness. They also made a potential step forward on the cost-effectiveness criterion by emphasizing the role of mitigation actions in the forestry sector (UNFCCC, 2010; Grassi et al., 2012), which could be integrated with other actions through market mechanisms. Including forestry in market mechanisms could reduce global mitigation costs by taking advantage of low-cost mitigation opportunities in that sector (Eliasch, 2008; Busch et al., 2009; Bosetti et al., 2011; UNEP, 2013b) (see also Section 13.5.1.1).

Assessing distributional impacts accurately depends both on the mitigation costs for developing-country emission reductions and the sources of financing for such reductions. The distributional equity of recent emission-reduction pledges could be increased through financing of reductions in non-Annex I countries. By one study's estimate, between 2.1–3.3 $GtCO_2eq$ could be reduced in non-Annex I countries with 50 billion USD in financing, half of the financing agreed to under the Copenhagen Accord (Carraro and Massetti, 2012). Studies of the climate change mitigation 'financing gap' have suggested potential approaches to providing financial resources (Ballesteros et al., 2010; AGF, 2010; Haites, 2011) (see also Sections 16.2 and 13.11).

Assessments of climate agreements following the Copenhagen, Cancún, and Durban UN climate conferences reflect differing interpretations of recent negotiations with regard to institutional feasibility (Dubash, 2009; Rajamani, 2010, 2012a; Werksman and Herbertson, 2010; Müller, 2010). Copenhagen (2009) was assessed as a failure by those who expected a new climate treaty and a second commitment period of the Kyoto Protocol. Others saw the political agreement reached among a small group of world leaders (eventually espoused by more than fifty) as a major step forward, even though not legally binding, especially because it moved toward a future agreement on emissions reductions by all major emitting countries, rather than continuing to divide developed from developing countries (Ladislaw, 2010). Others noted more specific effects, such as the change in the organization of carbon markets (Bernstein et al., 2010). The literature suggests that views diverge on the Cancún Agreements: some see them as a step forward in the multilateral process (Grubb, 2011) potentially towards a subsequent legal agreement (Bodansky and Diringer, 2010), while others suggest that the move to a voluntary pledge system has weakened the multilateral climate regime (Khor, 2010b). The participation of 97 countries in the form of emission reduction pledges (42 countries) or mitigation actions (55 countries) speaks to the institutional feasibility of the Cancún Agreements (see Section 13.5.1.1). The Durban Platform in 2011 further de-emphasized the distinction between developing and developed countries, with regard to mitigation commitments, and mandated a new treaty by 2015, to take effect by 2020, mobilizing emissions reductions by all countries (UNFCCC, 2011a).

13.13.1.4 Assessment of envisioned international cooperation outside of the UNFCCC

A wide variety of international institutions outside of the UNFCCC have some role in international climate change policy. These are described in Section 13.5 and depicted graphically in Figure 13.1, above. They include activities at the international, regional, national, subnational, and local scales, and they include public, private and civil society actors. Here, we discuss those institutions for which there exist published assessments of performance for at least one of the criteria from Section 13.2.2.

The breadth of group membership poses a potential tradeoff between global participation and other aspects of institutional feasibility (see Sections 13.2.2.4, 13.3.3, and 13.5.1). To the extent that a group's membership includes only a subset of countries, this may facilitate negotiations and implementation, thereby improvinginstitutional feasibility (Houser, 2010), but this may reduce environmental and economic performance due to incomplete global coverage—omitting others' emissions, yielding leakage, and forgoing low-cost opportunities for abatement (Wiener, 1999; see also Sections 13.13.1 and 13.5.1.2). Moreover, bringing climate discussions into smaller international forums has been criticized by some as attempts to circumvent the UNFCCC and reduce its legitimacy (Hurrell and Sengupta, 2012). Because the UNFCCC's Kyoto Protocol provides for emissions commitments only by Annex B countries (which account for a declining share of global emissions, with increased risk of leakage), some of the smaller groups discussed in this subsection have tried to engage major developing countries as well, to reduce leakage and increase environmental effectiveness.

The G8

The G8 includes eight major industrialized countries (United States, United Kingdom, Canada, France, Germany, Italy, Japan, and Russia), plus the European Union. At the 2007 G8 summit, member countries agreed (though without a binding commitment) to set a goal of a 50 % reduction in GHG emissions below 1990 levels by 2050, conditional on major developing countries making significant reductions. A comparison of four models of global emission pathways (including the G8 plus China, India, and other major developing countries, a group which resembles the MEF or G20 more than the G8), to achieve concentration levels of 550, 450, or 400 ppm by 2100, found that aggregate global costs through 2100 would be below 0.8 % of global GDP to achieve 550 ppm and about 2.5 % for 400 ppm (but highly sensitive to the availability of CCS and biofuels) (Edenhofer et al., 2010); see also Section 6.3.2.1.

Analysts have examined the economic impacts of achieving reductions approximating the G8 pledge on individual countries, such as the United Kingdom (Dagoumas and Barker, 2010) and the United States (Paltsev et al., 2008).The former finds no simple tradeoff between emission reductions and economic growth in the United Kingdom. Of the more aggressive reductions modelled for the United States, Paltsev et al. (2008) finds carbon prices rising to between 120 and 210 USD by 2050, a level of cost that "would not seriously affect US GDP growth but would imply large-scale changes in its energy system." Paltsev et al. (2009) found somewhat higher costs, noting moreover that the details of policy design and incomplete sectoral coverage could raise these costs further. Meanwhile, actions by the G8 countries alone (excluding major developing countries) would address a declining share of global emissions and would be subject to leakage to non-G8 members.

The Major Economies Forum on Energy and Climate

The MEF, described in Section 13.5.1.3, is a forum for the discussion of policy options and international collaboration with regard to climate and energy, not a forum for negotiation. There are no published assessments of the MEF's effectiveness. Massetti (2011) considers a scheme that achieves the MEF's informal, aspirational objective of "reducing global emissions by 50 % in 2050" (similar to the G8 goal, described above) through hypothetical 80 % reductions by high-income MEF countries and 25–30 % reductions by low-income countries, and finds costs would exceed 1.5 % of GDP.

The G20

The G20, described in Section 13.5.1.3, came to a political agreement at its 2009 Pittsburgh meeting to "phase out and rationalize over the medium term inefficient fossil fuel subsidies while providing targeted support for the poorest" (G20, 2009). This was not followed by a legally binding agreement. In terms of environmental effectiveness, this effort could significantly affect GHG emissions, if countries in fact implemented it; by one modelled estimate, complete phaseout of such subsidies by 2020, could reduce CO_2 emissions by 4.7 % (IEA, 2011). Analysis suggests that, of the economies identified by the IEA as having fossil-fuel consumption subsidies, almost half had either implemented fossil-fuel subsidy reforms or announced related plans by 2011 (IEA et al., 2011). However, other analysts suggest that progress towards this goal can be attributed to changes in reporting and subsidy estimation, and that no fossil fuel subsidies have been eliminated under this pledge (Koplow, 2012).

Studies have confirmed that countries reforming fossil fuel consumer subsidies would realize positive economic benefits (IEA et al., 2011). However, "these economic benefits would be offset by trade impacts if other countries also removed their subsidies and thus reduced their demand for fossil-fuel imports" (IEA et al., 2011). The G20 initiative on fossil fuel subsidies could have positive distributional impacts within some countries, however. Since fossil fuel subsidies tend to benefit high-income households more than the poor in developing countries, their removal would be progressive in such nations (World Bank, 2008c).

Some note that the creation of the G20 and its elevation to a premier global international economic forum during the financial crisis in 2008 (Houser, 2010) has led to more open and dynamic negotiations between industrialized and developing countries (Hurrell and Sengupta, 2012), suggesting a potentially positive route forward.

The Montreal Protocol

The Montreal Protocol is one agreement outside of the UNFCCC that has achieved nearly universal participation and has made a significant contribution to reducing GHG emissions (Molina et al., 2009; Velders et al., 2007). (The UNFCCC does not address GHGs already controlled by the Montreal Protocol.) In its effort to reduce emissions of ozone-depleting substances (ODS), the Montreal Protocol initially phased down chlorofluorocarbons (CFCs), which harm the ozone layer and also have very high global warming potential (GWP), and in 2007 decided to accelerate the phase-down schedule for HCFCs—an interim replacement for CFCs with a somewhat lower, but still very significant, GWP. The latter decision was affected by climate considerations (Bodansky, 2011a). Even before the HCFC decision, one estimate suggested that the Montreal Protocol's overall net contribution to climate change mitigation had been approximately 5 times what the Kyoto Protocol would achieve under its first commitment period (Velders et al., 2007, 2012). However, this comparison may be unfair because the progress in reducing ozone depleting gases relative to GHGs may be due to the major ozone depleting gases being less central to economic activities than the major GHGs. In addition, the time-periods in which the two agreements have been operating makes comparison difficult.

Hydrofluorocarbons are being widely adopted as a longer-term substitute for CFCs. Many of these have extremely high GWP, and their use will partially negate climate gains otherwise achieved by the Montreal Protocol (Moncel and van Asselt, 2012). Zaelke et al. (2012) suggest that a combination of reductions of HFCs and significant cuts in CO_2, the largest contributor to climate change, can significantly increase the chances of remaining below the 2 °C limit. Proposals have been made in the Montreal Protocol process to phase down HFCs (even though these gases are not ozone-depleting substances), but as of mid-2013, parties to the Montreal Protocol had not agreed to an HFC phasedown. However, in June 2013 the presidents of the United States and China announced a joint initiative to phase down HFCs.

In terms of distributional equity, unlike the Kyoto Protocol, which placed no restrictions on developing country emissions, the Montreal Protocol applied equally-stringent emission requirements on all countries. However, the Montreal Protocol allowed for a 10-year 'grace period' for countries with low per capita CFC consumption to meet their implementation requirements, consistent with the principle of CBDRRC. The Montreal Protocol also established mechanisms for financing and provided technical support to assist developing countries in reducing their ODS emissions; the most notable mechanism is the Multilateral Fund, which has transferred more than 3 billion USD to assist developing country ODS mitigation (Molina et al., 2009).

The International Maritime Organisation and the International Civil Aviation Organisation

Under the Kyoto Protocol's Article 2.2, Annex I parties agreed to pursue GHG limitations from maritime and air transport through the IMO and ICAO.

Approximately 3.3 % of global CO_2 emissions in 2007 were attributable to shipping (IMO, 2009). In 2011, the IMO adopted the first mandatory standards for a sector relating to GHG emissions, instituting a performance-based energy-efficiency regulation for large ships "for which the building contract is placed on or after January 1, 2013" (Bodansky, 2011c). This regulation applies uniformly to all countries, extending participation in GHG emissions regulation. These standards were adopted by majority vote (over some objections), and include a provision to promote technical cooperation and assistance, especially for developing countries (Bodansky, 2011c), to address equity concerns, enhancing institutional feasibility.

The ICAO adopted a resolution on climate change in 2010. In contrast to the IMO, the ICAO's climate change goals are 'voluntary and aspirational.' Perceived inadequate progress by the ICAO toward aviation emissions reduction goals may have prompted the inclusion of aviation emissions in the EU-ETS in January 2012 (Bodansky, 2011c) (see Section 13.8.2).

Agreements among non-state actors and agreements among sub-national actors

It is unclear whether agreements among non-state (NGOs, private sector) or sub-national actors (transnational city networks) have been effective in reducing emissions. Partly this is because of their novelty and partly because the units of measurement for such effectiveness are considerably more complex than for interstate agreements (Pinkse and Kolk, 2009). For subnational efforts, the question of attribution requires better disaggregation, to understand whether reductions are additional to national effort, or only contribute to delivering national pledges. While these sub-national efforts may make a small contribution to climate action, they may be valuable in influencing nation states or helping them meet commitments (Osofsky, 2012).

Other measures of impacts do exist. In private sector initiatives, the Carbon Disclosure Project has high rates of reporting, with about 91 % of Global 500 companies surveyed in 2011 disclosing GHG emissions (Carbon Disclosure Project, 2011). There is little evidence of substantial changes in investor behaviour, with disagreement as to the potential for such changes in the future (Kolk et al., 2008; Harmes, 2011; MacLeod and Park, 2011). Some assessments have focused on how transnational city initiatives promote technology uptake within cities (Hoffmann, 2011) or on how they create a combination of competition and learning among member cities.

The voluntary carbon market (VCM) (see Section 13.5.2) had grown to 131 million tCO_2eq (about one-tenth of the size of the CDM), with a value of 424 million USD, by 2010 (Peters-Stanley et al., 2011). In 2004, virtually no VCM projects underwent third-party verified certification, but by 2010, this figure had reached 90 % and the VCM has created a varied landscape of emission-offset providers, registries, and standards (Peters-Stanley et al., 2011).

For some, the VCM is complementary to the CDM, and provides for learning about new ways of developing emissions reduction projects

(Benessaiah, 2012). However, Dhanda and Hartman (2011) find that the voluntary market is not transparent and suffers from large swings of demand for specific project types. Offset prices for the same project type differs by up to two orders of magnitude. As noted, competing registries and standard providers proliferate, and additionality of a significant share of projects is doubtful. Some regard voluntary certification systems as primarily public relations exercises (Bumpus and Liverman, 2008). An earlier assessment by Corbera et al. (2009) concluded that the voluntary market does not perform better than the CDM. However, performance in the VCM seems to improve with the increased use of third-party certification systems (Hamilton et al., 2008; Capoor and Ambrosi, 2009; Newell and Paterson, 2010).

There is evidence that the importance of partnerships between the private sector and government depends on their relationship to more traditional state-led governance. Partnerships may work once government regulations send strong signals to investors (Pfeifer and Sullivan, 2008). Rules developed in private sector agreements may then become incorporated in government regulations (Knox-Hayes and Levy, 2011), and private carbon market offset standards may be introduced into regulated carbon markets (Hoffmann, 2011).

13.13.2 Performance assessment of proposed international climate policy architectures

This section describes proposed global climate policy architectures (surveyed in Section 13.4), focusing on those that have been described for the first time since AR4, and older proposals for which new research on anticipated performance is available. Earlier proposals are listed in Table 13.2 of Gupta et al. (2007). The performance assessment of proposed architectures is difficult because it depends on both the architecture and the specific design elements of its regulatory targets and mechanisms.

For analytical purposes, this chapter classifies proposals using the taxonomy developed in Section 13.4.3 and Table 13.2: (a) strong multilateralism, (b) harmonized national policies, and (c) decentralized architectures and coordinated national policies. Combinations of these categories have also been proposed and assessed. For example, strong multilateralism can be advanced by 'clubs' of selected ambitious countries (Weischer et al., 2012)or by non-state actors (Blok et al., 2012).

13.13.2.1 Strong multilateralism

The anticipated performance of various proposals for strong multilateralism has been assessed in the literature. In addition, another body of research has examined the ends (but not the policy architecture) associated with various aggregate goals in terms of country- or region-level emission targets based on specific notions of distributional equity, so-called 'burden sharing approaches' (see Section 13.2, as well as Sections 4.6.2 and 6.3.6.6 for quantitative assessments).

Comprehensive proposals for strong multilateralism have in some cases been closely related to the targets-and-timetables approach of the Kyoto Protocol. This approach aims to be based on the UNFCCC principle of CBDRRC while introducing a more nuanced differentiation and broader base of participation, along with some details of the means of implementation. This is well reflected in the literature on reduction proposals with national emission targets and emissions trading (see Table 13.2 in Gupta et al. (2007) for literature prior to AR4). Since AR4, this literature has studied gradually-increasing emission-reduction commitments linked to indicators such as per capita income (Cao, 2010a; Frankel, 2010; Bosetti and Frankel, 2011), differentiating groups of countries (den Elzen et al., 2007; Rajamani, 2013), common but differentiated convergence (Luderer et al., 2012), and per capita targets (Agarwala, 2010).

Distributional impacts vary significantly with underlying criteria for effort sharing. For example, proposals that use 'responsibility and capability' as a criterion for allocating effort would result in relatively more stringent implied actions for 'early' emitters, assigning them lower allocations. Proposals based on the criterion of 'mitigation potential' would be less stringent for 'early' emitters, capturing the mitigation potential in developing countries, assumed to be relatively low-cost (Höhne et al., 2013). Especially for low-stabilization levels, the approaches differ in the extent to which they rely on contributions from all countries, from emissions reductions within their borders, and on international assistance between countries. Section 4.6.2 details many more possible criteria for effort sharing, and Section 6.3.6.6 quantifies the implications of these various effort sharing criteria in terms of regional emission allocations and costs.

Sectoral approaches are generally not anticipated to perform optimally in terms of environmental effectiveness or economic performance when compared with economy-wide approaches; therefore, sectoral approaches can be thought of as second-best policies (Bradley et al., 2007; Schmidt et al., 2008; den Elzen et al., 2008; Meckling and Chung, 2009). Sectors that are homogenous and already globally integrated, such as aviation, may lend themselves better to international cooperation than those that are heterogeneous. Omitting some sectors makes it more difficult to achieve emissions or stabilization goals and also reduces cost-effectiveness, relative to economy-wide approaches, as required emissions reductions must be made within-sector, failing to take advantage of the lower of heterogeneous marginal abatement costs across sectors. Transaction costs may also be higher with sectoral approaches, including, for example, greater challenges to negotiation (Bradley et al., 2007).

However, these approaches could potentially help mitigate leakage within particular industries (Bradley et al., 2007; Sawa, 2010). In terms of institutional feasibility, sectoral approaches may encourage the participation of a wider range of countries than economy-wide approaches, because sectoral agreements can be more politically manageable in domestic policy processes (Bradley et al., 2007; Sawa, 2010). Developing countries may also be more likely to participate meaningfully in sectoral processes than economy-wide agreements limiting emissions (Meckling and Chung, 2009).

Several researchers have suggested that a 'regime complex' is emerging (see Sections 13.3 and 13.5), with the strong implication that component regimes may display a range of architectures—from strong multilateralism through more decentralized systems (Carraro et al., 2007; Biermann et al., 2009; Barrett, 2010; Keohane and Victor, 2011). The portfolio of treaties approach is similar in some ways to the sectoral approaches described above. However, the approach described in (Barrett, 2010) includes much more significant enforcement possibilities, potentially increasing environmental effectiveness, while potentially reducing institutional feasibility.

13.13.2.2 Harmonized national policies

In principle, a wide variety of national climate policies can be harmonized across countries. This holds for cap-and-trade systems (e.g., a global emissions permit trading system (Ellerman, 2010)), as we discuss in the context of linkage below, as well as for national carbon or other GHG taxes. The most-studied approach in terms of performance assessments has been harmonized carbon taxes. Their environmental performance would depend upon the level of the tax, but relative to non-market-based approaches, this approach would be cost-effective. The impact of a carbon tax on economic efficiency will depend, in part, on how tax revenues are used (Bovenberg and de Mooij, 1994; Parry, 1995; Bovenberg and Goulder, 1996; Cooper, 2010).

Estimates in the recent literature of the environmental effectiveness and economic performance of proposed carbon taxes vary dramatically depending upon assumptions (Edmonds et al., 2008; Clarke et al., 2009; van Vuuren et al., 2009; Bosetti et al., 2010; Luderer et al., 2012). The distributional impacts of a carbon tax include negative impacts on the fossil fuel industry as a whole, with stronger impacts for fuels with higher carbon emissions per unit of energy. For example, impacts on coal would be much greater than on natural gas (Cooper, 2010). Impacts of national carbon taxes on consumers would likely be somewhat regressive in high-income countries but progressive in low-income countries (see Section 15.5 for detail). Tax revenues could be used by individual countries to address these domestic distributional concerns (See e.g.,Winkler and Marquard, 2011; Alton et al., 2012).

Under a harmonized national carbon tax regime, fossil-fuel-exporting countries might experience negative impacts, and net importers could experience decreasing prices due to reduced demand, while some regions could experience increased bio-energy exports (Persson et al., 2006; OECD, 2008; Cooper, 2010; Leimbach et al., 2010). International transfers drawing on revenues of such a tax could, in theory, be used to address these concerns or to encourage participation by developing countries (Nordhaus, 2006). As with emissions trading (Frankel, 2010), the extent of developing country participation in an international carbon tax scheme could be based upon income thresholds (Nordhaus, 2006).

The institutional feasibility of a global carbon tax has not been thoroughly considered in the literature. The relatively large number of studies on a global carbon tax is at least partly due to the fact that economic modellers often model a global carbon tax as a proxy for other mitigation policy instruments that would impose shadow prices on the carbon content of fossil fuels and/or CO_2 emissions.

Many hybrid market-based approaches to mitigation, combining tradable emissions permits with some characteristics of a carbon tax, have been proposed and examined in the recent literature (Pizer, 2002; Murray et al., 2009; FELL et al., 2010; Webster et al., 2010; Grüll and Taschini, 2011). In principle, these hybrid approaches can provide better aggregate economic performance, lowering compliance costs and reducing price volatility, at the potential expense of environmental effectiveness in the form of uncertain changes in aggregate emissions (Grüll and Taschini, 2011). However, recent research suggests that 'soft' price collars, which provide a modest reserve of additional emission allowances at the price ceiling, may achieve most of the expected compliance cost savings provided by 'hard' collars (unlimited supplies of additional allowances), while maintaining a more predictable cap on emissions (Fell et al., 2012). In terms of distributional equity, hybrid systems may reduce expected compliance costs for regulated firms, though they may increase regulatory costs (Grüll and Taschini, 2011). This characteristic may also increase political feasibility.

13.13.2.3 Decentralized architectures and coordinated national policies

In principle, many types of national climate policies could be linked to each other. In the literature to date, most discussion is of linked carbon markets. The recent literature on these suggests that economic performance of existing GHG allowance trading systems could be enhanced through linkage, which would reduce abatement costs and improve market liquidity (Haites and Mehling, 2009; Mehling and Haites, 2009; Sterk and Kruger, 2009; Anger et al., 2009; Jaffe et al., 2009; Jaffe and Stavins, 2010; Grüll and Taschini, 2011; Metcalf and Weisbach, 2012; Ranson and Stavins, 2013).

In terms of environmental performance, linkage can increase or reduce emissions leakage, depending on the stringency of caps, and the quality of offset credits within linked systems.

Linkages among cap-and-trade systems as well as linkages with and among emission-reduction-credit systems would create winners and losers, generating distributional impacts relative to un-linked systems, depending upon impacts on allowance prices and whether participating entities are net buyers or net sellers of emissions (Jaffe and Stavins, 2010). While it does preserve the ability of countries to meet their commitments through means of their own choice, consistent with the Kyoto Protocol, linkage also poses some challenges for institutional feasibility, since it reduces domestic control over prices, emissions, and other aspects of policy design and impact (Buchner and Carraro, 2007; Jaffe et al., 2009; Jaffe and Stavins, 2010; Ranson and Stavins, 2013). Linking may not benefit all participating countries due to potential market distortions and the rebalancing of production and consumption patterns in multiple markets (i.e., general equilibrium effects) (Marschinski et al., 2012). In one analysis that modelled the heterogeneous costs and benefits of participation in a climate coalition using a game-theoretic framework, incentives to deviate from cooperation could not be compensated by transfers (Bosetti et al., 2013).

Institutional-feasibility challenges may be more significant for linked heterogeneous policy instruments (such as taxes and emissions permit systems, or taxes and technology standards) relative to linked regimes that use similar instruments (Metcalf and Weisbach, 2012). For example, unrestricted linkage would effectively turn a permit trading system into a tax, pegging the permit price to the other country's tax rate, and allowing aggregate emissions above the permit system's established cap (Metcalf and Weisbach, 2012).

Climate policy architectures that can be characterized as technology-oriented agreements may seek to share and coordinate knowledge and enhance technology research, development, demonstration, and transfer. Some literature suggests that such agreements may increase the efficiency and environmental effectiveness of international climate cooperation, but will have limited environmental effectiveness operating alone (de Coninck et al., 2008). Though technology-oriented policies can promote the development of new technologies, environmental effectiveness hinges on the need for other policies to provide incentives for adoption (Fischer, 2008; Newell, 2010b). For example, (Bosetti et al., 2009b) show that R&D alone is insufficient to stabilize CO_2 levels without an accompanying carbon tax or functionally equivalent policy instrument. See Section 13.9.3 for details of international cooperation on technology.

13.14 Gaps in knowledge and data

Current understanding of agreements and instruments for international cooperation continues to evolve. At the time of this publication, there are a number of gaps in the scholarly literature of international cooperation for climate change mitigation, as identified below:

- There exist few comparisons of proposals in terms of any or all of the four criteria used in this report. Research that would be particularly useful would be comparisons of aggregate cost, or disaggregated regional- or country-level costs per year, with incorporation of uncertainty.
- There exist few assessments of the emerging range of new intergovernmental and transnational arrangements, including 'hybrid' approaches and approaches that interact across the landscape of climate agreements, which might enable better assessment of the sum of efforts.
- Current understanding of the complementarities and tradeoffs between policies affecting mitigation and adaptation is incomplete.
- Current understanding of how international cooperation on climate change can help achieve co-benefits and development goals of countries and what policies and practices work and do not work in capacity building projects is incomplete.
- Current understanding of the factors that affect national decisions to join and form international agreements and how international cooperation can directly influence achievement of various performance criteria is incomplete.

13.15 Frequently Asked Questions

FAQ 13.1 Given that GHG emissions abatement must ultimately be carried out by individuals and firms within countries, why is international cooperation necessary?

International cooperation is important to achieve significant emissions reductions for a number of reasons. First, climate protection is a public good that requires collective action, because firms and individuals will not otherwise bear the private costs needed to achieve the global benefits of abatement (see Section 13.2.1.1). Second, because GHGs mix globally in the atmosphere, anthropogenic climate change is a global commons problem. Third, international cooperation helps to give every country an opportunity to ascertain how responsibilities are to be divided among them, based on principles adopted in international agreements (see Section 13.3). This is important because individual countries are the entities with jurisdiction over individuals and firms, whose actions ultimately determine if emissions are abated. Fourth, international cooperation allows for linkages across policies at different scale, notably through harmonizing national and regional policies, as well as linkages across issues, and through enhanced cooperation may reduce mitigation costs, create opportunities for sharing the benefits of adaptation, increase credibility of price signals, and expand market size and liquidity. Fifth, international cooperation may help bring together international science and knowledge, which may improve the performance of cooperatively-developed policy instruments.

FAQ 13.2 What are the advantages and disadvantages of including all countries in international cooperation on climate change (an 'inclusive' approach) and limiting participation (an 'exclusive' approach)?

The literature suggests that there are tradeoffs between 'inclusive' approaches to negotiation and agreement (i.e., approaches with broad participation, as in the UNFCCC) and 'exclusive' approaches (i.e., limiting participation according to chosen criteria—for example, including only the largest emitters, or groups focused on specific issues). Regarding an 'inclusive' approach, the universal membership of the UNFCCC is an indicator of its high degree of legitimacy among states as a central institution to develop international climate policy. However, the scholarly literature offers differing views over whether or not the outcomes of recent negotiations strengthen or weaken the multilateral climate regime (Section 13.13.1.3). A number of other multilateral forums have emerged as potentially valuable in advancing the international process through an 'exclusive' approach. These smaller groups can advance the overall process through informal consultations, technical analysis and information sharing, and implementation of UNFCCC decisions or guidance (e.g., with regard to climate finance). They might also be more effective in advancing agreement among the largest emitters, but so far have not been able to do so. Examples include the MEF, the G20 and G8, and the city-level C-40 Climate Leadership Group. Section 13.5 goes into more detail, and Figure 13.1 illustrates the overall landscape of climate change-relevant agreements and institutions.

FAQ 13.3 What are the options for designing policies to make progress on international cooperation on climate change mitigation?

There are a number of potential structures for formalized international cooperation on climate change mitigation, referred to in the text as policy 'architectures' (see Section 13.4). Architectures vary by the degree to which their authority is centralized and can be roughly categorized into three groups: strong multilateralism, harmonized national policies, and decentralized architectures (see Section 13.4.1). An example of strong multilateralism is a targets-and-timetables approach, which sets aggregate quantitative emissions-reduction targets over a fixed period of time and allocates responsibility for this reduction among countries, based on principles jointly accepted. The UNFCCC's Kyoto Protocol is an example of a strong multilateral approach. The second architecture is harmonized national policies. An example in principle (though not put into practice) might be multilaterally harmonized domestic carbon taxes. An example of the third architecture, decentralized approaches and coordinated national policies, would be linkage among domestic cap-and-trade systems, driven not through a multilateral agreement but largely by bilateral arrangements. The literature suggests that each of the various proposed policy architectures for global climate change has advantages and disadvantages with regard to four evaluation criteria: environmental effectiveness, aggregate economic performance, distributional equity, and institutional feasibility. Section 13.4.1.4 goes into more detail.

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14

Regional Development and Cooperation

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Contents

Executive Summary

Regional cooperation already is a powerful force in the global economy (*medium evidence, high agreement*). This is reflected in numerous agreements related to trade and technology cooperation, as well as trans-boundary agreements related to water, energy, transport, etc. As a result, there is growing interest in regional cooperation as a means to achieving mitigation objectives. A regional perspective (where regions are defined primarily geographically, with further differentiation related to economic proximity) recognizes differences in the opportunities and barriers for mitigation, opportunities for joint action on mitigation and common vulnerabilities, and assesses what regional cooperation can and has already achieved in terms of mitigation. Regional cooperation can provide a linkage between global and national/subnational action on climate change and can also complement national and global action. [Section 14.1.2, 14.4.1]

Regions can be defined in many different ways depending upon the context. Mitigation challenges are often differentiated by region, based on their levels of development. For the analysis of greenhouse gas (GHG) projections, as well as of climate change impacts, regions are typically defined in geographical terms. Regions can also be defined at a supra-national or sub-national level. This chapter defines regions as supra-national regions (sub-national regions are examined in Chapter 15). Ten regions are defined based on a combination of proximity in terms of geography and levels of economic and human development: East Asia (China, Korea, Mongolia) (EAS); Economies in Transition (Eastern Europe and former Soviet Union) (EIT); Latin America and Caribbean (LAM); Middle East and North Africa (MNA); North America (USA, Canada) (NAM); Pacific Organisation for Economic Co-operation and Development 1990 (Japan, Australia, New Zealand) (POECD); South-East Asia and Pacific (PAS); South Asia (SAS); sub-Saharan Africa (SSA); Western Europe (WEU). Where appropriate, we also examine the category of least-developed countries (LDC), which combines 33 countries in SSA, 5 in SAS, 9 in PAS, and one each in LAM and the MNA, and which are classified as such by the United Nations based on their low incomes, low human assets, and high economic vulnerabilities. We also examine regional cooperation initiatives through actual examples that bear upon mitigation objectives, which do not typically conform to the above listed world regions. [14.1.2]

There is considerable heterogeneity across and within regions in terms of opportunities, capacity, and financing of climate action, which has implications for the potential of different regions to pursue low-carbon development (*high confidence*). Several multi-model exercises have explored regional approaches to mitigation. In general, these regional studies find that the costs of climate stabilization for an individual region will depend on the baseline development of regional emission and energy-use and energy-pricing policies, the mitigation requirement, the emissions reduction potential of the region, and terms of trade effects of climate policy, particularly in energy markets. [14.1.3, 14.2]

At the same time, there is a mismatch between opportunities and capacities to undertake mitigation (*medium confidence*). The regions with the greatest potential to leapfrog to low-carbon development trajectories are the poorest developing regions where there are few lock-in effects in terms of modern energy systems and urbanization patterns. However, these regions also have the lowest financial, technological, and human capacities to embark on such low-carbon development paths and their cost of waiting is high due to unmet energy and development needs. Emerging economies already have more lock-in effects but their rapid build-up of modern energy systems and urban settlements still offers substantial opportunities for low-carbon development. Their capacity to reorient themselves to low-carbon development strategies is higher, but also faces constraints in terms of finance, technology, and the high cost of delaying the installation of new energy capacity. Lastly, industrialized economies have the largest lock-in effects, but the highest capacities to reorient their energy, transport, and urbanizations systems towards low-carbon development. [14.1.3, 14.3.2]

Heterogeneity across and within regions is also visible at a more disaggregated level in the energy sector (*high confidence*). Access to energy varies widely across regions, with LDC and SSA being the most energy-deprived regions. These regions emit less CO_2, but offer mitigation opportunities from future sustainable energy use. Regional cooperation on energy takes different forms and depends on the degree of political cohesion in a region, the energy resources available, the strength of economic ties between participating countries, their institutional and technical capacity, political will and the available financial resources. Regional cooperation on energy offers a variety of mitigation and adaptation options, through instruments such as harmonized legalization and regulation, energy resources and infrastructure sharing (e.g., through power pools), joint development of energy resources (e.g., hydropower in a common river basin), and know-how transfer. As regional energy cooperation instruments interact with other policies, notably those specifically addressing climate change, they may affect their ability to stimulate investment in low-carbon technologies and energy efficiency. Therefore, there is a need for coordination between these energy cooperation and regional/national climate policy instruments. In this context, it is also important to consider spillovers on energy that may appear due to trade. While mitigation policy would likely lead to lower import dependence for energy importers, it can also devalue endowments of fossil fuel exporting countries (with differences between regions and fuels). While the effect on coal exporters is expected to be negative in the short- and long-term, as policies could reduce the benefits of using coal, gas exporters could benefit in the medium-term as coal is replaced by gas. The overall impact on oil is more uncertain. [14.3.2, 14.4.2]

The impact of urbanization on carbon emissions also differs remarkably across regions (*high confidence*). This is due to the regional variations in the relationship between urbanization, economic growth, and industrialization. Developing regions and their cities have significantly higher energy intensity than developed regions, partly due to different patterns and forms of urban settlements. Therefore, regional cooperation to promote environmentally friendly technology, and to follow sustainably socioeconomic development pathways, can induce great opportunities and contribute to the emergence of low-carbon societies. [14.3.3]

In terms of consumption and production of GHG emissions, there is great heterogeneity in regional GHG emissions in relation to the population, sources of emissions and gross domestic product (GDP) (*high confidence*). In 2010, NAM, POECD, EIT, and WEU, taken together, had 20.5 % of the world's population, but accounted for 58.3 % of global GHG emissions, while other regions with 79.5 % of population accounted for 41.7 % of global emissions. If we consider consumption-based emissions, the disparity is even larger with NAM, POECD, EIT, and WEU generating around 65 % of global consumption-based emissions. In view of emissions per GDP (intensity), NAM, POECD and WEU have the lowest GHG emission intensities, while SSA and PAS have high emission intensities and also the highest share of forestry-related emissions. This shows that a significant part of GHG-reduction potential might exist in the forest sector in these developing regions. [14.3.4]

Regional prospects of mitigation action and low-carbon development from agriculture and land-use change are mediated by their development level and current pattern of emissions (*medium evidence, high agreement*). Emissions from agriculture, forestry, and other land use (AFOLU) are larger in ASIA (SAS, EAS, and PAS combined) and LAM than in other regions, and in many LDC regions, emissions from AFOLU are greater than from fossil fuels. Emissions were predominantly due to deforestation for expansion of agriculture, and agricultural production (crops and livestock), with net sinks in some regions due to afforestation. Region-specific strategies are needed to allow for flexibility in the face of changing demographics, climate change and other factors. There is potential for the creation of synergies with development policies that enhance adaptive capacity. [14.3.5]

In addition, regions use different strategies to facilitate technology transfer, low-carbon development, and to make use of opportunities for leapfrogging (*robust evidence, medium agreement*). Leapfrogging suggests that developing countries might be able to follow more sustainable, low-carbon development pathways and avoid the more emissions-intensive stages of development that were previously experienced by industrialized nations. Time and absorptive capacity, i.e., the ability to adopt, manage, and develop new technologies, have been shown to be a core condition for successful leapfrogging. The appropriateness of different low-carbon pathways depends on the nature of different technologies and the region, the institutional architecture and related barriers and incentives, as well as the needs of different parts of society. [14.3.6, 14.4.3]

In terms of investment and finance, regional participation in different climate policy instruments varies strongly (*high confidence*). For example, the Clean Development Mechanism (CDM) has developed a distinct pattern of regional clustering of projects and buyers of emission credits, with projects mainly concentrated in Asia and Latin America, while Africa and the Middle East are lagging behind. The regional distribution of the climate change projects of the Global Environment Facility (GEF) is much more balanced than that of the CDM. [14.3.7]

Regional cooperation for mitigation can take place via climate-specific cooperation mechanisms or existing cooperation mechanisms that are (or can be) climate-relevant. Climate-specific regional initiatives are forms of cooperation at the regional level that are designed to address mitigation challenges. Climate-relevant initiatives were launched with other objectives, but have potential implications for mitigation at the regional level. [14.4.1]

Our assessment is that regional cooperation has, to date, only had a limited (positive) impact on mitigation (*medium evidence, high agreement*). Nonetheless, regional cooperation could play an enhanced role in promoting mitigation in the future, particularly if it explicitly incorporates mitigation objectives in trade, infrastructure, and energy policies, and promotes direct mitigation action at the regional level. [14.4.2, 14.5]

Most literature suggests that climate-specific regional cooperation agreements in areas of policy have not played an important role in addressing mitigation challenges to date (*medium confidence*). This is largely related to the low level of regional integration and associated willingness to transfer sovereignty to supranational regional bodies to enforce binding agreements on mitigation. [14.4.2, 14.4.3]

Even in areas with deep regional integration, economic mechanisms to promote mitigation (including the European Union (EU) Emission Trading Scheme (ETS)) have not been as successful as anticipated in achieving intended mitigation objectives (*high confidence*). While the EU-ETS has demonstrated that a cross-border cap-and-trade system can work, the persistently low carbon price in recent years has not provided sufficient incentives to motivate additional mitigation action. The low price is related to a number of factors, including the unexpected depth and duration of the economic recession, uncertainty about the long-term emission-reduction targets, import of credits from the CDM, and the interaction with other policy instruments, particularly related to the expansion of renewable energy as well as regulation on energy efficiency. As of the time of this assessment in late 2013, it has proven to be politically difficult to address this problem by removing emission permits temporarily, tightening the cap, or providing a long-term mitigation goal. [14.4.2]

Climate-specific regional cooperation using binding regulation-based approaches in areas of deep integration, such as EU directives on energy efficiency, renewable energy, and biofuels, have had some impact on mitigation objectives (*medium confidence*).

Nonetheless, theoretical models and past experience suggest that there is substantial potential to increase the role of climate-specific regional cooperation agreements and associated instruments, including economic instruments and regulatory instruments. In this context, it is important to consider carbon leakage of such regional initiatives and ways to address it. [14.4.2, 14.4.1]

In addition, non-climate-related modes of regional cooperation could have significant implications for mitigation, even if mitigation objectives are not a component (*medium confidence*). Regional cooperation with non-climate-related objectives but possible mitigation implications, such as trade agreements, cooperation on technology, and cooperation on infrastructure and energy, has to date also had negligible impacts on mitigation. Modest impacts have been found on the level of emissions of members of regional preferential trade areas if these agreements are accompanied with environmental agreements. Creating synergies between adaptation and mitigation can increase the cost-effectiveness of climate change actions. Linking electricity and gas grids at the regional level has also had a modest impact on mitigation as it facilitated greater use of low-carbon and renewable technologies; there is substantial further mitigation potential in such arrangements. [14.4.2]

Despite a plethora of agreements on technology, the impact on mitigation has been negligible to date (*medium confidence*). A primary focus of regional agreements surrounds the research, development, and demonstration of low-carbon technologies, as well as the development of policy frameworks to promote the deployment of such technologies within different national contexts. In some cases, geographical regions exhibit similar challenges in mitigating climate change, which can serve as a unifying force for regional technology agreements or cooperation on a particular technology. Other regional agreements may be motivated by a desire to transfer technological experience across regions. [14.4.3]

Regional development banks play a key role in mitigation financing (*medium confidence*). The regional development banks, the World Bank, the United Nations system, other multilateral institutions, and the reducing emissions from deforestation and degradation (REDD)+ partnership will be crucial in scaling up national appropriate climate actions, e.g., via regional and thematic windows in the context of the Copenhagen Green Climate Fund, such as a possible Africa Green Fund. [14.4.4]

Going forward, regional mechanisms have considerably greater potential to contribute to mitigation goals than have been realized so far (*medium confidence*). In particular, these mechanisms have provided different models of cooperation between countries on mitigation, they can help realize joint opportunities in the field of trade, infrastructure, technology, and energy, and they can serve as a platform for developing, implementing, and financing climate-specific regional initiatives for mitigation, possibly also as part of global arrangements on mitigation. [14.5]

14.1 Introduction

14.1.1 Overview of issues

This chapter provides an assessment of knowledge and practice on regional development and cooperation to achieve climate change mitigation. It will examine the regional trends and dimensions of the mitigation challenge. It will also analyze what role regional initiatives, both with a focus on climate change and in other domains such as trade, can play in addressing these mitigation challenges.

The regional dimension of mitigation was not explicitly addressed in the IPCC Fourth Assessment Report (AR4). Its discussion of policies, instruments, and cooperative agreements (Working Group III AR4, Chapter 13) was focused primarily on the global and national level. However, mitigation challenges and opportunities differ significantly by region. This is particularly the case for the interaction between development/growth opportunities and mitigation policies, which are closely linked to resource endowments, the level of economic development, patterns of urbanization and industrialization, access to finance and technology, and—more broadly—the capacity to develop and implement various mitigation options. There are also modes of regional cooperation, ranging from regional initiatives focused specifically on climate change (such as the emissions trading scheme (ETS) of the European Union (EU)) to other forms of cooperation in the areas of trade, energy, or infrastructure, that could potentially provide a platform for delivering and implementing mitigation policies. These dimensions will be examined in this chapter.

Specifically, this chapter will address the following questions:

- Why is the regional level important for analyzing and achieving mitigation objectives?
- What are the trends, challenges, and policy options for mitigation in different regions?
- To what extent are there promising opportunities, existing examples, and barriers for leapfrogging in technologies and development strategies to low-carbon development paths for different regions?
- What are the interlinkages between mitigation and adaptation at the regional level?
- To what extent can regional initiatives and regional integration and cooperation promote an agenda of low-carbon climate-resilient development? What has been the record of such initiatives, and what are the barriers? Can they serve as a platform for further mitigation activities?

The chapter is organized as follows: after discussing the definition and importance of supra-national regions, sustainable development at the regional level, and the regional differences in mitigation capacities, Section 14.2 will provide an overview of opportunities and barriers for low-carbon development. Section 14.3 will examine current development patterns and goals and their emission implications at the regional level. In this context, this section will discuss issues surrounding energy and development, urbanization and development, and consumption and production patterns. Section 14.3 will also examine opportunities and barriers for low-carbon development by examining policies and mechanisms for such development-indifferent regions and sectors. Moreover, it will analyze issues surrounding technology transfer, investment, and finance. Section 14.4 will evaluate existing regional arrangements and their impact on mitigation, including climate-specific as well as climate-relevant regional initiatives. In this context, links between mitigation, adaptation and development will be discussed. Also, the experiences of technology transfer and leapfrogging will be evaluated. Section 14.5 will formulate policy options. Lastly, Section 14.6 will outline gaps in knowledge and data related to the issues discussed in this chapter.

The chapter will draw on Chapter 5 on emission trends and drivers, Chapter 6 on transformation pathways, the sectoral Chapters 7–12, and Chapter 16 on investment and finance, by analyzing the region-specific information in these chapters. In terms of policy options, it differs from Chapters 13 and 15 by explicitly focusing on regions as the main entities and actors in the policy arena.

We should note from the outset that there are serious gaps in the peer-reviewed literature on several of the topics covered in this chapter, as the regional dimension of mitigation has not received enough attention or the issues covered are too recent to have been properly analyzed in peer-reviewed literature. We will therefore sometimes draw on grey literature or state the research gaps.

14.1.2 Why regions matter

This chapter only examines supra-national regions (i.e., regions in between the national and global level). Sub-national regions are addressed in Chapter 15. Thinking about mitigation at the regional level matters mainly for three reasons:

First, regions manifest vastly different patterns in their level, growth, and composition of GHG emissions, underscoring significant differences in socio-economic contexts, energy endowments, consumption patterns, development pathways, and other underlying drivers that influence GHG emissions and therefore mitigation options and pathways (Section 14.3). For example, low-income countries in sub-Saharan Africa, whose contribution to consumption-based GHG emissions is currently very low, face the challenge to promote economic development (including broader access to modern energy and transport) while encouraging industrialization. Their mitigation challenge relates to choosing among development paths with different mitigation potentials. Due to their tight resource situation and severe capacity constraints, their ability to choose low-carbon development paths and their opportunities to wait for more mitigation-friendly technologies is severely constrained (Collier and Venables, 2012a). Moreover, these development paths may be costly. Nonetheless, with sufficient access to finance, technologies, and the appropriate institutional environment, these countries might be able to leapfrog to low-carbon development paths that would promote their economic development and contribute to mitigating climate change in the medium to long run. Emerging economies, on the other hand, which are further along the way of carbon-intensive development, are better able to adopt various mitigation options, but their gains from leapfrogging may be relatively smaller. For more rapidly growing economies, the opportunities to follow different mitigation paths are greater, as they are able to quickly install new energy production capacities and build up transport and urban infrastructure. However, once decisions have been made, lock-in effects will make it costly for them to readjust paths. In industrialized countries, the opportunities to leapfrog are small and the main challenge will be to drastically re-orient existing development paths and technologies towards lower-carbon intensity of production and consumption. We call this the 'regional heterogeneity' issue.

Second, regional cooperation is a powerful force in global economics and politics—as manifest in numerous agreements related to trade, technology cooperation, trans-boundary agreements relating to water, energy, transport, and so on. From loose free-trade areas in many developing countries to deep integration involving monetary union in the EU, regional integration has built up platforms of cooperation among countries that could become the central institutional forces to undertake regionally coordinated mitigation activities. Some regions, most notably the EU, already cooperate on mitigation, using a carbon-trading scheme and binding regulations on emissions. Others have focused on trade integration, which might have repercussions on the mitigation challenge. It is critical to examine to what extent these forms of cooperation have already had an impact on mitigation and to what extent they could play a role in achieving mitigation objectives (Section 14.3). We call this the 'regional cooperation and integration issue'.

Third, efforts at the regional level complement local, domestic efforts on the one hand and global efforts on the other hand. They offer the potential of achieving critical mass in the size of markets required to make policies, for example, on border tax adjustment, in exploiting opportunities in the energy sector or infrastructure, or in creating regional smart grids required to distribute and balance renewable energy.

Given the policy focus of this chapter and the need to distinguish regions by their levels of economic development, this chapter adopts regional definitions that are based on a combination of economic and geographic considerations. In particular, the chapter considers the following 10 regions: East Asia (China, Korea, Mongolia) (EAS); Economies in Transition (Eastern Europe and former Soviet Union) (EIT); Latin America and Caribbean (LAM); Middle East and North Africa (MNA); North America (USA, Canada) (NAM); Pacific Organisation for Economic Co-operation and Development (OECD)-1990 members (Japan, Australia, New Zealand) (POECD); South East Asia and Pacific (PAS); South Asia (SAS); sub-Saharan Africa (SSA); Western Europe (WEU). These regions can, with very minor deviations, readily be aggregated to regions used in scenarios and integrated models. They are also consistent with commonly used World Bank regional classifications, and can be aggregated into the geographic regions used by WGII. However, if dictated by the reviewed literature, in some cases other regional classifications are used. Regional cooperation initiatives define regions by membership of these ventures. The least-developed countries (LDC) region is orthogonal to the above regional definitions and includes countries from SSA, SAS, PAS, and LAM.

14.1.3 Sustainable development and mitigation capacity at the regional level

Sustainable development refers to the aspirations of regions to attain a high level of well-being without compromising the opportunities of future generations. Climate change relates to sustainable development because there might be tradeoffs between development aspirations and mitigation. Moreover, limited economic resources, low levels of technology, poor information and skills, poor infrastructure, unstable or weak institutions, and inequitable empowerment and access to resources compromise the capacity to mitigate climate change. They will also pose greater challenges to adapt to climate change and lead to higher vulnerability (IPCC, 2001).

Figure 14.1 shows that regions differ greatly in development outcomes such as education, human development, unemployment, and poverty. In particular, those regions with the lowest level of per capita emissions also tend to have the worst human development outcomes. Generally, levels of adult education (Figure 14.1b), life expectancy (Figure 14.1c), poverty, and the Human Development Index (Figure 14.1d) are particularly low in SSA, and also in LDCs in general. Unemployment (Figure 14.1a) is high in SSA, MNA, and EIT, also in LDCs, making employment-intensive economic growth a high priority there (Fankhauser et al., 2008).

The regions with the poorest average development indicators also tend to have the largest disparities in human development dimensions (Grimm et al., 2008; Harttgen and Klasen, 2011). In terms of income, LAM faces particularly high levels of inequality (Figure 14.1f). Gender gaps in education, health, and employment are particularly large in SAS and MNA, with large educational gender gaps also persisting in SSA. Such inequalities will raise distributional questions regarding costs and benefits of mitigation policies.

When thinking about inter-generational inequality (Figure 14.2b), adjusted net savings (i.e., gross domestic savings minus depreciation of physical and natural assets plus investments in education and minus damage associated with CO_2 emissions) is one way to measure whether societies transfer enough resources to next generations. As shown in Figure 14.2b, there is great variation in these savings rates. In several regions, including SSA, MNA, LAM, as well as LDCs, there are a number of countries where adjusted net savings are negative. Matters would look even worse if one considered that—due to substantial population growth—future generations are larger in some regions, considered a broader range of assets in the calculation of depreciation, or considered that only imperfect substitution is possible between financial savings and the loss of some natural assets. For these countries, maintenance of their (often low) living standards is already under threat. Damage from climate change might pose further challenges and thereby limit the ability to engage in costly mitigation activities.

14.1.3.1 The ability to adopt new technologies

Developing and adopting low-carbon technologies might be one way to address the mitigation challenge. However, the capacity to adopt new technologies, often referred to as absorptive capacity, as well as to develop new technologies, is mainly located in four regions: NAM, EAS, WEU, and POECD. This is also shown in Figure 14.2a, which plots high-technology exports as share of total manufactured exports. High-technology exports refer to products with high research and development intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery. As visible in the figure, these exports are very low in most other regions, suggesting low capacity to develop and competitively market new technologies. Since most technological innovation happens in developed regions, technological spillovers could significantly increase the mitigation potential in developing regions.

While Section 13.9 discusses inter-regional technology transfer mechanisms, which could help foster this process, there is an emerging literature that looks at the determinants and precursors of successful technology absorption. Some studies have found that for energy technologies, the more technologically developed a country is, the more likely it is to be able to receive innovations (Verdolini and Galeotti, 2011; Dechezleprêtre et al., 2013). However, more recent work looking at a wider range of mitigation technologies finds that domestic technological development tends to crowd out foreign innovations (Dechezleprêtre et al., 2013). But the determinants of the receptivity of a host country or region go beyond the technological development of the receiving countries. Some of these aspects are relatively harder (or impossible) to influence with policy interventions such as the geographical distance from innovating countries (Verdolini and Galeotti, 2011) and linkages with countries with CO_2-efficient economies (Perkins and Neumayer, 2009). However, other aspects can be influenced such as institutional capacity (Perkins and Neumayer, 2012), and in particular the strength of intellectual property laws to protect incoming technologies (Dechezleprêtre et al., 2013).

Two further challenges for promoting mitigation in different regions are the costs of capital, which circumscribe the ability to invest in new low-

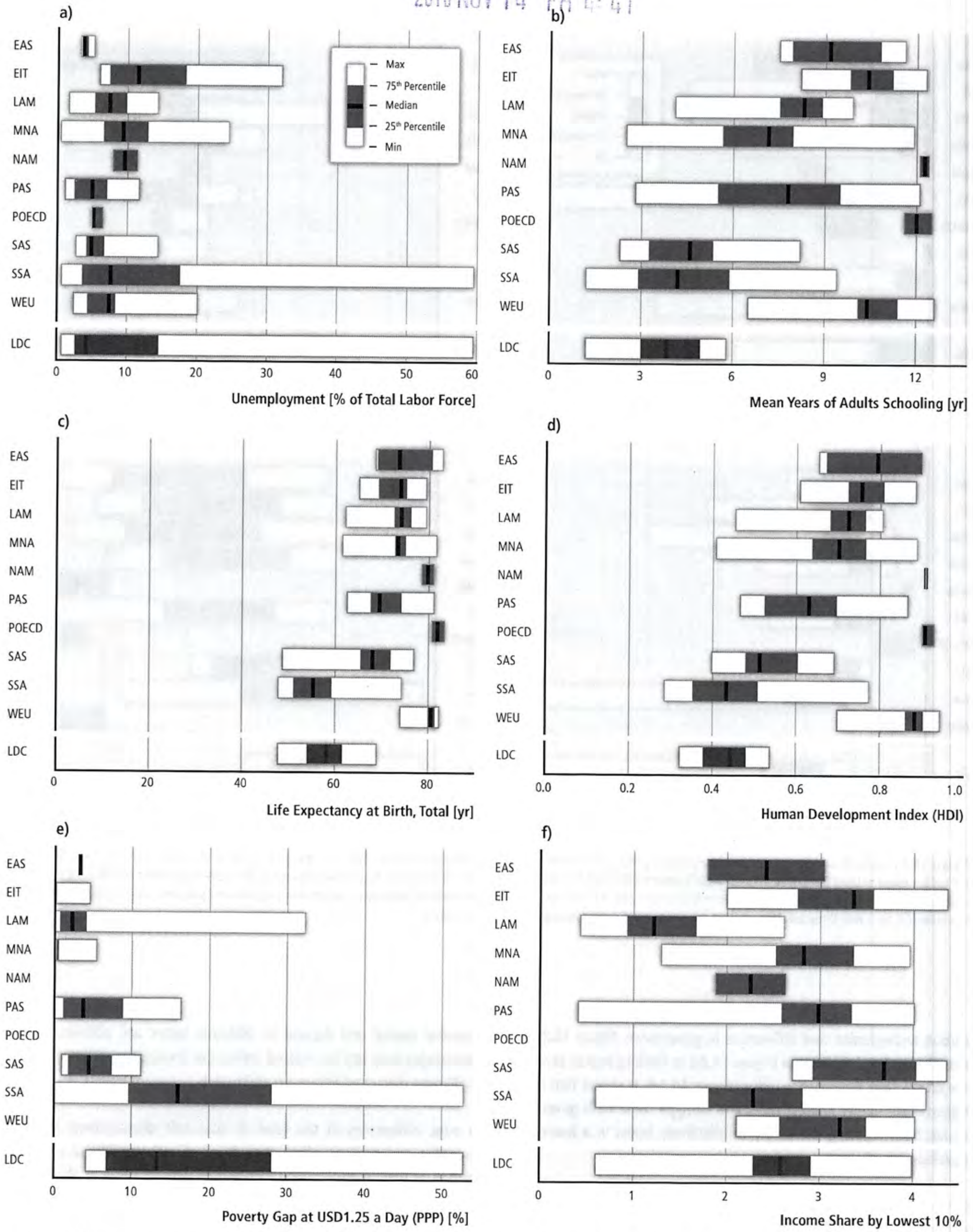

Figure 14.1 | Social provisions enabling regional capacities to embrace mitigation policies. Statistics refer to the year 2010 or the most recent year available. The red bar refers to Least Developed Countries (LDC). Source: UNDP (2010), World Bank (2011).

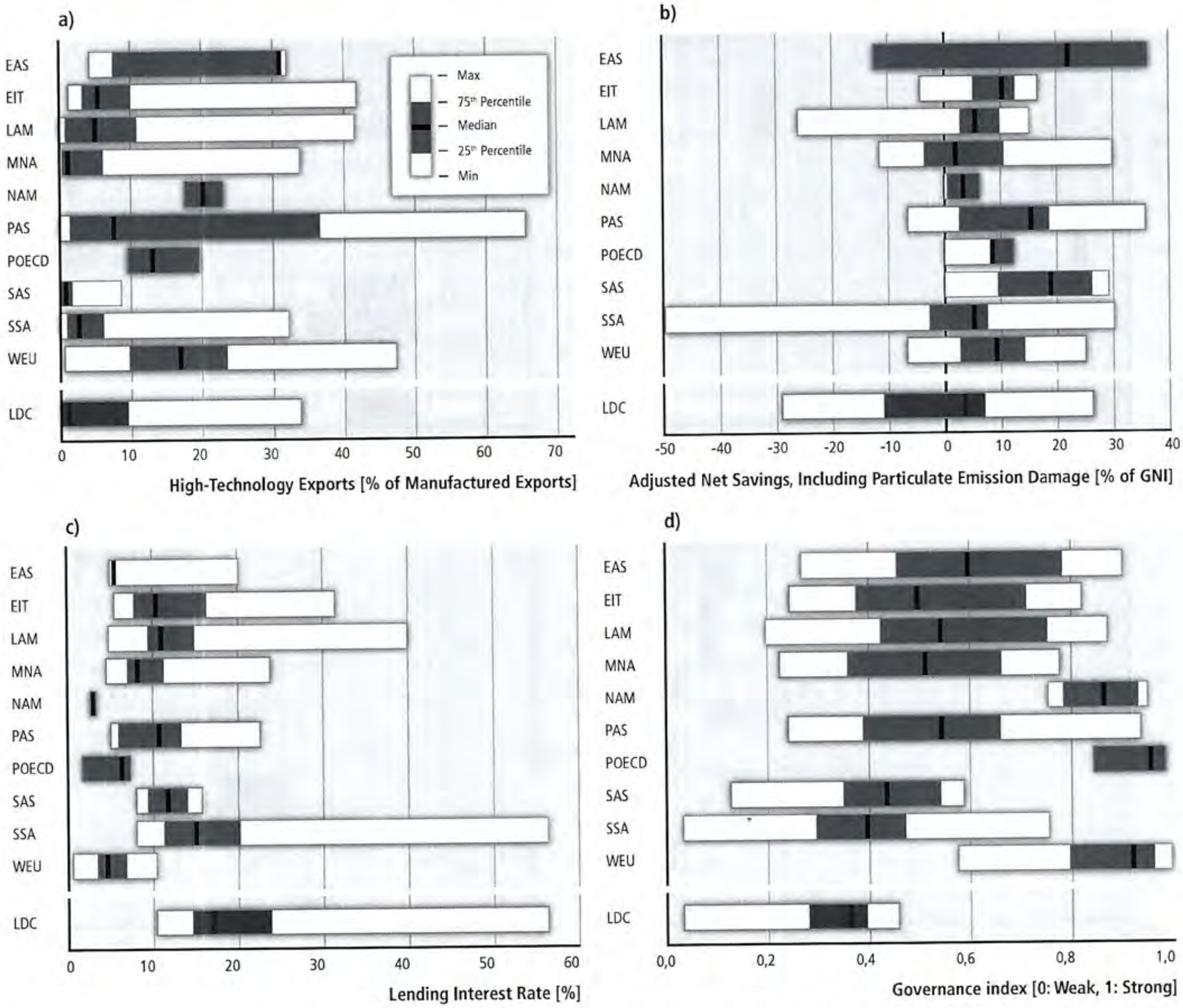

Figure 14.2 | Economic and governance indicators affecting regional capacities to embrace mitigation policies. Statistics refer to the year 2010 or the most recent year available. The red bar refers to Least Developed Countries (LDC). Source: UNDP (2010), World Bank (2011). Note: The lending interest rate refers to the average interest rate charged by banks to private sector clients for short- to medium-term financing needs. The governance index is a composite measure of governance indicators compiled from various sources, rescaled to a scale of 0 to 1, with 0 representing weakest governance and 1 representing strongest governance.

carbon technologies, and differences in governance. Figure 14.2 presents the lending interest rate (Figure 14.2c) to firms by region as well as the World Bank Governance index (Figure 14.2d). It shows that poorer regions face higher interest rates and struggle more with governance issues, both reducing the ability to effectively invest in a low-carbon development strategy.

Conversely, there are different regional opportunities to promote mitigation activities. As discussed by Collier and Venables (2012a), Africa has substantial advantages in the development of solar energy and hydropower. However, as these investments are costly in human and financial capital and depend on effective states and policies, these advantages may not be realized unless the financing and governance challenges discussed above are addressed.

In sum, differences in the level of economic development among countries and regions affect their level of vulnerability to climate change as well as their ability to adapt or mitigate (Beg et al., 2002). Given these regional differences, the structure of multi-national or multi-regional environmental agreements affects their chance of success (Karp and Zhao, 2010). By taking these differences into account, regional cooperation on climate change can help to foster mitigation that considers distributional aspects, and can help addressing climate-change impacts (Asheim et al., 2006). At the same time, disparities between and within regions diminish the opportunities that countries have to undertake effective mitigation policies (Victor, 2006).

14.2 Low-carbon development at the regional level: opportunities and barriers

There are great differences in the mitigation potential of regions. One way to assess these heterogeneities is through integrated models on the regional distribution of costs of mitigation pathways as well as regional modelling exercises that compare integrated model results for particular regions. The region-specific results are discussed in detail in Chapter 6 using a higher level of regional aggregation than adopted here (Section 6.3.6.4). They show that in an idealized scenario with a universal carbon price, where mitigation costs are distributed in the most cost-effective manner across regions, the macroeconomic costs of mitigation differ considerably by region. In particular, in OECD countries (including the regions WEU, NAM, and POECD), these costs would be substantially lower, in LAM they would be average, and in other regions they would be higher (Clarke et al., 2009; Tavoni et al., 2014). These differences are largely due to the following: First, energy and carbon intensities are higher in non-OECD regions, leading to more opportunities for mitigation, but also to higher macroeconomic costs. Second, some developing regions face particularly attractive mitigation options (e.g., hydropower or afforestation) that would shift mitigation there. Third, some developing regions, and in particular countries exporting fossil energy (which are concentrated in MNA, but include countries in other regions as well), would suffer negative terms of trade effects as a result of aggressive global mitigation policies, thus increasing the macroeconomic impact of mitigation (see also Section 14.4.2). The distribution of these costs could be adjusted through transfer payments and other burden sharing regimes. The distribution of costs would shift towards OECD countries, if there was limited participation among developing and emerging economies (de Cian et al., 2013).

One should point out, however, that these integrated model results gloss over many of the issues highlighted in this chapter, including the regional differences in financial, technological, institutional, and human resource capacities that will make the implementation of such scenarios very difficult.

As many of the region-specific opportunities and barriers for low-carbon development are sector-specific, we will discuss them in the relevant sectoral sub-sections in Section 14.2.

14.3 Development trends and their emission implications at the regional level

14.3.1 Overview of trends in GHG emissions and their drivers by region

Global GHG emissions have increased rapidly over the last two decades (Le Quéré et al., 2009, 2012). Despite the international financial and economic crisis, global GHG emissions grew faster between 2000 and 2010 than in the previous three decades (Peters et al., 2012b). Emissions tracked at the upper end of baseline projections (see Sections 1.3 and 6.3) and reached around 49–50 $GtCO_2eq$ in 2010 (JRC/PBL, 2013; IEA, 2012a; Peters et al., 2013). In 1990, EIT was the world's highest emitter of GHG emissions at 19 % of global total of 37 $GtCO_2eq$, followed by NAM at 18 %, WEU at 12 %, and EAS at 12 %, with the rest of the world emitting less than 40 %. By 2010, the distribution had changed remarkably. The EAS became the major emitter with 24 % of the global total of 48 $GtCO_2eq$ (excluding international transport) (JRC/PBL, 2013; IEA, 2012a). The rapid increase in emissions in developing Asia was due to the region's dramatic economic growth and its high population level.

Figure 14.3 shows the change in GHG emissions in the 10 regions (and additionally reporting for LDC including countries from several regions) over the period from 1990 to 2010, broken down along three drivers: Emissions intensity (emissions per unit of gross domestic product (GDP)), GDP per capita, and population. As shown in the figure, the most influential driving force for the emission growth has been the increase of per capita income. Population growth also affected the emission growth but decreases of GHG emission intensities per GDP contributed to lowering the growth rate of GHG emissions. These tendencies are similar across regions, but with notable differences. First, the magnitude of economic growth differed greatly by region with EAS showing by far the highest growth in GDP per capita, leading to the highest growth in emissions in the past 20 years; stagnating incomes in POECD contributed to low growth in emissions. Second, falling population levels in EIT contributed to lower emissions there. Third, improvements in the emission intensity were quantitatively larger than the increases in emissions due to income growth in all richer regions (WEU, POECD, NAM, and EIT), while the picture is more mixed in developing and emerging regions. Note also that in LDCs emissions were basically flat with improvements in emission intensity making up for increases in GDP and population.

Other ways to look at heterogeneity of regional GHG emissions are relative to the size of the total population, the size of the overall economy and in terms of sources of these emissions. These perspectives are shown in the two panels of Figure 14.4. In 2010, NAM, EIT, POECD, and WEU, taken together, had 20 % of the world's population, but accounted for 39 % of global GHG emissions, while other regions

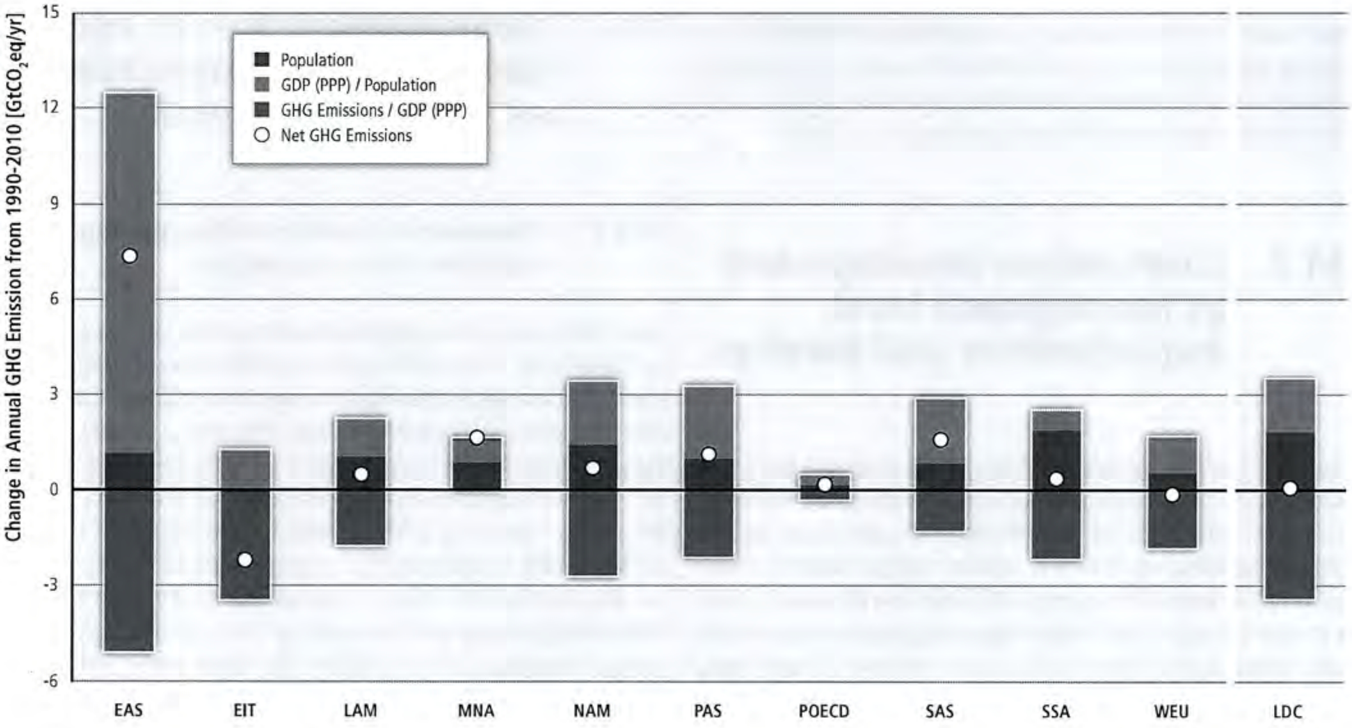

Figure 14.3 | Decomposition of drivers for changes in total annual GHG emissions (excluding international transport) in different world regions from 1990–2010 (Logarithmic Mean Divisia Index (LMDI) method according to Ang, 2004). The white dots indicate net changes of GHG emissions from 1990 to 2010, and the bars, which are divided by three colours, show the impacts on GHG emission changes resulting from changes in population, GDP per capita, and GHG emission per GDP. For example, the white dot for EAS shows its emission increased by 7.4 Gt CO$_2$eq, and the influence of the three driving factors are 1.2, 11, and –5.1 GtCO$_2$eq, which are indicated by red, yellow, and blue bars, respectively. Data sources: GHG emission data (in CO$_2$eq using 100-year GWP values) from JRC/PBL (2013) and IEA (2012a), see Annex II.9; GDP (PPP) [Int$2005] from World Bank (2013a); and population data from United Nations (2013).

with 80 % of population accounted for 61 % of global emissions (Figure 14.4). The contrast between the region with the highest per capita GHG emissions (NAM) and the lowest (SAS) is more pronounced: 5.0 % of the world's population (NAM) emits 15 %, while 23 % (SAS) emits 6.8 %. One of the important observations from Figure 14.4 (top panel) is that some regions such as SSA and PAS have the lowest levels of per capita emissions of CO$_2$ from non-forestry sources, but they have GHG emissions per capita that are comparable to other regions due to large emissions from land-use change and other non-CO$_2$ GHG emissions.

The cumulative distribution of emissions per GDP (emission intensity) shows a strikingly different picture (Figure 14.4 bottom panel). The four regions with highest per capita emissions, NAM, EIT, POECD, and WEU, have the lowest GHG emission intensities (emission per GDP), except EIT. Some regions with low per capita emissions, such as SSA and PAS, have high emission intensities and also highest share of forestry-related emissions. This shows that a significant part of GHG-reduction potential might exist in the forest sector in these developing regions (see Chapter 11).

14.3.2 Energy and development

14.3.2.1 Energy as a driver of regional emissions

Final energy consumption is growing rapidly in many developing countries. Consequently, energy-related CO$_2$ emissions in developing country regions such as EAS, MNA, and PAS in 2010 were more than double the level of 1990, while the CO$_2$ emission in EIT decreased by around 30 % (Figure 14.5). The composition of energy consumption also varies by region. Oil dominates the final energy consumption in many regions such as NAM, POECD, WEU, LAM, and MNA, while coal has the highest share in EAS. The share of electricity in final energy consumption has tended to grow in all regions.

When looking at trends in CO$_2$ emissions by source (see Figure 14.5), the largest growth in total CO$_2$ emissions between 1990 and 2010 has come from coal, followed by gas and oil. In this period, CO$_2$ emissions from coal grew by 4.4 GtCO$_2$ in EAS, which is equivalent to roughly half of the global net increase of CO$_2$ emissions from fossil fuel combustion.

These observations are in line with findings in the literature emphasizing the transformation of energy use patterns over the course of eco-

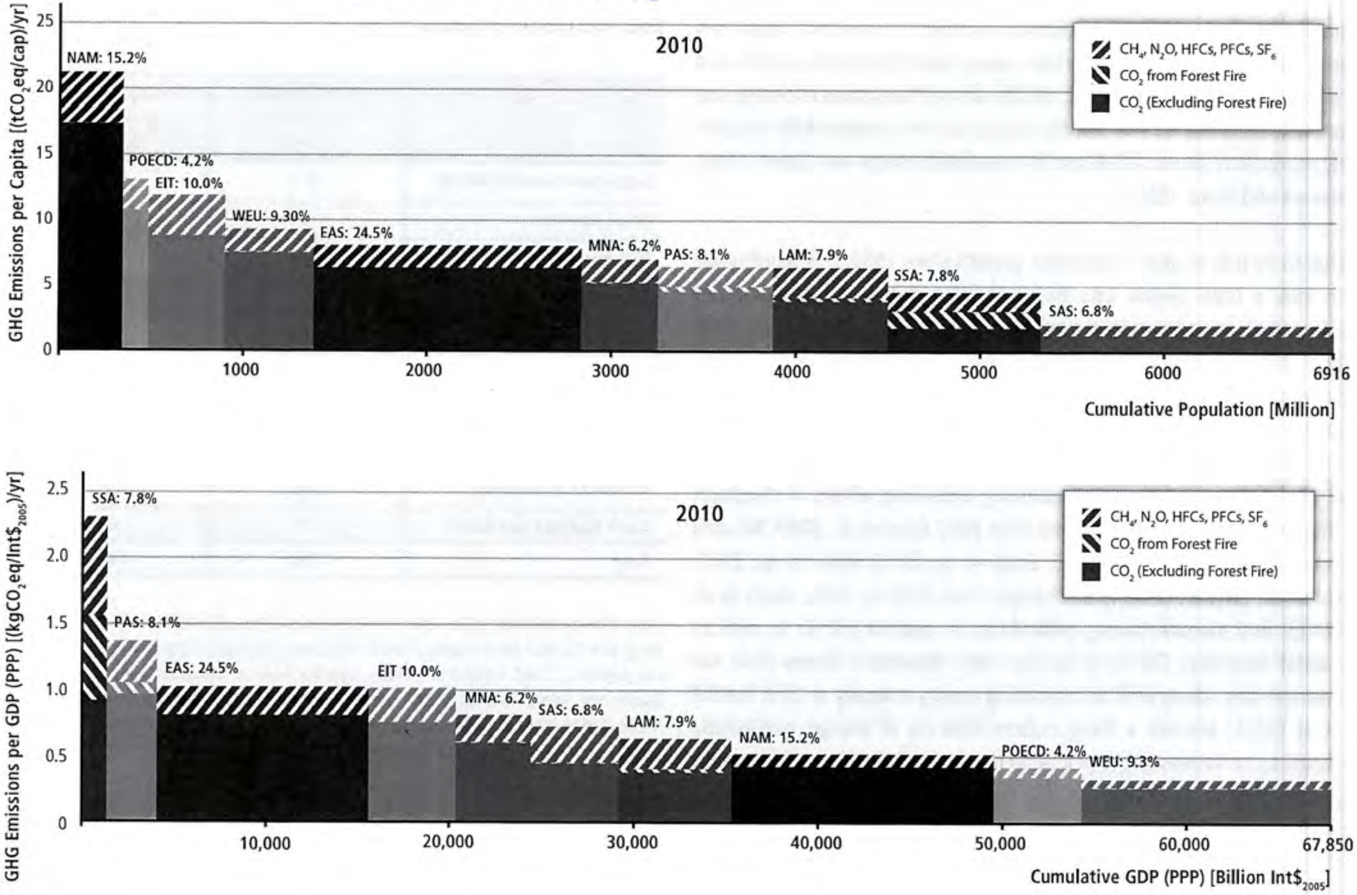

Figure 14.4 | Distribution of regional GHG emissions (excluding international transport) in relation to population and GDP: cumulative distribution of GHG emissions per capita (top panel) and GDP (bottom panel). The percentages in the bars indicate a region's share in global GHG emissions. Data sources: GHG emission data (in CO_2eq using 100-year GWP values) from JRC/PBL (2013) and IEA (2012a), see Annex II.9; GDP (PPP) [Int$2005] from World Bank (2013a); and population data from United Nations (2013).

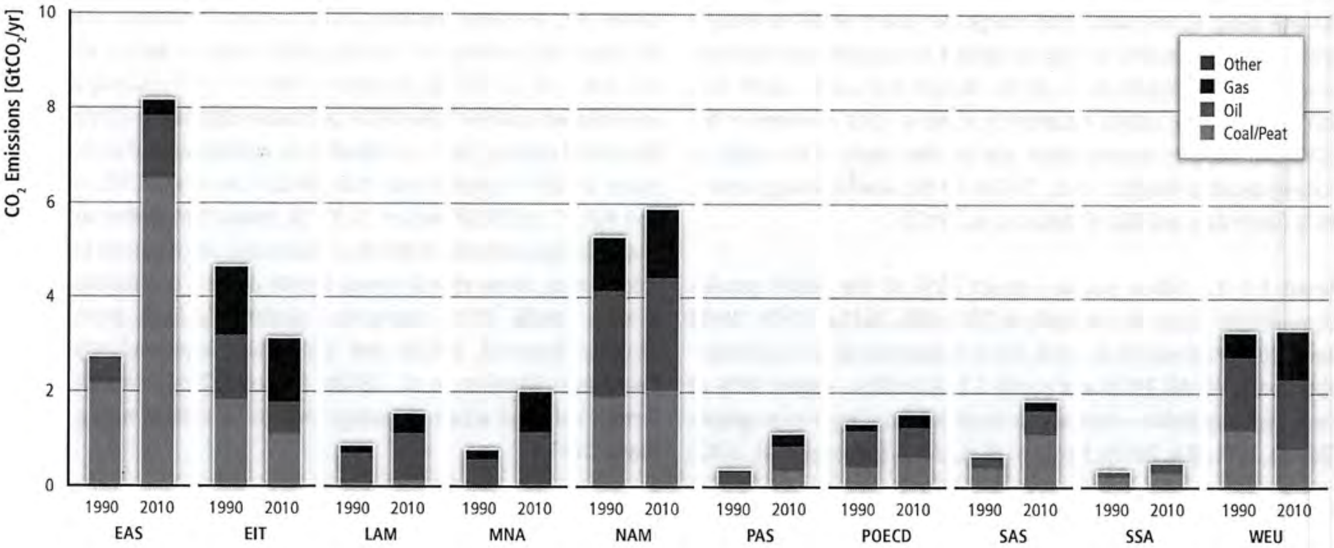

Figure 14.5 | CO_2 emissions by sources and regions. Data source: IEA (2012a).

nomic development from traditional biomass to coal and liquid fuel and finally natural gas and nuclear energy (Smil, 2000; Marcotullio and Schulz, 2007; Krausmann et al., 2008). Similar transitions in energy use are also observed for the primary energy carriers employed for electricity production (Burke, 2010) and in household energy use (Leach, 1992; Barnes and Floor, 1996).

Due to its role in global emissions growth since 1990, it is worthwhile to look a little deeper into the underlying drivers for emissions in EAS, which have been increased by nearly 8 $GtCO_2eq$ between 1990 and 2010. The major part of the increase has been witnessed in the years after 2002 (Minx et al., 2011). Efficiency gains and technological progress particularly in energy-intensive sectors that had a decreasing effect on emissions (Ma and Stern, 2008; Guan et al., 2009; Zhao et al., 2010) were overcompensated by increasing effects of structural changes of the Chinese economy after 2002 (Liao et al., 2007; Ma and Stern, 2008; Guan et al., 2009; Zhao et al., 2010; Minx et al., 2011; Liu et al., 2012a). Looking at changes from 2002 to 2005, Guan et al. (2009) find manufacturing, particularly for exports (50 %) as well as capital formation (35 %) to be the most important drivers from the demand side. Along with an increasing energy intensity of GDP, Steckel et al. (2011) identify a rising carbon intensity of energy, particularly driven by an increased use of coal to have contributed to rapid increase in emissions in the 2000s.

Figure 14.6 shows the relationship between GHG emissions and per capita income levels. Individual regions have different starting levels, directions, and magnitudes of changes. Developed regions (NAM, WEU, POECD) appear to have grown with stable per capita emissions in the last two decades, with NAM having much higher levels of per capita emissions throughout (Figure 14.6 top panel). Carbon intensities of GDP tended to decrease constantly for most regions as well as for the globe (Figure 14.6 bottom panel).

Despite rising incomes and rising energy use, lack of access to modern energy services remains a major constraint to economic development in many regions (Uddin et al., 2006; Johnson and Lambe, 2009; IEA, 2013). The energy access situation is acute in LDCs (Chaurey et al., 2012) but likely to improve there and in other parts of the world in coming decades (Bazilian et al., 2012a). Of the world's 'energy poor'[1], 95 % live in Asia and SSA (Rehman et al., 2012).

About 1.2–1.5 billion people—about 20 % of the global population—lacked access to electricity in 2010 (IEA, 2010a, 2012b; World Bank, 2012; Pachauri et al., 2012, 2013; Sovacool et al., 2012; Sustainable Energy for All, 2013) and nearly 2.5–3.0 billion—about 40 % of the global population—lack access to modern cooking energy options (Zerriffi, 2011; IEA, 2012b; Pachauri et al., 2012; Sovacool et al., 2012; Rehman et al., 2012; Sustainable Energy for All, 2013). There is considerable regional variation as shown in Table 14.1, with electricity access being particularly low in SSA, followed by SAS.

Table 14.1 | Access to electricity in 2009

	Population with Access (%)	Population Lacking Access (millions)
Latin America and Caribbean	93.4	30
North America	*100.0*	*0*
East Asia	97.8	29
Western Europe	*100.0*	*0*
POECD	*100.0*	*0*
Sub-Saharan Africa	32.4	487
Middle East and North Africa	93.7	23
South Asia	62.2	607
Economies in Transition	*100.0*	*0*
South East Asia and Pacific	74.3	149
Total	**79.5**	**1330**

Note: Information missing for several small islands, Mexico, Puerto Rico, Suriname, Hong Kong SAR (China), North Korea, Macao SAR (China), Burundi, Cape Verde, Central African Republic, Chad, Equatorial Guinea, Gambia, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Rwanda, Sierra Leone, Somalia, South Sudan, Swaziland, Djibouti, Malta, Turkey, West Bank and Gaza, Bhutan. For OECD and EIT, no data are listed but presumed to be 100 % access; these are recorded in italics. Source: World Bank (2012).

The lack of access to electricity is much more severe in rural areas of LDCs (85 %) and SSA (79 %) (IEA, 2010b; Kaygusuz, 2012). In developing countries, 41 % of the rural population does not have electricity access, compared to 10 % of the urban population (UNDP, 2009). This low access to electricity is compounded by the fact that people rely on highly polluting and unhealthy traditional solid fuels for household cooking and heating, which results in indoor air pollution and up to 3.5 million premature deaths in 2010—mostly women and children; another half-million premature deaths are attributed to household cooking fuel's contribution to outdoor air pollution (Sathaye et al., 2011; Agbemabiese et al., 2012) (Lim et al., 2012); see Section 9.7.3.1 and WGII Section 11.9.1.3). Issues that hinder access to energy include effective institutions (Sovacool, 2012b), good business models (e. g., ownership of energy service delivery organizations and finance; Zerriffi, 2011), transparent governance (e.g., institutional diversity; Sovacool, 2012a) and appropriate legal and regulatory frameworks (Bazilian et al., 2012b; Sovacool, 2013). Despite these factors, universal access to energy services by 2030 is taking shape (Hailu, 2012).

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[1] 'Energy poor' population is defined as population without electricity access and/or without access to modern cooking technologies (Rehman et al., 2012).

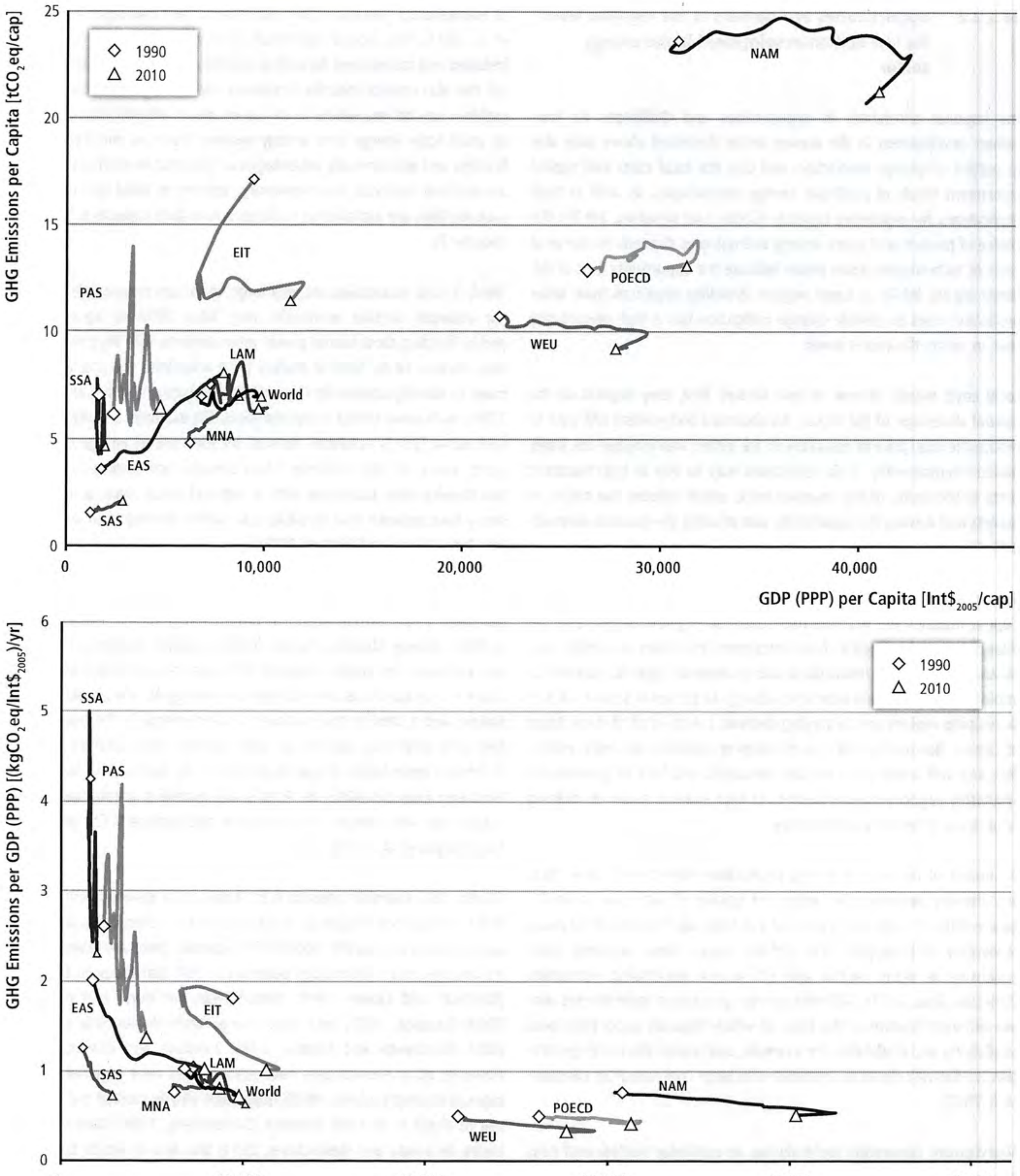

Figure 14.6 | Relationship between GHG emissions per capita and GDP per capita (top panel), and GHG emissions per GDP and GDP and per capita (bottom panel) (1990–2010). Data sources: GHG emission data (in CO_2eq using 100-year GWP values) from JRC/PBL (2013) and IEA (2012a), see Annex II.9; GDP (PPP) from World Bank (2013a); and population data from United Nations (2013).

14.3.2.2 Opportunities and barriers at the regional level for low-carbon development in the energy sector

The regional differences in opportunities and challenges for low-carbon development in the energy sector described above arise due to patters of energy production and use, the local costs and capital investment needs of particular energy technologies, as well as their implications for regulatory capacity (Collier and Venables, 2012b).The choice of present and future energy technologies depends on the local costs of technologies. Local prices indicate the opportunity cost of different inputs. While in some regions diverting resources from other productive uses to climate change mitigation has a high opportunity cost, in others the cost is lower.

Local costs mainly depend on two factors. First, they depend on the natural advantage of the region. An abundant endowment will tend to reduce the local price of resources to the extent that they are not freely traded internationally. Trade restrictions may be due to high transport costs or variability of the resource price, which reduces the return to exports and thereby the opportunity cost of using the resource domestically.

Second, local costs depend on the capital endowment of the region. Capital includes the accumulated stocks of physical capital and the financial capital needed to fund investment, the levels of human capital and skills, and the institutional and governance capacity required to implement and regulate economic activity. As shown in Section 14.1.3, developing regions are, to varying degrees, scarce in all of these types of capital. Borrowing costs for developing countries are high, education and skill levels are a serious constraint, and lack of government regulatory capacity creates barriers (a high shadow price) on running large-scale or network investments.

A number of features of energy production interact with local costs and thereby determine the extent of uptake of particular technologies in different regions. In general, the high capital intensity of many renewable technologies (IEA, 2010c) makes them relatively more expensive in many capital and skill-scarce developing economies (Strietska-Ilina, 2011). Different energy generation technologies also use different feedstock, the price of which depends upon their local availability and tradability; for example, coal-based electricity generation is relatively cheap in countries with large coal resources (Heptonstall, 2007).

Many power generation technologies, in particular nuclear and coal, but also large hydropower, create heavy demands on regulatory capacity because they have significant-scale economies and are long-lived projects. This has several implications. The first is that projects of this scale may be natural monopolies, and so need to be undertaken directly by the state or by private utilities that are regulated. Large-scale electricity systems have been ineffective in regions that are scarce in regulatory capacity, resulting in under-investment, lack of maintenance, and severe and persistent power shortages (Eberhard et al., 2011). The second implication of scale is that a grid has to be installed and maintained. As well as creating a heavy demand for capital, this also creates complex regulatory and management issues. This problem can be less severe in the cases where off-grid electrification or small-scale energy local energy systems (such as mini-hydro) are feasible and economically advantageous; but even in such cases, local institutional, financial, and regulatory capacity to build and maintain such facilities are a challenge in places where such capacity is low (see Chapter 7).

Third, if scale economies are very large, there are cross-border issues. For example, smaller economies may have difficulty agreeing on and/or funding cross-border power arrangements with their neighbors (see Section 14.4). Several studies have examined the use of roadmaps to identify options for low-carbon development (Amer and Daim, 2010), with some taking a regional focus. For example, a study by Doig and Adow (2011) examines options for low-carbon energy development across six SSA countries. More common are studies examining low-development roadmaps with a national focus, such as a recent study that explores four possible low-carbon development pathways for China (Wang and Watson, 2008).

Regional modelling exercises have also examined different mitigation pathways in the energy sector in different regions. For example, the Stanford Energy Modeling Forum (EMF)28, which focuses on mitigation pathways for Europe suggests that transformation pathways will involve a greater focus on a switch to bioenergy for the whole energy system and a considerable increase of wind energy in the power system until 2050 that catches up with nuclear, while solar PV is only of limited importance (Knopf et al., 2013). By contrast, in the Asian Modeling Exercise (AME) for Asia it will involve a greater switch to natural gas with carbon dioxide capture and storage (CCS) and solar (van Ruijven et al., 2012).

Studies that examine potentials for low-carbon development within different locations frequently focus on specific technologies and their opportunities in a specific context. For example, there are several studies on low-carbon technology potential in SSA that focus on biomass (Marrison and Larson, 1996; Hiemstra-van der Horst and Hovorka, 2009; Dasappa, 2011) and solar energy technologies (Wamukonya, 2007; Munzhedzi and Sebitosi, 2009; Zawilska and Brooks, 2011). However, other technologies have perhaps less clear regional advantages, including biofuels, which have been widely studied not just for use in Brazil or in Latin America (Goldemberg, 1998; Dantas, 2011; Lopes de Souza and Hasenclever, 2011) but also in South East Asia (focusing on Malaysia) (Lim and Teong, 2010) and in OECD countries (Mathews, 2007). Wind energy also has a wider geographic focus, with studies ranging from East and South Asia (Lema and Ruby, 2007; Lewis, 2007, 2011) to South America (Pueyo et al., 2011), and the Middle East (Gökçek and Genç, 2009; Keyhani et al., 2010; Ilkılıç et al., 2011). Examinations of geothermal energy and hydropower potential are likewise geographically diverse (Hepbasli and Ozgener, 2004; Alam

Zaigham et al., 2009; Kusre et al., 2010; Guzović et al., 2010; Kosnik, 2010; Fang and Deng, 2011).

Many developing regions are latecomers to large-scale energy production. While developed regions have sunk capital in irreversible investments in power supply, transport networks, and urban structures, many developing countries still need to do so. This creates a latecomer advantage, as developing countries will be able to use the new and more-efficient technologies that will be available when they make these investments. However, being a latecomer also implies that there are current energy shortages, a high shadow price on power, and an urgent need to expand capacity. Further delay in anticipation of future technical progress is particularly expensive (Collier and Venables, 2012b).

While the opportunities for switching to low-carbon development in different regions are circumscribed by capacity in poorer countries or lock-in effects in richer countries, there are low-cost options for reducing the carbon-intensity of the economies through the removal of energy subsidies and the introduction of energy taxes. Energy subsidy levels vary substantially by region (IEA, 2012; OECD, 2012; IMF, 2013). Pre-tax consumption subsidies compare the consumer price to a world price for the energy carrier, which may be due to direct price subsidies, subsidies to producers leading to lower prices, or low production costs for energy producers, relative to world market prices. Note that pre-tax figures therefore do not correspond to the actual fiscal outlays of countries to subsidize energy. In particular, for energy exporters, the domestic costs of production might be lower than the world market price and therefore a lower domestic price represents a lower fiscal outlay compared to an energy importer who pays world market prices (IEA, OECD, OPEC, and World Bank, 2010). Nevertheless, pre-tax figures represent the opportunity costs to these energy exporters (IEA, OPEC, OECD; and World Bank, 2011). An IMF policy paper (2013), reports that in MNA as well as EIT, pre-tax energy subsidies are very high as a share of GDP. Also in SAS, energy subsidies are substantial, and there are also some subsidies in LAM and SSA where they are concentrated among fuel exporters (IMF, 2013). Similar data on pre-tax subsidies is available from the International Energy Agency (IEA) for a reduced set of countries. These data confirm the regional distribution of pre-tax energy subsidies, particularly their high level in MNA and EIT (IEA, 2012c).

The OECD (2012) provides an inventory of various direct budgetary transfers and reported tax expenditures that support fossil fuel production or use in OECD countries. The OECD report finds that between 2005 and 2011, these incentives tended to benefit crude oil and other petroleum products (70 % in 2011) more than coal (12 %) and natural gas (18 %) in absolute terms (OECD, 2012).

Reducing energy subsidies would reduce the carbon-intensity of growth and save fiscal resources. A report prepared for the Group of Twenty Finance Ministers (G20) (IEA, OECD, OPEC, and World Bank, 2011) not only reports data on fossil fuel and other energy-support measures, but also draws some lessons on subsidy reform. It concludes that three of the specific challenges facing developing countries are strengthening social safety nets and improving targeting mechanisms for subsidies; informing the public and implementing social policy or compensatory measures; and implementing the reform in the context of broader energy sector reform (IEA, OECD, OPEC, and World Bank, 2011).This issue, as well as the political economy of fuel subsidies and fuel taxation, is discussed in more detail in Section 15.5.

14.3.3 Urbanization and development

14.3.3.1 Urbanization as a driver of regional emissions

Urbanization has been one of the most profound socioeconomic and demographic trends during the past decades, particularly in less-urbanized developed regions (UNDESA, 2010), see Section 12.2. Accompanying the changes in industrial structure and economic development, urbanization tends to increase fossil fuel consumption and CO_2 emissions at the global level (Jones, 1991; York et al., 2003; Cole and Neumayer, 2004; York, 2007; Liddle and Lung, 2010). Studies of the net impact of urbanization on energy consumption based on historical data suggest that—after controlling for industrialization, income growth and population density—a 1 % of increase in urbanization increases energy consumption per unit of GDP by 0.25 % (Parikh and Shukla, 1995) to 0.47 % (Jones, 1991), and increases carbon emissions per unit of energy use by 0.6 % to 0.75 % (Cole and Neumayer, 2004).

However, the impact of urbanization on energy use and carbon emissions differs remarkably across regions and development level (Poumanyvong and Kaneko, 2010; Martínez-Zarzoso and Maruotti, 2011; Poumanyvong et al., 2012). For instance, LAM has a similar urbanization level as NAM and WEU, but substantially lower per capita CO_2 emissions because of its lower-income level (World Bank, 2013b). In SSA, the per capita carbon emissions remained unchanged in the past four decades (JRC/PBL, 2013; IEA, 2012a), while the urbanization level of the region almost doubled (UNDESA, 2011). This is because in SSA the rapid urbanization was not accompanied by significant industrialization and economic growth, the so-called 'urbanization without growth' (Easterly, 1999; Haddad et al., 1999; Fay and Opal, 2000; Ravallion, 2002).

On the one hand, per capita energy use of developing countries is significantly lower than in developed countries (Figure 14.7 left panel). On the other hand, per capita energy use of cities in developing regions is usually higher than the national average, while the relationship is reversed in developed regions (Kennedy et al., 2009; Grübler et al., 2012). This is because in developing countries industrialization often happens through manufacturing in cities, while developed regions have mostly completed the industrialization process. Moreover, urban residents of developing regions usually have higher-income and energy-consumption levels than their rural counterparts (see Section 12.3.2 for a more-detailed discussion). This is particularly true in developing

Asia. In contrast, many cities in SSA and LAM have lower than national average per capita energy use because of the so-called 'urbanization of poverty' (Easterly, 1999; Haddad et al., 1999; Fay and Opal, 2000; Ravallion, 2002). Other studies reveal an inverted-U shape between urbanization and CO_2 emissions among countries of different economic development levels. One study suggests that the carbon emissions elasticity of urbanization is larger than 1 for the low-income group, 0.72 for the middle-income group, and negative (or zero) for the upper-income group of countries (Martínez-Zarzoso and Maruotti, 2011).

Per capita energy consumption in cities of developing countries is shown to be generally lower (Figure 14.7 left panel). At the same time, studies reveal that cities in developing regions have significantly higher energy intensity than cities in developed regions (Figure 14.7 right panel). Still, the majority of cities in both developed and developing countries (two-thirds in developed region and more than 60 % in developing regions) have lower than national average energy intensity. Important factors that contribute to the varying energy intensities across cities are the different patterns and forms of urban settlements (Glaeser and Kahn, 2010; Grübler and Fisk, 2012; see Section 12.3.2 for a detailed discussion). Comparative analyses indicate that United States cities consume 3.5 times more per capita energy in transportation than their European counterparts (Steemers, 2003) because the latter are five times as dense as the former and have significantly higher car ownership and average distance driven (Kahn, 2000). Suburbanization in the United States may also contribute to increasing residential fuel consumption and land-use change (Bento et al., 2005). See Section 12.4 for a more-detailed discussion on urban form as a driver for emissions.

14.3.3.2 Opportunities and barriers at the regional level for low-carbon development in urbanization

Urbanization has important implications for global and regional mitigation challenges and opportunities. Many developing regions are projected to become more urbanized, and future global population growth will almost entirely occur in cities of developing regions (IIASA, 2009; UNDESA, 2011) (see Section 12.1). Due to their early stage of urbanization and industrialization, many SSA and Asian countries will inevitably increase energy consumption and carbon emissions, which may become a barrier for these regions to achieve mitigation goals. Assuming that the historical effect of urbanization on energy use and carbon emissions remains unchanged, the doubling of current urbanization levels by 2050 in many low-urbanized developing countries (such as India) implies 10–20 % more energy consumption and 20–25 % more

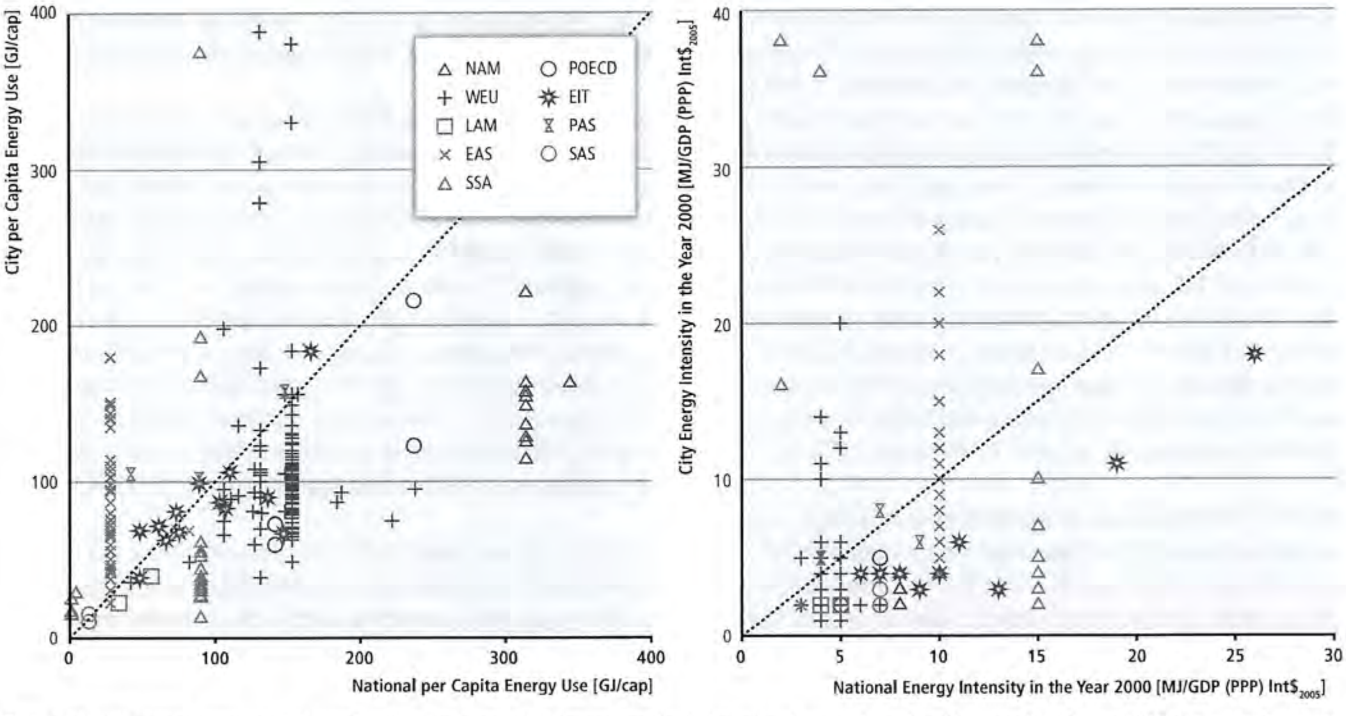

Figure 14.7 | Per capita energy use (left panel), and energy intensity in cities compared with the national average by regions (right panel), in the year 2000. The per capita energy use of cities, represented by a dot above the green line, is higher than the national average; otherwise, is lower than the national average. Data sources: (1) city energy data is from Grübler et al. (2012); (2) national energy data is from IEA energy balances (IEA, 2010d).

CO_2 emissions (Jones, 1991). On the other hand, because they are still at an early stage of urbanization and face large uncertainty in future urban development trends (O'Neill et al., 2012), these regions have great opportunities to develop energy-saving and resource-efficient urban settlements. For instance, if the African and Asian population increasingly grow into compact cities, rather than sprawl suburban areas, these regions have great potential to reduce energy intensity while proceeding urbanization.

An integrated and dynamic analysis reveals that if the world follows different socioeconomic, demographic, and technological pathways, urbanization may result in very different emission levels (O'Neill et al., 2010). The study compares the net contributions of urbanization to total emissions under the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios SRES A2 and B2 scenarios (Nakicenovic and Swart, 2000). Under the A2 scenario, the world is assumed to be heterogeneous, with fast population growth, slow technological changes and economic growth. If all regions follow the urbanization trends projected by the United Nations (UN) Urbanization Prospects (UNDESA, 2006), extrapolated up to 2100 by Grübler et al. (2007), the global total carbon emissions in 2100 increase by 3.7 GtC per year due to the impacts of urbanization growth (Figure 14.8). In a B2 world, which assumes local solutions to economic, social, and environmental sustainability issues, with continuous population growth and intermediate economic development, and faster improvement in environmentally friendly technology, the same urbanization trend generates a much smaller impact (1.1 GtC per year in 2100) on global total carbon emissions. Considering the differences in total emissions under different scenarios, the relative change in emissions due to urbanization under B2 scenarios (12 %) is also significantly lower than under A2 scenarios (15 %). Comparing the impacts in different regions, the 1.1 GtC per year more global total emissions due to urbanization under the B2 scenario is mostly due to East Asia, SAS and other less urbanized developing regions. Moreover, the relative changes in regional emissions due to urbanization are also very significant in EAS (27 %), SAS (24 %), and SSA, MNA, and PAS (15 %), considerably higher than in other regions (< 10 %). Therefore, a growing urban population in developing regions will inevitably pose significant challenges to global mitigation. Moreover, it also has important implications for adaption. However, urban climate change mitigation policies and strategies can have important co-benefits by reducing the urban heat island effect (see Section 12.8.4).

14.3.4 Consumption and production patterns in the context of development

As discussed in Section 5.4, the difference between production and consumption accounting methods are that the former identifies the place where emissions occur and the latter investigates emissions discharged for the goods and services consumed within a certain geographic area.

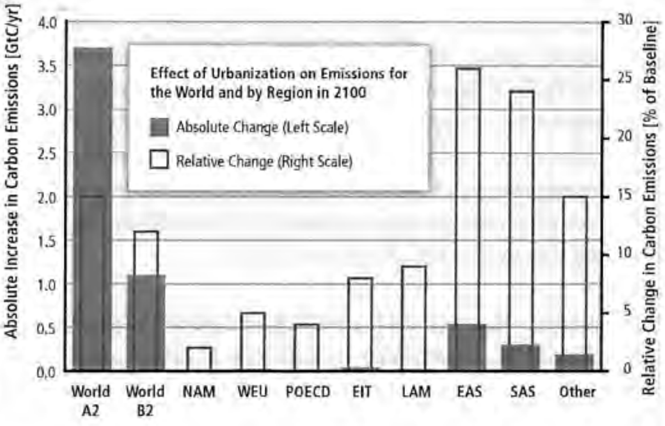

Figure 14.8 | Impact of urbanization on carbon emissions in 2100 for the world under SRES A2 and B2 scenarios and by regions only under SRES B2 scenario. This figure is based on O'Neill et al. (2010), data for NAM from the United States, POECD from Japan, EIT from Russia, LAM from Mexico and Brazil, EAS from China, SAS from India, and other from Indonesia. The urbanization scenario follows UN Urbanization Prospects (UNDESA, 2006), extrapolated up to 2100 by Grübler et al. (2007). The effect of urbanization on emissions for the world and by region is shown in absolute and relative terms.

14.3.4.1 Consumption as a driver of regional emissions growth

Researchers have argued that the consumption-based accounting method (Peters, 2008) provides a better understanding of the common but differentiated responsibility between regions in different economic development stages (Peters and Hertwich, 2008; Davis and Caldeira, 2010; Peters et al., 2011; Steinberger et al., 2012; Lenzen et al., 2012). Consequently, much research effort has been focused on estimating (1) country-level CO_2 emissions from both production and consumption perspectives (Kondo et al., 1998; Lenzen, 1998; Peters and Hertwich, 2006; Weber and Matthews, 2007; Peters et al., 2007; Nansai et al., 2008; Weber et al., 2008; Guan et al., 2009; Baiocchi and Minx, 2010); and (2) the magnitude and importance of international trade in transferring emissions between regions (Davis and Caldeira, 2010; Peters et al., 2012b; Wiebe et al., 2012). Reviews of modelling international emission transfers are provided by Wiedmann et al. (2007), Wiedmann (2009), Peters et al. (2012a), and Tukker and Dietzenbacher (2013).

During the period 1990–2008, the consumption emissions of EAS and SAS grew by almost 5–6 % annually from 2.5 to 6.5 $GtCO_2$ and from 0.8 to 2.0 $GtCO_2$, respectively. The other developing regions observed a steadier growth rate in consumption emissions of 1–2.5 % per year. This growth is largely driven by flourishing global trade, especially trade between developing countries. The transfer of emissions via traded products between developing countries grew at 21.5 % annually during 1990–2008 (Peters et al., 2011).

While per capita consumption emissions in developed regions are far larger than the average level of developing countries, many high-income households in large developing countries (e.g., China and India) are similar to those in developed regions (Feng et al., 2009;

Hubacek et al., 2009). Along with the rapid economic developments and lifestyle changes in Asia, average consumption emissions have increased 72 %, 74 %, and 120 % in PAS, SAS, and EAS, respectively, and the growth is projected to be further accelerating (Hubacek et al., 2007; Guan et al., 2008). Per capita consumption emissions in LDCs have changed relatively little, due to minimal improvements in lifestyle. In fact, per capita consumption emission in SSA has slightly decreased from 0.63 tCO_2 to 0.57 tCO_2 (Peters et al., 2011).

Methodologies, datasets, and modelling techniques vary between studies, producing uncertainties of estimates of consumption-based emissions and measures of emissions embodied in trade. These issues and associated uncertainties in the estimates are addressed in detail in Section 5.2.3.6.

14.3.4.2 Embodied emission transfers between world regions

Figure 14.9 illustrates the net CO_2 emission transfer between 10 world regions in 2007 using the Multi-Regional Input-Output Analysis (MRIO) method and economic and emissions (from fossil fuel combustion) data derived from the Global Trade Analysis Project (GTAP) Version 8. Focusing on production-related emissions, the left-hand side of Figure 14.9 explains the magnitudes and regional final consumption destinations of production emissions embodied in exports. Percentage values represent total exported production emissions as a share of total production emissions for each regional economy. Now, focusing on consumption-related emissions, the right-hand side of Figure 14.9 illustrates the magnitudes and origins of production emissions embodied

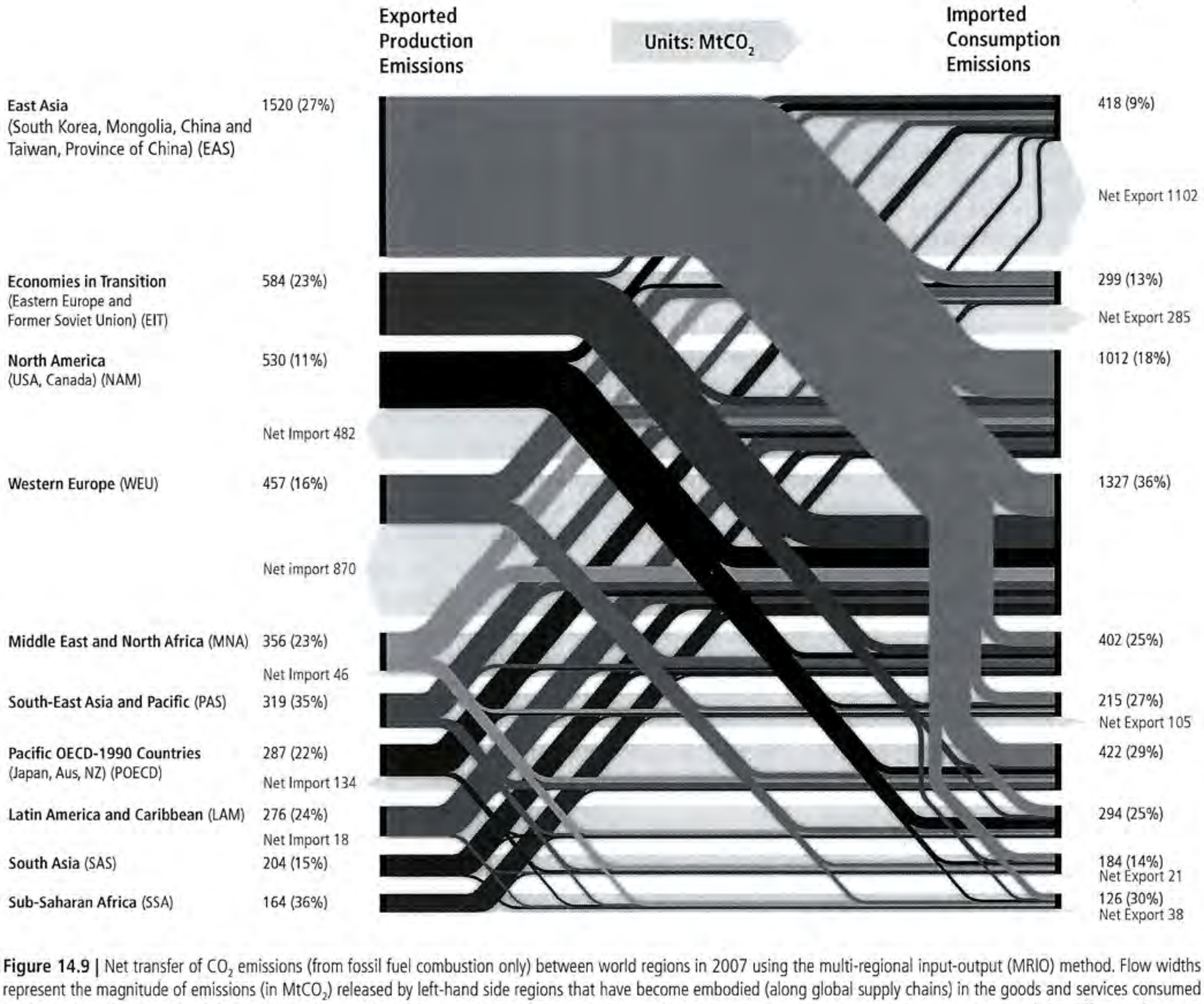

Figure 14.9 | Net transfer of CO_2 emissions (from fossil fuel combustion only) between world regions in 2007 using the multi-regional input-output (MRIO) method. Flow widths represent the magnitude of emissions (in $MtCO_2$) released by left-hand side regions that have become embodied (along global supply chains) in the goods and services consumed by the regions listed on the right-hand side. Figures for total exported production emissions and total imported consumption emissions are given, and the difference between these two measures is shown as either a net export or net import emissions transfer. Percentages on the left-hand side indicate the total exported emissions as percentage of total industry production emissions, while the percentage figures on the right-hand side indicate total imported emissions as percentage of the total industry consumption emissions. Data reports global CO_2 emissions of 26.5 $GtCO_2$ in 2007 (22.8 Gt from industry and a further 3.7 Gt from residential sources). The analysis is performed using the MRIO model and emissions data derived from GTAP Version 8 database, as explained and presented by Andrew and Peters (2013) .

in regional final consumption imports. The associated percentages represent total imported consumption emissions as a share of total consumption emissions. The difference between exported production emissions and imported consumption emissions are highlighted to represent the net emission transfer between regions.

For example, EAS was the largest net emission exporter (1102 $MtCO_2$) in 2007, with total exported production emissions (1520 $MtCO_2$) accounting for 27 % of total production emissions (5692 $MtCO_2$), while imported consumption emissions (418 $MtCO_2$) accounted for less than 10 % of total consumption emissions (4590 $MtCO_2$). OECD countries are the major destinations of export products in EAS. For example, NAM and WEU account for 34 % and 29 % of EAS's total exported production emissions, respectively. In China, the largest economy in EAS, the share of embodied emissions in exports to total annual emissions have increased from 12 % in 1987 to 21 % in 2002, further to 33 % in 2005 (Weber et al., 2008), and settled around 30 % in 2007 (Minx et al., 2011). Producing exports have driven half of emissions growth in China during 2002–2005 (Guan et al., 2009). Over 60 % of embodied emissions in Chinese exports in 2005, mainly formed by electronics, metal products, textiles, and chemical products, are transferred to developed countries (Weber et al., 2008). Based on the 2002 dataset, Dietzenbacher et al. (2012) argue that the embodied emissions in China may be over-estimated by more than 60 % if the distinction between processing exports and normal exports is not made. In contrast, WEU was the largest net emissions importer (870 $MtCO_2$) in 2007, with total exported production emissions (457 $MtCO_2$) accounting for 16 % of total production emissions, while imported consumption emissions (1327 $MtCO_2$) accounted for 36 % of total consumption emissions.

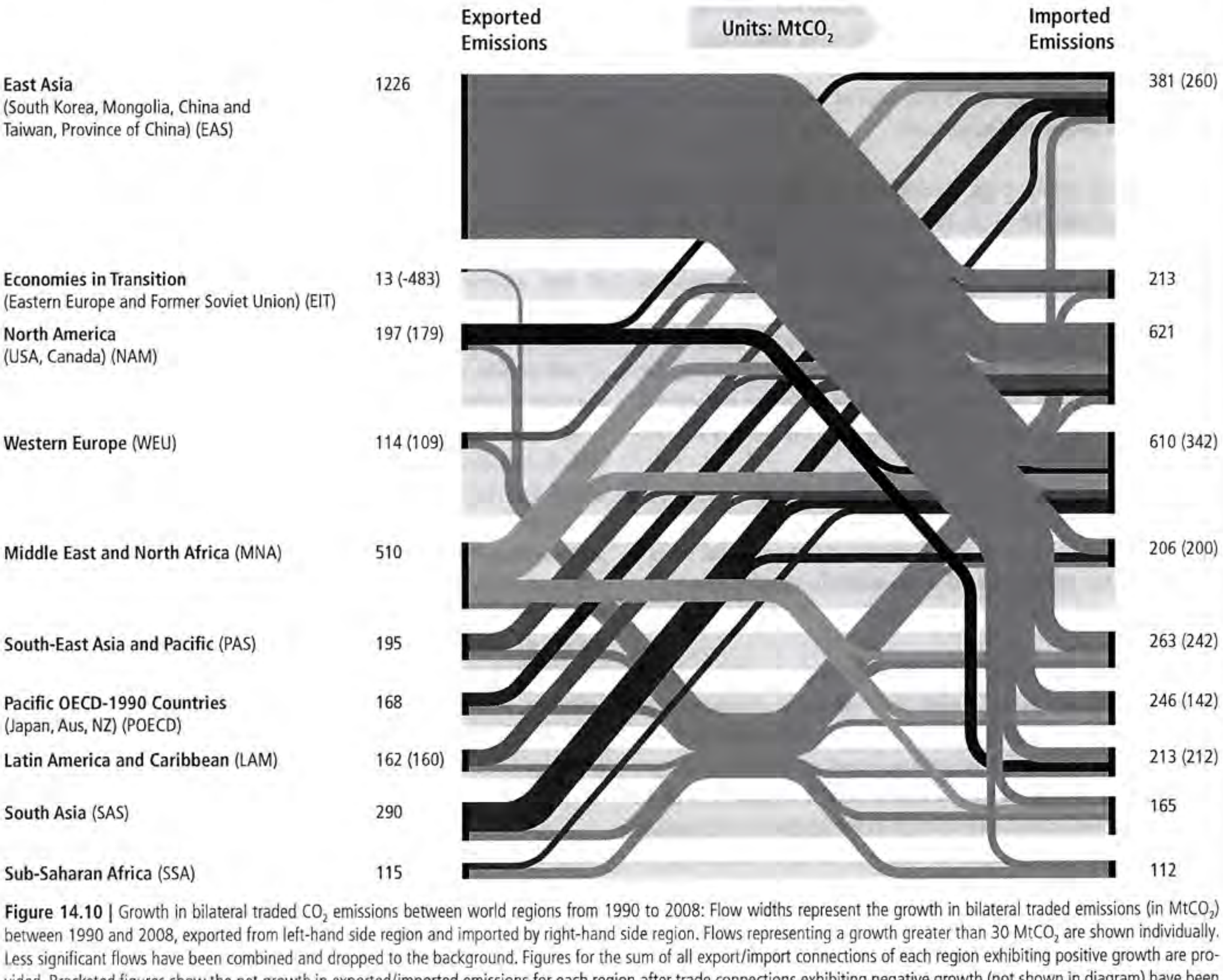

Figure 14.10 | Growth in bilateral traded CO_2 emissions between world regions from 1990 to 2008: Flow widths represent the growth in bilateral traded emissions (in $MtCO_2$) between 1990 and 2008, exported from left-hand side region and imported by right-hand side region. Flows representing a growth greater than 30 $MtCO_2$ are shown individually. Less significant flows have been combined and dropped to the background. Figures for the sum of all export/import connections of each region exhibiting positive growth are provided. Bracketed figures show the net growth in exported/imported emissions for each region after trade connections exhibiting negative growth (not shown in diagram) have been accounted for. Trade connections exhibiting significant negative growth include EIT to WEU (–267 $MtCO_2$), to EAS (–121 $MtCO_2$), to POECD (–80 $MtCO_2$), and to other regions (–15 $MtCO_2$). Total growth in inter-region traded emissions between 1990 and 2008 is found to be 2.5 $GtCO_2$ (this does not include intra-region traded emissions, e.g., between the United States and Canada). The analysis uses the emissions embodied in the bilateral trade (EEBT) approach. The input-output dataset, trade statistics, and emissions data derived from Peters et al. (2011).

Figure 14.10 demonstrates (using the emissions embodied in the bilateral trade (EEBT) method) that the embodied CO_2 emissions in international bilateral trade between the 10 world regions have grown by 2.5 Gt during 1990–2008. Considering exports, half of global growth is accounted for by exports from EAS (1226 $MtCO_2$), followed by exports from MNA and SAS with 20 % (510 $MtCO_2$) and 12 % (290 $MtCO_2$) of global growth, respectively. The NAM region has increased imports by 621 $MtCO_2$, with the three Asian regions providing 75 % of the increase. Although WEU observed positive import flows increase by 610 $MtCO_2$, it also saw a decrease of 268 $MtCO_2$ in some bilateral trade connections, primarily from EIT (257 $MtCO_2$).

Many developing country regions have also observed considerable increases in imported emissions during 1990–2008. The total growth in developing countries accounts for 48 % of the global total. For example, EAS, PAS, and LAM have increased their imported emissions by 260 $MtCO_2$, 242 $MtCO_2$, and 212 $MtCO_2$, respectively. Over half of the growth in EAS and LAM has been facilitated via trade with other developing country regions. While trade with other developing country regions has contributed over 90 % of increase in imported emissions to PAS and SAS. These results are indicative of further growth of emissions transfers within the Global South.

Recent research efforts have investigated the embodied emissions at the sectoral level (Liu et al., 2012a; b; Lindner et al., 2013; Vetőné Mózner, 2013) and emission transfers between industrial sectors within or across country borders (Sinden et al., 2011; Homma et al., 2012). Skelton et al. (2011) calculate total industrial sector production and consumption attributions to map the embodied emissions delivered from production to consumption end through the global production systems. They find that Western Europe tends to be a net importer of emissions in all sectors but particularly so in the primary and secondary sectors.

14.3.4.3 Opportunities and barriers at the regional level for low-carbon development in consumption patterns

The growing discrepancy between production- and consumption-based emissions discussed above, is most likely related to changing structures of international trade, although carbon leakage associated with efforts to curb emissions in industrialized countries can play a role here as well. It is also related to the fact that demand for emission-intensive goods has not been reduced by as much as the production of emission-intensive goods in industrialized countries. However, as identical goods can be produced with different carbon content in different countries, substitution processes need to be taken into account to assess how global emissions would change in reaction to a change of imported emissions (Jakob and Marschinski, 2013).

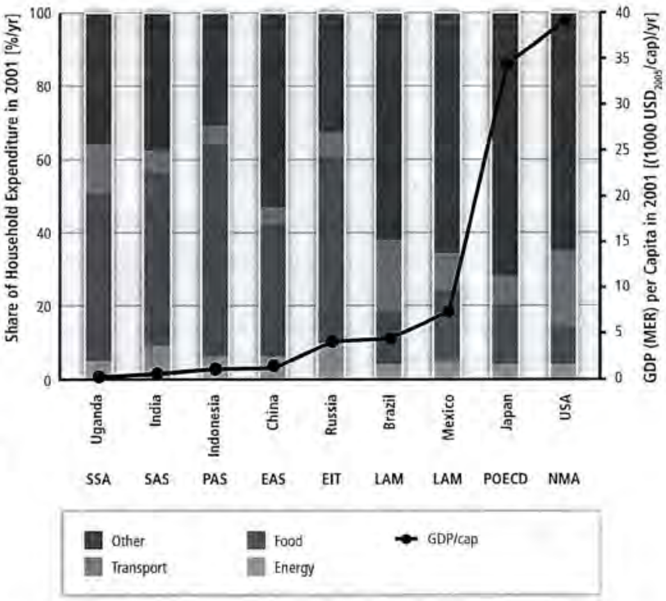

Figure 14.11 | Expenditure share of households and per capita income, 2001. Household expenditure is based on Zigova et al. (2009) and O'Neill et al. (2010). Per capita GDP is from World Bank Development Indicators (World Bank, 2011).

Climate change analysis and policies pay increasing attention to consumption (Nakicenovic and Swart, 2000; Michaelis, 2003). Analysis of household survey data from different regions shows that with improving income levels, households spend an increasing proportion of their income on energy-intensive goods (Figure 14.11) (O'Neill et al., 2010). Households in SSA and PAS have much lower income levels than more-developed regions, and spend a much larger share of their smaller income on food and other basic needs. Households in the more-developed PAS and NAM, on the other hand, spend a larger share of their income on transportation, recreation, etc. With economic growth, households in less-developed regions are expected to 'westernize' their lifestyles, which will substantially increase per capita and global total carbon emissions (Stern, 2006). Thus changing lifestyles and consumption patterns (using taxes, subsidies, regulation, information, and other tools) can be an important policy option for reducing the emission-intensity of consumption patterns (Barrett et al., 2013). To the extent that carbon leakage (see Section 5.4.1) contributes to this increasing discrepancy between production and consumption-based emissions, border-tax adjustments or other trade measures (Ismer and Neuhoff, 2007) can be an option in the absence of a global agreement on mitigation. This is discussed in more detail below.

14.3.5 Agriculture, forestry, and other land-use options for mitigation

Emission of GHGs in the Agriculture, Forestry, and Other Land-Use (AFOLU) options sector increased by 20 % from 9.3 $GtCO_2eq$/yr in 1970 to 11.2 $GtCO_2eq$/yr (Figure 5.18) in 2010, and contributed about 22 % to the global total in 2010 (JRC/PBL, 2013; IEA, 2012a). Over this period, the increase in the Agriculture sub-sector was 35 %, from

$4.2\ GtCO_2eq/yr$ to $5.7\ GtCO_2eq/yr$, and in the Forestry and Other Land Use (FOLU) sub-sector it rose from $5.1\ GtCO_2eq/yr$ to $5.5\ GtCO_2eq/yr$ (Section 5.3.5.4; see also Sections 11.2 and 11.3 for more-detailed sector-specific values). The AFOLU emissions have been relatively more significant in non-OECD-1990 regions, dominating, for example, total GHG emissions from Middle East and Africa (MAF) and LAM regions[2] (see Section 5.3.5.4 and Figure 5.6, Sections 11.2 and 11.4, Figures 11.5 and 11.7). In the LDCs, more than 90 % of the GHG emissions from 1970–2010 were generated by AFOLU (Figure 5.20), and emissions grew by 0.6 % per year over the past four decades (Box 5.3).

As outlined in Section 11.2.3, global FOLU CO_2 flux estimates are based on a wide range of data sources, and include different processes, definitions, and different approaches to calculating emissions; this leads to a large range across global FOLU flux estimates (Figures 11.6 and 11.7). For the period 1750–2011, cumulative CO_2 fluxes have been estimated at 660 (± 293) $GtCO_2$ based on the model approach of Houghton (2003, updated in Houghton, 2012), while annual emissions averaged $3.8 \pm 2.9\ GtCO_2/yr$ in 2000 to 2009 (see Table 11.1). In Chapter 11 of this assessment, Figure 11.7 shows the regional distribution of FOLU CO_2 over the last four decades from a range of estimates. For 2000 to 2009, FOLU emissions were greatest in ASIA (1.1 $GtCO_2/yr$) and LAM (1.2 $GtCO_2/yr$) compared to MAF (0.56 $GtCO_2/yr$), OECD (0.21 $GtCO_2/yr$), and EIT (0.12 $GtCO_2/yr$) (Houghton, 2003; Pongratz et al., 2009; Hurtt et al., 2011; Pan et al., 2011; Lawrence et al., 2012); these are means across seven estimates, noting that in OECD and EIT some estimates indicate net emissions, while others indicate a net sink of CO_2 due to FOLU. Emissions were predominantly due to deforestation for expansion of agriculture, and agricultural production (crops and livestock), with net sinks in some regions due to afforestation. There have been decreases in FOLU-related emissions in most regions since the 1980s, particular ASIA and LAM where rates of deforestation have decreased (FAOSTAT, 2013; Klein Goldewijk et al., 2011; Hurtt et al., 2011).

In the agriculture sub-sector 60 % of GHG emissions in 2010 were methane, dominated by enteric fermentation and rice cultivation (see Sections 5.3.5.4, 11.2.2, Figure 11.2). Nitrous oxide contributed 38 % to agricultural GHG emissions, mainly from application of fertilizer and manure. Between 1970 and 2010 emissions of methane increased by 18 % whereas emission of nitrous oxide increased by 73 %. The ASIA region contributed most to global GHG emissions from agriculture, particularly for rice cultivation, while the EIT region contributed least (see Figure 11.5). Due to the projected increases in food production by 2030, which drive short-term land conversion, the contribution of developing countries to future GHG emissions is expected to be very significant (Box 11.6).

Trajectories from 2006 to 2100 of the four Representative Concentration Pathways (RCPs) (see Table 6.2 in Section 6.3.2.1; Meinshausen et al., 2011) show different combinations of land cover change (cropland and grazing land) and wood harvest as developed by four integrated assessment models and harmonized in the Hurtt et al. (2011) dataset. These results in regional emissions as illustrated by Figure 14.12 show the results from one Earth System Model (Lawrence et al., 2012). However, even using a common land cover change dataset, resulting forest cover, net CO_2 flux, and climate change vary substantially across different Earth System Models (Brovkin et al., 2013). Furthermore, as shown by Popp et al. (2013) projections regarding regional land cover changes and related emissions can vary substantially across different integrated models for the same concentration scenario (see Figure 11.19).

Mitigation options in the AFOLU sector mainly focus on reducing GHG emissions, increasing carbon sequestration, or using biomass to

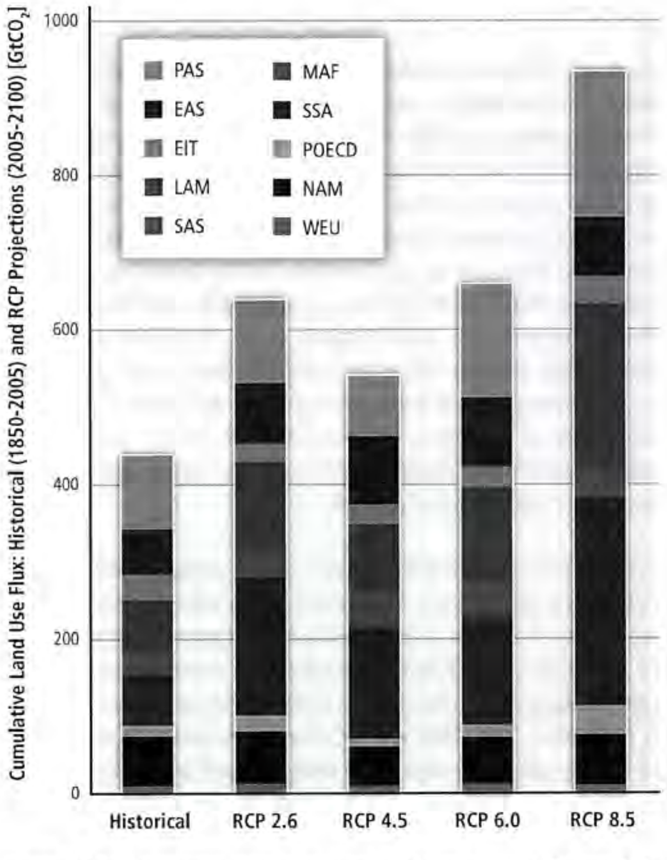

Figure 14.12 | Cumulative regional emissions of CO_2 from AFOLU. The four RCPs developed for this Assessment Report explore the implications of a broad range of future GHG concentration trajectories, resulting in a range of radiative forcing values in the year 2100: 2.6, 4.5, 6.0, and 8.5 Watts per square meter (see Table 6.2 in Section 6.3.2.1; Meinshausen et al., 2011). Past and future land cover change and wood harvest data was from Hurtt et al. (2011). The historical period is from 1850 to 2005, the RCPs cover the period from 2005 to 2100. This figure shows results running the scenarios in the Community Climate System Model (CCSM4) (Lawrence et al., 2012) as illustrative of one of several Earth System Model results presented in the IPCC Working Group I Report.

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[2] These belong to the so called five RC5 regions, which include ASIA, OECD-1990, LAM, MAF, and Economies in Transition (EIT) (see Annex II.2). The ten RC10 regions (see also Annex II.2) used in this chapter further disaggregate OECD-1990 (WEU, NAM, POECD), MAF (MNA and SSA), and ASIA (EAS, SAS, PAS).

generate energy to displace fossil fuels (Table 11.2). As such, potential activities involve reducing deforestation, increasing forest cover, agroforestry, agriculture, and livestock management, and the production of sustainable renewable biomass energy (Sathaye et al., 2005; Smith et al., 2013) (see Box 11.6). Since development conditions affect the possibilities for mitigation and leapfrogging, in business-as-usual conditions, the current level of emission patterns is to persist and intensify (Reilly et al., 2001; Parry et al., 2004; Lobell et al., 2008; Iglesias et al., 2011a). This poses challenges in terms of these regions' vulnerability to climate change, their prospects of mitigation actions and low-carbon development from agriculture and land-use changes. The WGII report shows that without adaptation, increases in local temperature of more than 1 °C above pre-industrial are projected to have negative effects on yields for the major crops (wheat, rice, and maize) in both tropical and temperate regions, although individual locations may benefit (see WGII 7.4). However, the quantification of adaptation co-benefits and risks associated with specific mitigation options is still in an emerging state (see Section 6.3.3 and 6.6) and, as referred to in Section 11.5.5, subject to technological but also societal constraints.

Moreover, linking land productivity to an increase in water irrigation demand in the 2080s to maintain similar current food production, offers a scenario of a high-risk from climate change, especially for regions such as South East Asia and Africa. These regions could benefit from more technology and investment, especially at the farm level, in the means of access to irrigation for food production to decrease the impacts of climate change (Iglesias et al., 2011b). 'Bottom-up' regional strategies to merge market forces, domestic policies, and finance have been recommended for LAM (Nepstad et al., 2013). Region-specific strategies are needed to allow for flexibility in the face of impacts and to create synergies with development policies that enhance adaptive lower levels of risk. This is the case for NAM, Western and Eastern Europe, and POECD, but also South East Asia, Central America, and Central Africa (Iglesias et al., 2011a).

Studies reveal large differences in the regional mitigation potential as well as clear differences in the ranking of the most-effective options (see Section 11.6.3). For a range of different mitigation scenarios across the RC5 regions and all AFOLU measures, ASIA shows the largest economic mitigation potential, both in forestry and agriculture, followed by LAM, OECD-1990, MAF, and EIT. Reduced deforestation dominates the forestry mitigation potential in LAM and MAF, but shows very little potential in OECD-1990 and EIT. Forest management, followed by afforestation, dominate in OECD-1990, EIT, and ASIA (see Figure 11.19). Among agricultural measures, almost all of the global potential in rice management practices is in ASIA, and the large potential for restoration of organic soils also in ASIA (due to cultivated South East Asian peats), and OECD-1990 (due to cultivated Northern peatlands).

Although climate and non-climate policies have been key to foster opportunities for adaptation and mitigation regarding forestry and agriculture, the above-mentioned scenarios imply very different abilities to reduce emissions from land-use change and forestry in different regions, with the RCP 4.5 implying the most ambitious reductions. Reducing the gap between technical potential and realized mitigation requires, in addition to market-based trading schemes, the elimination of barriers to implementation, including climate and non-climate policy, and institutional, social, educational, and economic constraints (Smith et al., 2008). Opportunities for cooperation schemes arise at the regional level as, for instance, combining reducing emissions from deforestation and degradation (REDD)+ and market transformation, which could potentially mitigate climate change impacts by linking biodiversity, regional development and cooperation favouring conservation (Nepstad et al., 2013), or river basin management planning (Cooper et al., 2008; González-Zeas et al., 2012).

14.3.6 Technology transfer, low-carbon development, and opportunities for leapfrogging

The notion of 'leapfrogging' has particular resonance in climate change mitigation. It suggests that developing countries might be able to follow more sustainable, low-carbon development pathways and avoid the more emissions-intensive stages of development that were previously experienced by industrialized nations (Goldemberg, 1998; Davison et al., 2000; Lee and Kim, 2001; Perkins, 2003; Gallagher, 2006; Ockwell et al., 2008; Walz, 2010; Watson and Sauter, 2011; Doig and Adow, 2011). Other forms of technological change that are more gradual than leapfrogging include the adoption of incrementally cleaner or more energy-efficient technologies that are commercially available (Gallagher, 2006).The evidence for whether such low-carbon technology transitions can or have already occurred, as well as specific models for low-carbon development, have been increasingly addressed in the literature reviewed in this section.

Most of the energy-leapfrogging literature deals with how latecomer countries can catch up with the energy-producing or consuming technologies of industrialized countries (Goldemberg, 1998; Perkins, 2003; Unruh and Carrillo-Hermosilla, 2006; Watson and Sauter, 2011; Lewis, 2012). Case studies of successful leapfrogging have shown that both the build-up of internal knowledge within a country or industry and the access to external knowledge are crucial (Lee and Kim, 2001; Lewis, 2007, 2011; Watson and Sauter, 2011). The increasing specialization in global markets can make it increasingly difficult for developing countries to gain access to external knowledge (Watson and Sauter, 2011). Other studies have identified clear limits to leapfrogging, for example, due to barriers in introducing advanced energy technologies in developing countries where technological capabilities to produce or integrate the technologies may be deficient (Gallagher, 2006).

14.3.6.1 Examining low-carbon leapfrogging across and within regions

The strategies used by countries to leapfrog exhibit clear regional differences. Many cases of technological leapfrogging have been documented in emerging Asia, including the Korean steel (D'Costa, 1994) and automobile industries (Lee, 2005; Yoon, 2009), and the wind power industries in China and India (Lema and Ruby, 2007; Lewis, 2007, 2011, 2012; Ru et al., 2012). Within Latin America, much attention has been focused on leapfrogging in transportation fuels, and specifically the Brazilian ethanol program (Goldemberg, 1998; Dantas, 2011; Souza and Hasenclever, 2011).

Absorptive capacity, i.e., the ability to adopt, manage, and develop new technologies, has been identified in the literature as a core condition for successful leapfrogging (Katz, 1987; Lall, 1987, 1998; Kim, 1998; Lee and Kim, 2001; Watson and Sauter, 2011). While difficult to measure, absorptive capacity includes technological capabilities, knowledge, and skills. It is therefore useful to examine regional differences across such technological capabilities, using metrics such as the number of researchers within a country, and total research and development (R&D) invested. These metrics are investigated on a national and regional basis in Figure 14.13 along with total CO_2 emissions from energy use.

14.3.6.2 Regional approaches to promote technologies for low-carbon development

The appropriateness of different low-carbon development pathways relies on factors that may vary substantially by region, including the nature of technologies and their appropriateness within different regions, the institutional architectures and related barriers and incentives, and the needs of different parts of society within and across

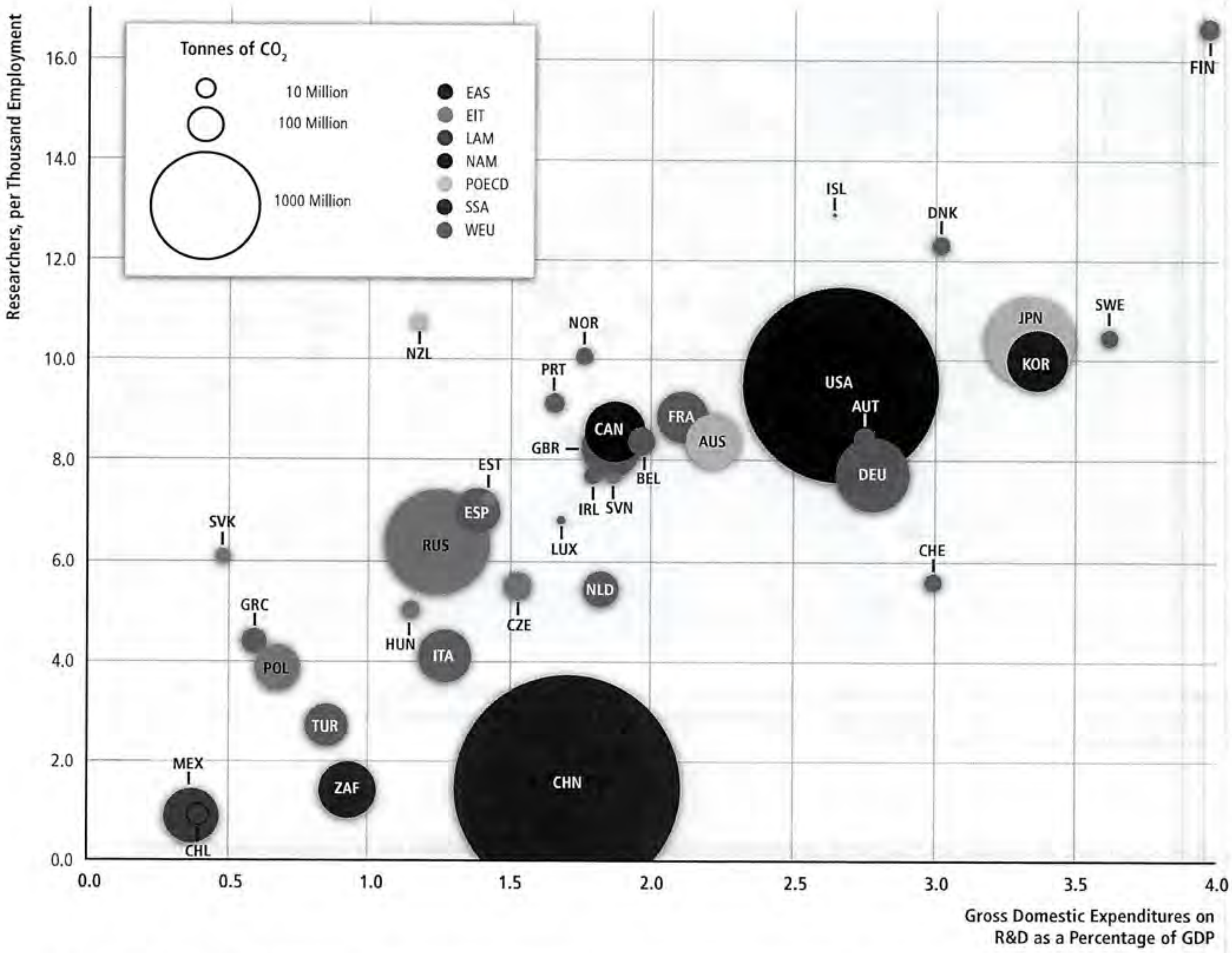

Figure 14.13 | Emissions contribution and innovative capacity: regional comparison. Source: Data on researchers and R&D expenditures as percentage of GDP from the OECD Main Science and Technology Indicators Database (OECD, 2011b); CO_2 from fossil fuels are for 2009 (IEA, 2011).

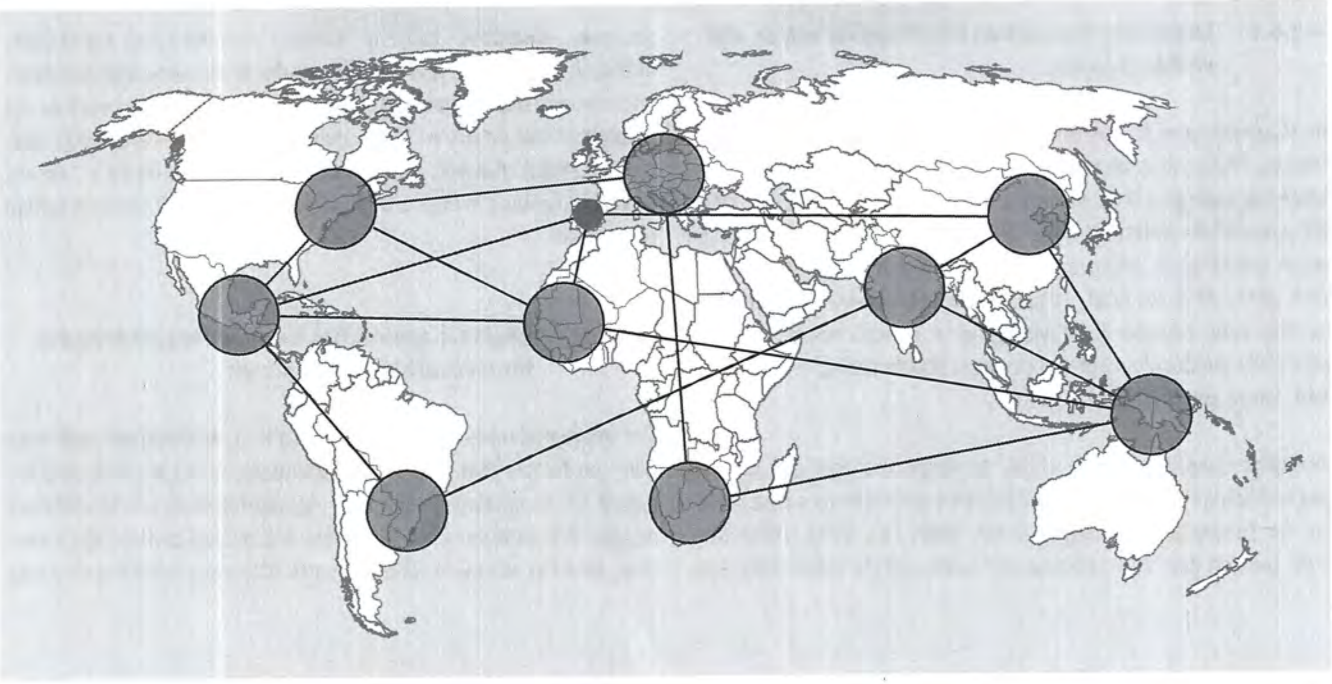

Figure 14.14 | Options for regionally coordinated climate technology networks. Upper map illustrates a network of climate technology research, development, and demonstration (RD&D) centers (large circles) with a small secretariat (small circle); lower map illustrates a network of climate technology RD&D centers with national hubs (red dots) and regional centers (yellow shapes). Source: Cochran et al. (2010).

regions. As a result, an appropriate low-carbon development pathway for a rapidly emerging economy in EAS may not be appropriate for countries in PAS or SSA (Ockwell et al., 2008). Low-carbon development pathways could also be influenced by climatic or ecological considerations, as well as renewable resource endowments (Gan and Smith, 2011).

Regional institutions for low-carbon development

Many studies propose that regions could be a basis for establishing low-carbon technology innovation and diffusion centres (Carbon Trust, 2008). Such centres could "enhance local and regional engagement with global technological developments" and "catalyze domestic capacity to develop, adapt and diffuse beneficial innovations" (Carbon

Trust, 2008). In a report prepared for the United Nations Environment Program (UNEP) by the National Renewable Energy Laboratory (NREL) and the Energy Research Center of the Netherlands (ECN), several options for structuring climate technology centres and networks were presented that focus on establishing regionally based, linked networks, as illustrated in Figure 14.14 (Cochran et al., 2010). A Climate Technology Center and Network (CTCN) was formally established by the United Nations Framework Convention on Climate Change (UNFCCC) at the Conference of Parties (COP) 17 as part of the Cancun Agreements. The CTCN, confirmed during COP 18 in Doha, is jointly managed by UNEP and the United Nations Industrial Development Organization (UNIDO), an advisory board, and 11 regionally based technology institutes serving as the CTCN consortium (UNEP Risoe Centre, 2013). The structure of the CTCN is therefore similar to the one illustrated in the left map in Figure 14.14.

14.3.7 Investment and finance, including the role of public and private sectors and public private partnerships

Since the signature of the UNFCCC in 1992, public finance streams have been allocated for climate change mitigation and adaptation in developing countries, e.g., through the Global Environment Facility (GEF) and the Climate Investment Funds of the World Bank, but also through bilateral flows (for a discussion of existing and proposed public climate finance instruments, see Chapter 16). Moreover, since the setup of the pilot phase for Activities Implemented Jointly in 1995 and the operationalization of the Clean Development Mechanism (CDM) and Joint Implementation (JI) from 2001 onwards, private finance has flown into mitigation projects abroad (for an assessment of these mechanisms, see Section 13.13.1). In this section, regional differences are assessed in use of public finance instruments and private finance triggered by market mechanisms.

14.3.7.1 Participation in climate-specific policy instruments related to financing

The CDM has developed a distinct pattern of regional clustering of projects and buyers of emission credits. Projects are concentrated in EAS, SAS, and LAM. PAS has a lower level of participation, while EIT, MNA, and SSA are lagging behind. Credit buyers are concentrated in WEU (see Figure 14.15 for project volumes). This pattern has been relatively stable since 2006, although in 2011 and 2012 the distribution has become more balanced in terms of volumes.

The reasons for the skewed regional concentration of CDM projects have been thoroughly researched. Jung (2006) assesses host country attractiveness through a cluster analysis, by looking at mitigation potential, institutional CDM capacity, and general investment climate. Jung's prediction that China, India, Brazil, Mexico, Indonesia, and Thailand would dominate was fully vindicated, and only Argentina and South Africa did not perform as well as expected. Oleschak and Springer (2007) evaluate host country risk according to the Kyoto-related institutional environment, the general regulatory environment, and the economic environment, and derive similar conclusions. Castro and Michaelowa (2010) assess grey literature on host country attractiveness and find that even discounting of CDM credits from advanced developing countries would not be sufficient to bring more projects to low-income countries. Okubo and Michaelowa (2010) find that capacity building is a necessary but not sufficient condition for successful implementation of CDM projects. Van der Gaast el al. (2009) discusses how technology transfer could contribute to a more equitable distribution of projects.

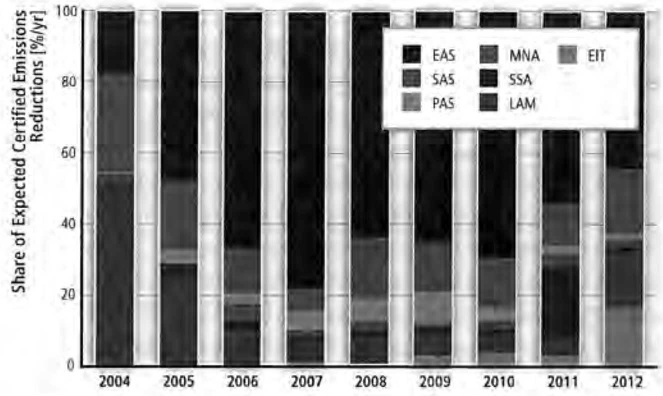

Figure 14.15 | Regional distribution of pre-2013 credit volumes for annual CDM project cohorts. Raw data source: UNEP Risoe Centre (2013).

For CDM programmes of activities that allow bundling an unlimited number of projects, the distribution differs markedly. According to the UNEP Riso Centre (2013), the SSA's share is 10 times higher than for ordinary CDM projects, while EAS and SAS's share are one-third lower. LAM region's share remains the same. The reason for this more-balanced distribution is the higher attractiveness of small-scale projects in a low-income context (Hayashi et al., 2010). However, high fixed-transaction costs of the CDM project cycle are a significant barrier for small-scale projects (Michaelowa and Jotzo, 2005).

The distribution of JI projects, of which 90 % are implemented in the EIT region, was not predicted by Oleschak and Springer (2007)'s list of most-attractive JI countries. The shares have not shifted substantially over time.

Figure 14.15 shows the regional distribution of pre-2013 credit volumes for annual CDM project cohorts. It confirms the regionally skewed distribution of CDM projects. In contrast, the 880 climate change projects of the GEF (a total of 3.1 billion current USD spent since the early 1990s) do not show a significant regional imbalance when assessed in terms of numbers. Once volumes are assessed, they are somewhat skewed towards EAS and SAS. Academic literature has evaluated the regional distribution of GEF projects only to a very limited extent. Mee et al. (2008) note that there is a correlation between national emissions level and the number of GEF mitigation projects, which would lead to a concentration of projects in the same countries that have a high share in CDM projects. Dixon et al. (2010) describe the regional distribution of the energy efficiency, renewable energy, and transport project portfolio, but do not discuss what drives this distribution.

While the general direction of bilateral climate finance flows from the North to the South is clear, regional specificities have only partially been addressed by the literature. Atteridge et al. (2009) assess the 2008 climate finance flows from France, Germany, and Japan as well as the European Investment Bank and find that 64 % of mitigation finance went to Asia and Oceania, 9 % to SSA, 8 % to MNA, and 5 % to LAM. With 11 %, EIT had a surprisingly high share. Climate Funds Update (2013) provides data on pledges, deposits, and recipients of the fast-start finance committed in the Copenhagen Accord. Of the 31.4 billion USD funds pledged by September 2011, 53 % came from Asia, 37 % from Europe, 9 % from North America, and 1 % from Australasia. Of 3.1 billion USD allocated to approved projects, 44 % was to be spent in Asia, 37 % in Africa, 13 % in Latin America, 13 % in North America and 6 % in Europe. There is no recent peer-reviewed literature discussing flows from Multilateral Development Banks.

As of 2009, a total of 79 REDD readiness activities and 100 REDD demonstration activities were reported (Cerbu et al., 2011). REDD readiness activities were evenly distributed among regions (21 in Amazon Region of South America, 19 in East Asia and the Pacific, 13 in Central America and the Caribbean, and 22 in Africa). In contrast, East Asia and the Pacific hold major REDD demonstration projects (40), followed by 31 in Amazon, 18 in Africa, and 2 in South Asia (Cerbu et al., 2011). Thirty-six countries, mainly in Latin America (15), Africa (15), and Asia-Pacific (8) participate in the global initiative Forest Carbon Partnership Facilities (Nguon and Kulakowski, 2013).

Other global and regional REDD+ initiatives include the UN-REDD Program, which aims to support REDD+ readiness in 46 partner countries in Africa, Asia-Pacific, and Latin America; the REDD+ Partnership, which serves as an interim platform for its partner countries to scale up actions and finance for REDD+ initiatives in developing countries; and the Forest Investment Program, which supports developing countries' efforts to REDD and promotes sustainable forest management (den Besten et al., 2013) (see also Section 11.10).

14.4 Regional cooperation and mitigation: opportunities and barriers

14.4.1 Regional mechanisms: conceptual

As a global environmental challenge, mitigation of climate change would ideally require a global solution (see Chapter 13). However, when global agreement is difficult to achieve, regional cooperation may be useful to accomplish global mitigation objectives, at least partially. The literature on international environmental governance emphasizes the advantages of common objectives, common historical and cultural backgrounds, geographical proximity, and a smaller number of negotiating parties, which make it easier to come to agreement and to coordinate mitigation efforts. As a caveat, regional fragmentation might hamper the achievement of global objectives (Biermann et al., 2009; Zelli, 2011; Balsiger and VanDeveer, 2012). However, game-theoretic models using the endogenous coalition formation framework suggest that several regional agreements are better than one global agreement with limited participation (Asheim et al., 2006; Osmani and Tol, 2010). The underlying reason is that endogenous participation in a global environmental agreement is very small since free-riders profit more from the agreement than its signatories unless the number of signatories is very small.

The discussion in this section distinguishes between climate-specific and climate-relevant initiatives. Climate-specific regional initiatives address mitigation challenges directly. Climate-relevant initiatives were launched with other objectives, but have potential implications for mitigation at the regional level, e. g. regional trade agreements and regional cooperation on energy. This section will also address tradeoffs and synergies between adaptation, mitigation, and development at the regional level. Questions addressed in this chapter are in regard to what extent the existing schemes have had an impact on mitigation and to what extent they can be adjusted to have a greater mitigation potential in future. Since this section focuses on the mitigation potential of regional cooperation, well-being, equity, intra- and inter-generational justice will not be considered (see Sections 3.3 and 3.4 for a discussion on these issues).

An important aspect of regional mechanisms is related to efficiency and consistency. As GHGs are global pollutants and their effect on global warming is largely independent of the geographical location of the emission source, all emitters of GHGs should be charged the same implicit or explicit price. If this 'law of one price' is violated, mitigation efforts will be inefficient. This would imply that regions should strive for internal and external consistency of prices for GHGs. The law of one price should apply within and across regions. As regards internal consistency, regional markets for GHG emission permits, such as the EU ETS, have the potential to achieve this goal at least in theory (Montgomery, 1972). However, since existing trading schemes cover only a part of GHG emissions, the law of one price is violated and mitigation efforts tend to be inefficiently allocated.

External consistency is linked to the problem of GHG leakage. Specifically, regional climate regimes can lead to both carbon leakage (discussed in Section 5.4.1) and a decrease in competitiveness for participating countries (discussed in Section 13.8.1). Thus, the specific policies addressing these concerns, particularly the latter, have a large impact on an agreement's regional and national acceptability. One of the most widely discussed policies to correct for climate-related cost differences between countries is border tax adjustments (BTAs), which are similar to the (non-climate) value-added tax in the EU (Lockwood and Whalley, 2010). There is agreement that BTAs can enhance competitiveness of GHG- and trade-intensive industries within a given climate regime (Alexeeva-Talebi et al., 2008; Kuik and Hofkes, 2010; Böhringer et al., 2012; Balistreri and Rutherford, 2012; Lanzi et al., 2012). However, while BTAs ensure the competitiveness of acting countries, they lead to severe welfare losses for non-acting ones (Winchester et al., 2011; Böhringer et al., 2012; Ghosh et al., 2012; Lanzi et al., 2012), particularly developing countries and the global South (Curran, 2009; Brandi, 2013). Other solutions to the problem of carbon leakage include incorporating more countries into regional agreements (Peters and Hertwich, 2008, p. 1406), and linking regional emission trading systems. Tuerk et al. (2009) and Flachsland et al. (2009) show that linking regional emission trading systems does not necessarily benefit all parties, even though it is welfare-enhancing at a global level (see also Section 13.7).

14.4.2 Existing regional cooperation processes and their mitigation impacts

While there is ongoing discussion in the literature on the continued feasibility of negotiating and implementing global environmental agreements (see Chapter 13), a distinct set of studies has emerged that examines international coordination through governance arrangements that aim at regional rather than universal participation(Balsiger and VanDeveer, 2010, 2012; Balsiger and Debarbieux, 2011; Elliott and Breslin, 2011). Much of the literature adopts a regional focus (Kato, 2004; Selin and Vandeveer, 2005; Komori, 2010; van Deveer, 2011) or focuses on a particular environmental issue (Schreurs, 2011; Pahl-Wostl et al., 2012). Since 60 % of the international environmental agreements are regional (UNEP, 2001; Balsiger et al., 2012), this broader set of regional environmental agreements can provide insights on designing regional climate initiatives, although further research is needed. In addition, several regional environmental agreements have climate change components, such as the Alpine Convention's Action Plan on Climate Change in the Alps in March 2009 (Alpine Convention, 2009).

This section examines a variety of regional initiatives with climate implications. Figure 14.16 illustrates three major areas in which regional climate change coordination can be classified: climate-specific agreements, technology-focused agreements, and trade-related agreements. Most, but not all, regionally coordinated initiatives fit into one of these three categories, though some span multiple categories. In addition, some of the programs within each category have been implemented within a single geographic region, while others are intra-regional. The following sections examine regional initiatives with climate-specific objectives, trade agreements with climate implications, regional cooperation on energy, and regional cooperation schemes where mitigation and adaptation are important.

14.4.2.1 Climate specific regional initiatives

To date, specific regional climate policy initiatives have been rare, and they need to be distinguished from transnational initiatives that abound (Andonova et al., 2009). Grunewald et al. (2013) survey existing regional cooperation agreements on mitigation (except the agreements in the European Union for which a large literature exists). Of the 15 agreements surveyed, they find that most are built on existing trade or regional integration agreements or are related to efforts by donors and international agencies. Most relate to technology (see discussion below), some to finance, and some to trade. Few of them have been rigorously evaluated and the likely impact of most of these activities appears to be limited, given their informal and mostly voluntary nature. The technology-focused agreements are discussed in more detail below. The EU has been an exception to this pattern of rather loose and voluntary agreements, where deep integration has generated binding and compulsory market-based as well as regulation-based initiatives. Therefore, the discussion of impacts of the EU experience offers lessons of the promise and challenges to use regional cooperation mechanisms to further a mitigation agenda also for other regions.

Of the wide array of mitigation policy instruments (see Chapter 15 for a discussion of such instruments), only emission trading systems have been applied on a regional scale: the EU ETS covering the EU's 27 member states, Iceland, Norway, and Liechtenstein; and the Western Climate Initiative (WCI), which initially included several states in the United States and provinces in Canada, and now includes just California and Quebec (see Section 13.7.1.2 for a detailed review).

While the EU has tried over many years to introduce a common CO_2 tax, these efforts have failed and only a minimum level of energy taxes to apply across the EU could be defined. Most other supranational climate policy initiatives specialize on certain technologies. These include the Methane to Markets Initiative, the Climate Technology Initiative, the Carbon Sequestration Leadership Forum, and the International Partnership for the Hydrogen Economy, which are open for global membership (see Bäckstrand, (2008) for a summary of these initiatives). In selected cases regional initiatives have emerged, such as the Asia-Pacific Partnership for Climate Change, and the addition of regional collaboration in the framework of the UNFCCC (e.g., the Central Group 11 (CG 11) of Eastern European countries in transition or the African Group). An evaluation of these initiatives follows.

The EU ETS

The EU ETS is a mandatory policy, which has evolved over a decade in strong interaction between the EU Commission, the European Parliament, member state governments, and industry lobbies (for an overview of the role of the different interests, see Skjærseth (2010). It has gone through three phases, and shifted from a highly decentralized to a centralized system.

The EU ETS is by far the largest emission trading system in the world, covering over 12,000 installations belonging to over 4,000 companies

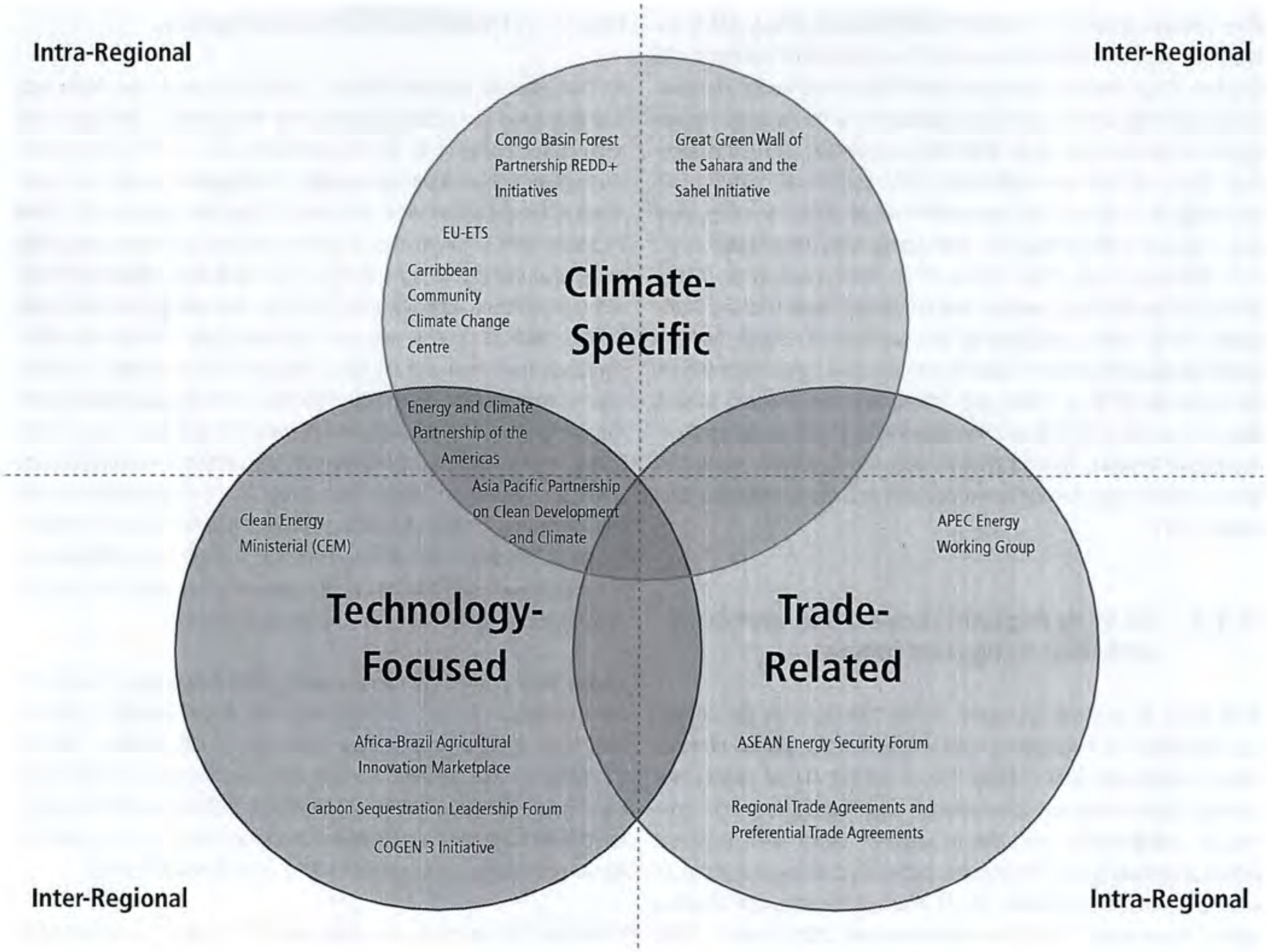

Figure 14.16 | Typology of regional agreements with mitigation implications. Figure includes selected regional agreements only, and is not comprehensive. While not all agreements fit into the typology presented in this diagram, many do.

and initially over 2 Gt of annual CO_2 emissions. It has thus been thoroughly researched (see Convery, (2009a), for a review of the literature, and Lohmann, (2011), for a general critique).

How was institutional, political, and administrative feasibility achieved in the case of the EU ETS? According to Skjærseth and Wettestad (2009), from being an opponent of market mechanisms in climate policy as late as 1997, the EU became a supporter of a large-scale emissions trading system since 2000 due to a rare window of opportunity. The Kyoto Protocol had increased the salience of climate policy, and according to EU rules, trading could be agreed through a qualified majority, whereas a carbon tax required unanimity. Industry was brought on board through grandfathering (Convery, 2009b) and the lure of windfall profits generated by passing through the opportunity cost of allowances into prices of electricity and other products not exposed to international competition.

Environmental effectiveness of the EU ETS has essentially been determined by the stringency of allowance allocation. Initially, a decentralized allocation system was put in place, which has been criticized by researchers as leading to a 'race to the bottom' by member states (Betz and Sato, 2006). Nevertheless, allowance prices reached levels of almost 40.5 USD_{2010} (30 EUR_{2008}), which was unexpected by analysts, and in the 2005–2007 pilot phase triggered emission reductions estimated from 85 $MtCO_2$ (Ellerman and Buchner, 2008) up to over 170 $MtCO_2$ (Anderson and Di Maria, 2011). The wide range is due to the difficulty to assess baseline emissions. Hintermann (2010) sees the initial price spike not as sign of a shortfall of allowances but as market inefficiency due to a bubble, exercise of market power or companies hedging against uncertain future emissions levels. This is corroborated by the fact that the release of the 2005 emissions data in April–May 2006 showed an allowance surplus and led to a price crash, as allowances could not be banked into the second period starting

2008 (see Alberola and Chevallier, (2009) for an econometric analysis of the crash). A clampdown of the EU Commission on member states' allocation plan proposals for 2008–2012 reduced allocation by 10 % (230 million tCO_2 per year for the period 2008–2012) and bolstered price levels, the crash of industrial production due to the financial and economic crisis of 2008 led to an emissions decrease by 450 $MtCO_2$ and an allowance surplus for the entire 2008–2012 period. As a result, prices fell by two-thirds but did not reach zero because allowances could be banked beyond 2012, and the Commission acted swiftly to set a stringent centralized emissions cap for the period 2013–2020 (see Skjærseth, 2010, and Skjærseth and Wettestad, 2010, for the details of the new rules and how interest groups and member states negotiated them). This stabilized prices until late 2011. But again, the unexpected persistence of industrial production decreases led to a situation of general over-allocation and pressure on allowance prices. The European Parliament and member states decided in late 2013 to stop auctioning allowances between 2013 and 2015 to temporarily take up to 900 million allowances out of the market ('backloading').

While there is a literature investigating short-term spot carbon price fluctuations, which attributes price volatility to shifts in relative coal, gas, and oil prices, weather, or business cycles (Alberola et al., 2008; Hintermann, 2010), the unexpected low prices in the EU ETS are more likely to be driven by structural factors. Four structural factors discussed in the literature are (1) the financial and economic crises (Neuhoff et al., 2012; Aldy and Stavins, 2012); (2) the change of offset regulations (Neuhoff et al., 2012); (3) the interaction with other policies (Fankhauser et al., 2010; Van den Bergh et al., 2013); and (4) regulatory uncertainty and lack of long-term credibility (Blyth and Bunn, 2011; Brunner et al., 2012; Clò et al., 2013; Lecuyer and Quirion, 2013). There is no analysis available that quantitatively attributes a relative share of these explanatory factors in the overall European Union Allowances (EUA) price development, but all four factors seemed to have played a role in the sense that the absence of any of them would have led to a higher carbon price. The following paragraphs briefly review each of the four price drivers.

Financial and economic crises—the crash of industrial production due to the financial and economic crisis of 2008 led to an emissions decrease by 450 $MtCO_2$ and an allowance surplus for the entire 2008–2012 period. This has led to a decrease in EUA prices (Aldy et al., 2003; Neuhoff et al., 2012) prices fell by two thirds but did not reach zero because allowances could be banked beyond 2012, and the Commission acted swiftly to set a stringent centralized emissions cap for the period 2013–2020 (see Skjærseth (2010) and Skjærseth and Wettestad (2010) for the details of the new rules and how interest groups and member states negotiated them). This action stabilized prices until late 2011. Nonetheless, since then the price has again dropped and the surplus has reached approximately 2 billion tCO_2 (European Commission, 2013a). Schopp and Neuhoff (2013) argue that when the surplus of permits in the market exceeds the hedging needs of market participants—which they find to be the case in the period from 2008 to at least 2020—the remaining purchase of allowance is driven by speculators applying high discount rates. As a consequence, the EUA price remains below its long-term trend in the short-term until sufficient scarcity is back in the market.

Import of offsets—The use of offsets should not have influenced the price, as market participants should consider the future scarcity of offset credits and there is a limit to the maximum cumulated use of offsets between 2008 and 2020. Most large companies covered by the EU ETS engaged in futures contracts for CER acquisition as early as 2006. However, changes in offset regulations in 2009 and 2011 led to a pressure to rapidly import Certified Emission Reductions and Emission Reduction Units (CERs, ERUs). As due to rapidly rising issuance of CERs, imports approached the maximum level allowed for the period 2008–2020, price pressure on CERs/ERUs increased, which in turn generated pressure on the price of EUAs (Neuhoff et al., 2012).

Interaction with other policies—Interaction of the EU ETS with other mitigation policies and the resulting effects on economic efficiency has been discussed by del Río (2010) for renewable energy and energy-efficiency policies, by Sorrell et al. (2009) for renewable energy certificates, by Frondel et al. (2010) for renewable feed-in tariffs, and by Kautto et al. (2012) for biomass energy. These studies find that other mitigation policies can drive the allowance price down due to a decrease in the demand of allowances (Fankhauser et al. 2010; Van den Bergh et al., 2013). However, there is no robust scientific assessment that identifies which share of the price decline is due to expansion of renewable energy and improvement of energy efficiency. Section 15.7.3 deals with this issue of policy interactions such as those of the EU ETS and EU policies on energy efficiency, renewable, and biofuels in more detail, including also a welfare analysis of such interactions.

Regulatory uncertainty and lack of long-term credibility—Regulatory uncertainty (Clò et al., 2013; Lecuyer and Quirion, 2013) and the lack of long-term credibility (Brunner et al., 2012) might also have influenced the decline of the carbon price. The uncertainties surrounding 2030 and 2040 targets, potential short-term interventions to address the low allowance price, the outcome of international climate negotiations, as well as the inherent lack of credibility of long-term commitment due to potential time inconsistency problems (Brunner et al., 2012) probably increases the discount rate applied by market participants on future carbon prices. Indeed, it has been pointed out that the current linear reduction factor of 1.74 % per year is not in line with ambitious 2050 emission targets (achieving only around 50 % emissions reduction compared to the EU's 80–95 % target) (Neuhoff, 2011). However, while lack of credibility as a factor driving EU ETS prices has been discussed in some theoretical articles, no empirical evidence on the magnitude of this factor on EUA prices is available.

Economic effectiveness of the EU ETS has been discussed with respect to the mobilization of the cheapest mitigation options. While cheap options such as biomass co-firing for coal power plants have been exploited, it is contested whether price levels of allowances have been sufficiently high after the 2005 and 2009 crashes to drive emissions reduction. Literature suggests that they have not been high enough to drive renewable energy investment in the absence of feed-in tariffs (Blanco and Rodrigues, 2008). Engels et al. (2008) surveyed companies covered by the EU ETS and found widespread evidence of irrational behavior, i.e., companies not mitigating even if costs were substantially below allowance prices. Engels (2009) even finds that many companies did not know their abatement costs. A barrier to participation in trading could have been the highly scale-specific transaction costs, which were estimated to reach over 2 EUR/EUA for small companies in Ireland (Jaraitė et al., 2010). Given that 75 % of installations were responsible for just 5 % of emissions in 2005–2006 (Kettner et al., 2008), this is a relevant barrier to market participation. Another way of mobilizing cheap options is increasing the reach of the EU ETS, either through linking to other trading schemes or by allowing import of offset credits. Anger et al. (2009) find that linking can substantially reduce compliance cost, especially if the allocation is done in an efficient way that does not advantage energy-intensive industries. Linking to the states of the European Economic Area and Switzerland has not been researched to a large extent, with the exception of Schäfer (2009), who shows how opposition of domestic interest groups in Switzerland and lacking flexibility of the EU prevented linking. Access to credits from the project-based mechanisms was principally allowed by the 'Linking Directive' agreed in 2004. In 2005–2007, companies covered by the EU ETS could import credits from the mechanisms without limit, but access to the mechanisms has been reduced over time, e.g., by national level limitations in the 2008–2012 period and a central limitation for 2013–2020. The import option was crucial for the development of the CDM market (Wettestad, 2009) and drove CER prices. Skjærseth and Wettestad (2008), Chevallier (2010) and Nazifi (2010) discuss the exchange between the member states and the EU Commission about import thresholds for the 2008–2012 period.

Distributional and broader social impacts of the EU ETS have not been assessed by the literature to date except for impacts on specific industrial sectors. While the majority of allowances for the electricity sector are now sold through auctions, other industries receive free allocations according to a system of 52 benchmarks. Competitiveness impacts of the EU ETS have been analyzed intensively. Demailly and Quirion (2008) find that auctioning of 50 % of allocations would only lead to a 3 % loss in profitability of the steel sector, while in their analysis for the cement sector Demailly and Quirion (2006) see a stronger exposure with significant production losses at 50 % auctioning. Grubb and Neuhoff (2006) and Hepburn et al. (2006) extended this analysis to other sectors and concluded that higher shares of auctioning are not jeopardizing competitiveness.

Summing up the experiences from the EU ETS, institutional feasibility was achieved by a structurally lenient allocation, which puts into doubt its environmental effectiveness. There was a centralization of allocation over time, taking competences away from national governments. Several factors have pushed the carbon prices down in the second phase of the EU ETS. This has created a situation in which the target set by European policy makers is achieved, but carbon prices are low; while there are efforts to stabilize the carbon price through backloading or an ambitious emission target for 2030, at the time of this writing it has proven politically difficult to reach agreement on these matters. Future reform of the EU ETS will need to clarify the objectives of the scheme, i.e., a quantitative emissions target or a strong carbon price (e.g., to stimulate development of mitigation technologies). The link to the project-based mechanisms was important to achieve cost-effectiveness, but this has been eroded over time due to increasingly stringent import limits.

14.4.2.2 Regional cooperation on energy

Given the centrality of the energy sector for mitigation, regional cooperation in the energy sector could be of particular relevance. Regional cooperation on renewable energy sources (RES) and energy efficiency (EE) typically emerges from more general regional and/or interregional agreements for cooperation at economic, policy, and legislative levels. It also arises through initiatives to share available energy resources and to develop cross-border infrastructure. Regional cooperation mechanisms on energy take different forms depending, among others, on the degree of political cohesion in the region, the energy resources available, the strength of economic ties between participating countries, their institutional and technical capacity, and the financial resources that can be devoted to cooperation efforts.

In this context, it is also important to consider spillovers on energy that may appear due to trade. As discussed in Chapter 6 (Section 6.6.2.2), mitigating climate change would likely lead to lower import dependence for energy importers (Shukla and Dhar, 2011; Criqui and Mima, 2012). The flip side of this trend is that energy-exporting countries could lose out on significant energy-export revenues as the demand for and prices of fossil fuels drops.[3] The effect on coal exporters is very likely to be negative in the short- and long-term as mitigation action would reduce the attractiveness of coal and reduce the coal wealth of exporters (Bauer et al., 2013a; b; Cherp et al., 2013; Jewell et al., 2013). Gas exporters could win out in the medium term as coal is replaced by gas. The impact on oil is more uncertain. The effect of climate policies on oil wealth and export revenues is found to be negative in most studies (IEA, 2009; Haurie and Vielle, 2011; Bauer et al., 2013a; b; McCollum et al., 2014; Tavoni et al., 2014). However, some studies find that climate policies would increase oil export revenues of mainstream exporters by pricing carbon-intensive unconventionals out of the market (Persson et al., 2007; Johansson et al., 2009; Nemet and Brandt, 2012). See also Section 6.3.6.6.

In the following section, some examples of regional cooperation will be briefly examined, namely the implementation of directives on renewable energy resources in the EU (European Commission, 2001, 2003, 2009b) and in South East Europe under the Energy Community Treaty

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[3] See also Section 13.4 on burden sharing regimes that could be used to offset the possible decrease in export revenue for fossil exporters.

(Energy Community, 2005, 2008 and 2010), and energy resource sharing through regional power pools and regional cooperation on hydropower.

Regional cooperation on renewable energy in the European Union

The legislative and regulatory framework for renewable energy in the EU has been set up through several directives of the European Commission adopted by EU member states and the European parliament (European Commission, 2001, 2003, 2009b). These directives are an example of a regulatory instrument, in contrast to the cap-and-trade mechanism of the EU ETS described above. In the past, the European Community adopted two directives on the promotion of electricity from renewable sources and on the promotion of biofuels (European Commission, 2001, 2003). These two EU directives established indicative targets for electricity from renewable sources and biofuels and other renewables in transport, respectively, for the year 2010. Furthermore, they started a process of legal and regulatory harmonization and required actions by EU member states to improve the development of renewable energy (Haas et al., 2006, 2011; Harmelink et al., 2006). There was progress toward the targets, but it did not occur at the required pace (Rowlands, 2005; Patlitzianas et al., 2005; European Commission, 2009a; Ragwitz et al., 2012). Therefore, the European Commission proposed a comprehensive legislative and regulatory framework for renewable energy with binding targets.

This led to the introduction of the Directive 2009/28/EC on the promotion of RES (European Commission, 2009b). In this directive, EU Member States agreed to meet binding targets for the share of RES in their gross final energy consumption by the year 2020. The overall target for the European Union is 20 % of EU gross final energy consumption to come from RES by the year 2020. The share of renewables in gross final energy consumption has indeed increased substantially after passage of the directive and stands at around 13 % in 2011.

The RES Directive is part of the EU climate and energy package (European Commission, 2008). As such, it has interactions with the other two pillars, namely the EU ETS and the EE-related directives. On the basis of model analysis, the European Commission (European Commission, 2011b) estimates that the implementation of the EU RES directive could represent an emissions reduction of between 600 and 900 $MtCO_2eq$ by the year 2020 in the EU-27 compared to a baseline scenario (Capros et al., 2010). The introduction of regulatory instruments targeted at RES and/or EE on top of the EU ETS appears justified on the grounds of the failure of the market to provide incentives for the uptake of these technologies (European Commission, 2013a). Still, the combined emission reductions resulting from RES deployment and EE measures leave the EU ETS with a reduced portion of the effort necessary to achieve the 20 % EU emission reduction target by 2020 (e.g., European Commission, 2013a). This, as discussed above, has contributed to a reduced carbon price in the EU ETS (Abrell and Weigt, 2008; OECD, 2011a), affecting its strength as a signal for innovation and investments in efficiency and low-carbon technologies (e.g., European Commission, 2013b). Therefore, coordination between RES and EE policies and the EU ETS is needed and could include introducing adjustment mechanisms into the EU ETS.

The implementation of the EU directives for renewable energy and the achievement of the national targets have required considerable efforts to surmount a number of barriers (Held et al., 2006; Haas et al., 2011; Patlitzianas and Karagounis, 2011; Arasto et al., 2012). One obstacle is the heterogeneity between EU member states regarding their institutional capacity, know-how, types of national policy instruments and degrees of policy implementation (e.g., European Commission, 2013c). Still, the EU directives for renewable energy have contributed to advancing the introduction of RES in the member states (Cardoso Marques and Fuinhas, 2012). This regional cooperation has taken place in the framework of a well-developed EU integration at the political, legal, policy, economic, and industrial level. Only with these close integration ties has it been possible to implement EU directives on RES.

Power pools for energy resources sharing

Power pools have evolved as a form of regional cooperation in the electricity sector and are an example of an opportunity for mitigation that only arises for geographically close countries. Electricity interconnections and common markets in a region primarily serve the purpose of sharing least-cost generation resources and enhancing the reliability of supply. Getting regional electricity markets to operate effectively supports mitigation programs in the electricity sector. Cross-border transmission systems (interconnectors), regional markets and trade, and system-operating capability play a major role in both the economics and feasibility of intermittent renewables. In some cases, power pools provide opportunities for sharing renewable energy sources, notably hydropower and wind energy, facilitating fuel switching away from fossil fuels (ICA, 2011; Khennas, 2012). In this context, there is a correlation between the development of the power pool and the ability of a region to develop renewable electricity sources (Cochran et al., 2012). A combination of electricity sector reform, allowing power utilities to be properly run and sustainable, and regional wholesale market development, with the corresponding regional grid development, is necessary to tap their potential.

An example of a well-established power pool is the Nord Pool, the common market for electricity in Scandinavia, covering Denmark, Sweden, Norway, and Finland. The Nordic power system is a mixture of hydro, nuclear, wind, and thermal fossil power. With this mix, the pool possesses sizeable amounts of flexible regulating generation sources, specifically hydropower in Norway. These flexible hydropower plants and pump storage plants allow compensating the inflexibility of wind power generation (e.g., in Denmark), which cannot easily follow load changes. Through the wholesale market, the Nord Pool can absorb and make use of excess wind electricity generation originating in Denmark, through complementary generation sources. This allows the Nord Pool to integrate a larger share of wind energy (e.g., Kopsakangas-Savolainen and Svento, 2013).

Box 14.1 | Regional cooperation on renewable energy in the Energy Community

The Energy Community extends the EU internal energy market to South East Europe and beyond, based on a legally binding framework. The Energy Community Treaty (EnCT) establishing the Energy Community entered into force on 1 July 2006 (Energy Community, 2005). The Parties to the Treaty are the European Union, and the Contracting Parties Albania, Bosnia and Herzegovina, Croatia, Former Yugoslav Republic of Macedonia, Montenegro, Serbia, the United Nations Interim Administration Mission in Kosovo (UNMIK), Moldova and Ukraine. The Energy Community treaty extended the so-called *'acquis communautaire'*, the body of legislation, legal acts, and court decisions, which constitute European law, to the contracting parties. As a result, contracting parties are obliged to adopt and implement several EU directives in the areas of electricity, gas, environment, competition, renewable energies, and energy efficiency. In the field of renewable energy, the EU acquis established the adoption of the EU directives on electricity produced from renewable energy sources and on biofuels. As a further step, in 2012, the Energy Community adopted the EU RES Directive 2009/28/EC (Energy Community, 2012). This allows contracting parties to use the cooperation mechanisms (statistical transfers, joint projects, and joint support schemes) foreseen by the RES directive under the same conditions as the EU member states.

Analyses of the implementation of the *acquis* on renewables in the energy community (EIHP, 2007, p. 2007; Energy Community, 2008; IEA, 2008; IPA and EPU-NTUA, 2010) found that progress in implementing the EU directives has been dissimilar across Contracting Parties, among others due to the heterogeneity between these countries in institutional capacity, know-how, and pace of implementation of policies and regulatory frameworks (Energy Community, 2010; Mihajlov, 2010; Karakosta et al., 2011; Tešić et al., 2011; Lalic et al., 2011). Still, economic and political ties between South East Europe and the European Union and the prospect of contracting parties to become EU member states have contributed to the harmonization of legal, policy, and regulatory elements for RES (Renner, 2009, p. 20). Through the legally binding Energy Community Treaty, the European Union has exported its legislative frameworks on RES and EE to a neighboring region. Their further implementation, however, requires strengthening national and regional institutional capacity, developing regional energy markets and infrastructure, and securing financing of projects.

In Africa there are five main power pools, namely the Southern Africa Power Pool (SAPP), the West African Power Pool (WAPP), the East African Power Pool (EAPP), the Central African Power Pool (CAPP), and the Comité Maghrébin de l'Electricité (COMELEC). The SAPP, for example, includes 12 countries: Botswana, Lesotho, Malawi, South Africa, Swaziland, Zambia, Zimbabwe, Namibia, Tanzania, Angola, Mozambique, and Democratic Republic of the Congo. Its generation mix is dominated by coal-based power plants from South Africa, which has vast coal resources and the largest generation capacity within SAPP. Other resources available in the SAPP are hydropower from the northern countries and, to a lower extent, nuclear power, and gas and oil plants (Economic Consulting Associates (ECA), 2009; ICA, 2011). Overall the scale of trade within these power pools is small, leading to continued inefficiencies in the distribution of electricity generation across the continent (Eberhard et al., 2011). One of the driving forces in SAPP is supplying rapid demand growth in South Africa with hydropower generated in the northern part of the SAPP region. This way, the power pool can contribute to switching from coal to hydropower (ICA, 2011; IRENA, 2013). African power pools and related generation and transmission projects are financed through different sources, including member contributions, levies raised on transactions in the pool and donations and grants (Economic Consulting Associates (ECA), 2009). To the extent that financial sources are grants or loans from donor countries or multi-lateral development banks, there exists the possibility to tie financing to carbon performance standards imposed on electricity generation and transmission infrastructure projects.

Regional gas grids

Regional gas grids offer similar opportunities for mitigation (see Chapter 7). In particular, they allow the replacement of high-carbon coal-fired and diesel generation of electricity by gas-fired plants. Such gas grids are developing in East Asia linking China with gas exporting countries as well as in Eastern Europe, again linking gas exporters in Eastern Europe and Central Asia with consumers in Western Europe with the EU taking a coordinating role (Victor, 2006).

Regional cooperation on hydropower

Regional cooperation on hydropower may enable opportunities for GHG-emissions reduction for geographically close countries by exploiting hydropower power potential in one country and exporting electricity to another, by joint development of a transboundary river system (van Edig et al., 2001; Klaphake and Scheumann, 2006; Wyatt and Baird, 2007; Grumbine et al., 2012), or by technology cooperation and transfer to promote small hydropower (UNIDO, 2010; Kumar et al., 2011; Kaunda et al., 2012). The development of hydropower potential, however, needs to comply with stringent environmental, social and economic sustainability criteria as it has important ramifications for development and climate change in the affected regions (Kumar et al., 2011). In addition, there are difficult economic, political, and social issues regarding water sharing, upstream and downstream impacts, and other development objectives. Given its vulnerability to droughts and other impacts of climate change, hydropower development requires careful planning, including provisions for complementary electricity generation sources (Zarsky, 2010; Nyatichi Omambi et al., 2012)

Regional cooperation on energy efficiency standards and labelling

Standards and labels (S&L) for energy-efficient products are useful in accelerating market transformation towards more energy-efficient technologies. Energy-efficiency S&L programs help, for instance, reducing consumption of fossil fuels (e.g., diesel) for electricity generation. Also, when applied to biomass-based cook stoves, S&L help decreasing the use of traditional biomass for cooking (Jetter et al., 2012). Standards and labelling programs at a regional-scale provide critical mass for the creation of regional markets for energy efficiency and, therefore, incentives to equipment manufacturers. They are also useful in reducing non-tariff barriers to trade (NAEWG, 2002). Examples of existing S&L regional programs are the European Energy Labelling directive, first published as Directive 92/75/EEC by the European Commission in 1992 (European Commission, 1992) and subsequently revised (Directive 2010/30/EU; European Commission, 2010), to harmonize energy-efficiency S&L throughout EU member states and harmonization efforts on energy-efficiency S&L between the U.S, Canada, and Mexico as a means to reduce barriers to trade within the North American Free Trade Agreement (NAFTA), (NAEWG, 2002; Wiel and McMahon, 2005; Geller, 2006). Currently, several regional S&L initiatives are being developed, such as the Economic Community of West African States (ECOWAS) regional initiative on energy-efficiency standards and labelling (ECREEE, 2012a), and the Pacific Appliance Labelling and Standards (PALS) program in Pacific Island Countries (IIEC Asia, 2012).

14.4.2.3 Climate change cooperation under regional trade agreements

International trade regulation is particularly relevant as mitigation and adaptation policies often depend on trade policy (Cottier et al., 2009; Hufbauer et al., 2010; Aerni et al., 2010). On the one hand, trade liberalization induces structural change, which can have a direct impact on emissions of pollutants such as GHGs. On the other hand, regional trade agreements (RTAs), while primarily pursuing economic goals, are suitable to create mechanisms for reducing emissions and establish platforms for regional cooperation on mitigation and adaptation to climate change. In parallel to provisions on elimination of tariff and non-tariff trade barriers, the new generation of RTAs contains so called WTO-X provisions, which promote policy objectives that are not discussed at the multilateral trade negotiations (Horn et al., 2010). In particular, they offer the potential to refine criteria for distinctions made on the basis of process and production methods (PPMs), which are of increasing importance in addressing the linkage of trade and environment and of climate change mitigation in particular.

Regional trade agreements have flourished over the last two decades. As of December 2013, the World Trade Organization (WTO) acknowledged 379 notifications of RTAs to be in force(WTO, 2013), half of which went into force only after 2000. This includes bilateral as well as multilateral agreements such as, e.g., the EU, the NAFTA, the Southern Common Market (MERCOSUR), the Association of Southeast Asian Nations (ASEAN) and the Common Market of Eastern and Southern Africa (COMESA). Regional trade agreements increasingly transgress regional relations and encompass transcontinental preferential trade agreements (PTAs).

According to the economic theory of international trade, PTAs foster trade within regions and amongst member countries (trade creation) and they are detrimental to trade with third parties since trade with non-member countries is replaced by intraregional trade (trade diversion). Although the impacts of trade creation and trade diversion have not been analyzed theoretically with respect to their environmental impacts, conclusion by analogy implies that the effects on pollution-intensive and green industries can be positive or negative depending on the patterns of specialization. Most empirical studies look at NAFTA and find mixed evidence on the environmental consequences of regional trade integration in North America (Kaufmann et al., 1993; Stern, 2007). The effects of NAFTA on Mexico turn out to be small. Akbostancı et al. (2008) look at the EU-Turkey free trade agreement and find weak evidence that the demand for dirty imports declined slightly. A study including 162 countries that were involved in RTAs supports the view that regional trade integration is good for the environment (Ghosh and Yamarik, 2006). Among empirical studies looking at the effects of trade liberalization in general, Antweiler et al. (2001), Frankel and Rose (2005), Kellenberg (2008) and Managi et al. (2009) indicate that freer trade is slightly beneficial to the environment. As shown in Section 14.3.4, carbon embodied in trade is substantial and it has been increasing from 1990 to 2008 (Peters et al., 2011).

Trade liberalization in major trade regions has fostered processes that are relevant to climate change mitigation via the development of cooperation on climate issues. (Dong and Whalley, 2010, 2011) look at environmentally motivated trade agreements and find that their impacts, albeit positive, are very small. Many PTAs contain environmental chapters or environmental side-agreements, covering the issues of environmental cooperation and capacity building, commitments on enforcement of national environmental laws, dispute settlement mechanisms regarding environmental commitments, etc. (OECD, 2007). In the case of NAFTA, the participating countries (Canada, Mexico, and the United States) created the North American Agreement on Environmental Cooperation (NAAEC). The NAAEC established an international organization, the Commission for Environmental Cooperation (CEC), to facilitate collaboration and public participation to foster conservation, protection, and enhancement of the North American environment in the context of increasing economic, trade, and social links among the member countries. Several factors, such as the CEC's small number of actors, the opportunities for issue linkage, and the linkage between national and global governance systems have led to beneficial initiatives; yet assessments stress its limitations and argue for greater interaction with other forms of climate governance in North America (Betsill, 2007). The Asia-Pacific Economic Forum (APEC) provides an example of how trade-policy measures can be used to promote trade and investment in environmental goods and services. In 2011, APEC leaders reaffirmed to reduce the applied tariff rate to 5 % or less on goods on the APEC list of environmental goods by the end of 2015 (APEC, 2011). Although the legal status of these political declarations is non-binding, this 'soft law' can help to define the standards of good behavior of a 'well-governed state' (Dupuy, 1990; Abbott and Snidal, 2000).

Recent evidence suggests that environmental provisions in RTAs do affect CO_2 emissions of member countries (Baghdadi et al., 2013). Member countries of RTAs that include environmental harmonization policies converge in CO_2 emissions per capita, with the gap being 18 % lower than in countries without an RTA. On the other hand, member countries of RTAs not containing such an environmental agreement tend to diverge in terms of CO_2 emissions per capita. Moreover, the authors find that membership in an RTA *per se* does not affect average CO_2 emissions significantly whereas environmental policy harmonization within an RTA has a very small (0.3 %) but significant effect on reducing emissions. Thus, regional agreements with environmental provisions lead to slightly lower average emissions in the region and a strong tendency for convergence in those emissions.

There is a potential to expand PTA environmental provisions to specifically cover climate policy concerns. One of the few existing examples of enhanced bilateral cooperation on climate change under PTAs relates to the promotion of capacity building to implement the CDM under the Kyoto Protocol provided for in Article 147 of the Japan-Mexico Agreement for the Strengthening of the Economic Partnership. Holmes et al. (2011) argue that PTAs can include provisions on establishment of ETSs with mutual recognition of emissions allowances (i.e., linking national ETSs in a region) and carbon-related standards. In promoting mitigation and adaptation goals, PTAs can go beyond climate policy cooperation provisions in environmental chapters and make climate protection a crosscutting issue. Obligations to provide know-how and transfer of technology, as well as concessions in other areas covered by a PTA can provide appropriate incentives for PTA parties to accept tariff distinctions based on PPMs (Cosbey, 2004). Although PTAs constitute their own regulatory system of trade relations, the conclusion of PTAs, the required level of trade liberalization, and trade measures used under PTAs are subject to WTO rules (Cottier and Foltea, 2006). While trade measures linked to emissions is a contentious issue in the WTO (Bernasconi-Osterwalder et al., 2006; Holzer, 2010; Hufbauer et al., 2010; Conrad, 2011), the use of carbon-related trade measures under PTAs provides greater flexibility compared to their application in normal trade based on the most-favored nation (MFN) principle. Particularly, it reduces the risk of trade retaliations and the likelihood of challenge of a measure in the WTO dispute settlement (Holzer and Shariff, 2012).

While concerns are expressed in the literature about the coherence between regional and multilateral cooperation (Leal-Arcas, 2011), it is also recognized that PTAs could play a useful role in providing a supplementary forum for bringing together a number of key players (Lawrence, 2009) and fostering bilateral, regional, and trans-regional environmental cooperation (Carrapatoso, 2008; Leal-Arcas, 2013). With the current complexities of the UNFCCC negotiations, PTAs with their negotiation leverages and commercial and financial incentives can facilitate achievement of climate policy objectives. They can also form a platform for realization of mitigation and adaptation policies elaborated at a multilateral level (Fujiwara and Egenhofer, 2007).

14.4.2.4 Regional examples of cooperation schemes where synergies between adaptation and mitigation are important

Referring to potential regional actions to integrate adaptation and mitigation, Burton et al. (2007) point out the need to incorporate adaptation in mitigation and development policies. An integrated approach to climate change policies was considered and large-scale mitigation opportunities at the national and regional level were identified, indicating that scaling up could be realized through international initiatives (Kok and De Coninck, 2007).The UNFCCC Cancun agreements include mandates for multiple actions at the regional level, in particular related to adaptation and technology (UNFCCC, 2011). Some authors also underlined the importance of the linkage between adaptation and mitigation at the project level, in particular where the mitigative capacity is low and the need for adaptation is high. This linkage facilitates the integration of sustainable development priorities with climate policy, as well as the engagement of local policymakers in the mitigation agenda (Ayers and Huq, 2009). Section 4.6 underlines the large similarities and the complementarities between mitigative and adaptive capacities.

Opportunities of synergies vary by sector (Klein et al., 2007). Promising options can be primarily identified in sectors that can play a major role in both mitigation and adaptation, notably land use and urban planning, agriculture and forestry, and water management (Swart and Raes, 2007). It has been stated that forest-related mitigation activities can significantly reduce emissions from sources and increase CO_2 removals from sinks at a low cost. It was also suggested that those activities can be designed promoting synergies with adaptation and sustainable development (IPCC, 2007). Adaptation measures in the forestry sector are essential to climate change mitigation, for maintaining the forest functioning status addressing the negative impacts of climate change ('adaptation for forests'). They are also needed due to the role that forests play in providing local ecosystem services that reduce vulnerability to climate change ('adaptation for people') (Vignola et al., 2009; Locatelli et al., 2011). Information and multiple examples on interactions between mitigation and adaptation that are mutually reinforcing in forests ecosystems and agriculture systems are provided in Section 11.5.

Examples where integration of mitigation and adaptation processes are necessary include REDD+ activities in the Congo Basin, a region where there are well-established cooperation institutions to deal with common forest matters, such as the Central Africa Forest Commission (COMIFAC) and the Congo Basin Forest Partnership (CBFP). Some authors consider that the focus is currently on mitigation, and adaption is insufficiently integrated (Nkem et al., 2010). Other authors have suggested designing an overarching environmental road map or policy strategy. The policy approaches for implementing REDD+, adaptation, biodiversity conservation and poverty reductions may arise from them (Somorin et al., 2011).

The Great Green Wall of the Sahara, launched by the African Union, is another example to combine mitigation and adaptation approaches to address climate change. It is a priority action of the Africa-EU Partnership on Climate (European Union, 2011). The focus of the initiative is adaptation and mitigation to climate change through sustainable land management (SLM) practices. These practices are increasingly recognized as crucial to improving the resilience of land resources to the potentially devastating effects of climate change in Africa (and elsewhere). Thus, it will contribute to maintaining and enhancing productivity. SLM practices, which are referred in Section 14.3.5 of this report, also contribute to mitigate climate change through the reduction of GHG emissions and carbon sequestration (Liniger et al., 2011).

There may, however, also be significant differences across regions in terms of the scope of such opportunities and related regional cooperative activities. At present there is not enough literature to assess these possible synergies and tradeoffs between mitigation and adaptation in sufficient depth for different regions.

14.4.3 Technology-focused agreements and cooperation within and across regions

A primary focus of regional climate agreements surrounds the research, development, and demonstration (RD&D) of low-carbon energy technologies, as well as the development of policy frameworks to promote the deployment of such technologies within different national contexts (Grunewald et al., 2013). While knowledge-sharing and joint RD&D agreements related to climate change mitigation are possible in bilateral, regional, and larger multilateral frameworks (de Coninck et al., 2008), regional cooperation mechanisms may evolve as geographical regions often exhibit similar challenges in mitigating climate change. In some cases these similarities serve as a unifying force for regional technology agreements or for cooperation on a particular regionally appropriate technology.

Other regional agreements do not conform to traditional geographically defined regions, but rather may be motivated by a desire to transfer technological experience across regions. In the particular case of technology cooperation surrounding climate change mitigation, regional agreements are frequently comprised of countries that have experience in developing or deploying a particular technology, and countries that want to obtain such experience and deploy a similar technology. While many such agreements include countries from the North sharing such experience with countries from the South, it is increasingly common for agreements to also transfer technology experiences from North to North, or from South to South. Other forms of regional agreements on technology cooperation, including bilateral technology cooperation agreements, may serve political purposes such as to improve bilateral relations, or contribute to broader development assistance goals. Multilateral technology agreements, such as those facilitated under the UNFCCC, the Montreal Protocol, the IEA, and the GEF, are not included in the scope of this chapter as they are discussed in Chapter 13.

While there has been limited assessment of the efficacy of regional agreements, when available such assessments are reviewed below.

14.4.3.1 Regional technology-focused agreements

Few regional technology-focused agreements conform to traditional geographically defined regions. One exception is the Energy and Climate Partnership of the Americas (ECPA), which was initiated by the United States, and is a regional partnership among Western hemisphere countries to jointly promote clean energy, low-carbon development, and climate-resilient growth (ECPA, 2012). Argentina, Brazil, Canada, Chile, Colombia, Costa Rica, Dominica, Mexico, Peru, Trinidad, and Tobago, and the United States as well as the Inter-American Development Bank (IDB) and the Organization of American States (OAS) have announced initiatives and/or are involved in ECPA-supported projects. They focus on a range of topics, including advanced power sector integration and cross border trade in electricity, advancing renewable energy, and the establishment of an Energy Innovation Center to serve as a regional incubator for implementation and financing of sustainable energy innovation (ECPA, 2012). The ECPA could provide a model for other neighboring countries to form regionally coordinated climate change partnerships focused on technologies and issues that are of common interest within the region.

While not explicitly focused on climate, the Regional Innovation and Technology Transfer Strategies and Infrastructures (RITTS) program provides an interesting example of a regionally coordinated technology innovation and transfer agreement that could provide a model for regional technology cooperation. RITTS reportedly helped to develop the EU's regional innovation systems, improve the efficiency of the support infrastructure for innovation and technology transfer, enhance institutional capacity at the regional level, and promote the exchange of experiences with innovation policy (Charles et al., 2000).

The ASEAN is a particularly active region in organizing initiatives focused on energy technology cooperation that may contribute to climate change mitigation. ASEAN has organized the Energy Security Forum in cooperation with China, Japan, and Korea (the ASEAN+3) that aims to promote greater emergency preparedness, wider use of energy efficiency and conservation measures, diversification of types and sources of energy, and development of indigenous petroleum (Philippine Department of Energy Portal, 2014). The Forum of the Heads of ASEAN Power Utilities/Authorities (HAPUA) includes working groups focused on electricity generation, transmission, and distribution; renewable energy and environment; electricity supply industry services; resource development; power reliability and quality; and human resources (Philippine Department of Energy Portal, 2014). ASEAN's Center on Energy (ACE) (previously called the ASEAN-EC Energy Management Training and Research Center) was founded in 1990 as an intergovernmental organization to initiate, coordinate, and facilitate energy cooperation for the ASEAN region, though it lacks a mandate to implement actual projects (Kneeland et al., 2005; UNESCAP, 2008; Poocharoen and Sovacool, 2012). In addition, the European Commission partnered with the ASEAN countries in the COGEN 3 initiative, focused on promoting cogeneration demonstration projects using biomass, coal, and gas technologies (COGEN3, 2005). Regional energy cooperation in the ASEAN region has been mainly motivated by concerns about security of energy supply (Kuik et al., 2011) and energy access (Bazilian et al., 2012a), an increasing energy demand, fast-rising fossil fuel imports, and rapidly growing emissions of GHGs and air pollutants (USAID, 2007; UNESCAP, 2008; Cabalu et al., 2010; IEA, 2010b; c). As a result, some policies have translated into action on the ground. For example, during the APAEC 2004–2009, the regional 10% target to increase the installed renewable energy-based capacities for electricity generation was met (Kneeland et al., 2005; Sovacool, 2009; ASEAN, 2010; IEA, 2010c).

The APEC also has an Energy Working Group (EWG) that was launched in 1990 to maximize the energy sector's contribution to the region's economic and social well-being, while mitigating the environmental effects of energy supply and use (APEC Secretariat, 2012).

The ECOWAS regional energy program aims to strengthen regional integration and to boost growth through market development to fight poverty (ECOWAS, 2003, 2006). The ECOWAS Energy Protocol includes provisions for member states to establish energy-efficiency policies, legal and regulatory frameworks, and to develop renewable energy sources and cleaner fuels. It also encourages ECOWAS member states to assist each other in this process. The ECOWAS has recently expanded further energy access initiatives, which were launched by The Regional Centre for Renewable Energy and Energy Efficiency (ECREEE, 2012a; b).

There are also examples of institutions that have been established to serve as regional hubs for international clean energy technology cooperation. For example, the Asia Energy Efficiency and Conservation Collaboration Center (AEEC), which is part of the Energy Conservation Center of Japan, promotes energy efficiency and conservation in Asian countries through international cooperation (ECCJ/AEEC, 2011). One of the longest-established institutions for promoting technology transfer and capacity building in the South is the Asian and Pacific Center for Transfer of Technology (APCTT), based in New Delhi, India. Founded in 1977, APCTT operates under the auspices of the United Nations Economic and Social Commission for Asia and the Pacific to facilitate technology development and transfer in developing countries of the region, with special emphasis on technological growth in areas such as agriculture, bioengineering, mechanical engineering, construction, microelectronics, and alternative energy generation (Asia-Pacific Partnership on Clean Development and Climate, 2013).

14.4.3.2 Inter-regional technology-focused agreements

Some technology agreements have brought together non-traditional regions, or spanned multiple regions. For example, the Asia-Pacific Partnership on Clean Development and Climate (APP) brought together Australia, Canada, China, India, Japan, Korea, and the United States. These countries did not share a specific geography, but had common interests surrounding mitigation technologies, as well as a technology-oriented approach to climate change policy. The purpose of the APP was to build upon existing bilateral and multilateral initiatives, although it was perceived by some to be offered forth by the participating nations as an alternative to the Kyoto Protocol (Bäckstrand, 2008; Karlsson-Vinkhuyzen and Asselt, 2009; Lawrence, 2009; Taplin and McGee, 2010). The APP was a public-private partnership that included many active private sector partners in addition to governmental participants that undertook a range of projects across eight task forces organized by sector. Initiated in 2006, the work of the APP was formally concluded in 2011, although some projects have since been transferred to the Global Superior Energy Performance Partnership (GSEP) under the Clean Energy Ministerial. This includes projects from the sectoral task forces on power generation and transmission, cement, and steel (US Department of State, 2011; Clean Energy Ministerial, 2012). One study reviewing the implementation of the APP found that a majority of participants found the information and experiences exchanged within the program to be helpful, particularly on access to existing technologies and know-how (Okazaki and Yamaguchi, 2011; Fujiwara, 2012). The APP's record on innovation and access to newer technologies was more mixed, with factors such as limited funding and a lack of capacity for data collection and management perceived as barriers (Fujiwara, 2012). As discussed in Section 13.6.3, it may also have had a modest impact on governance (Karlsson-Vinkhuyzen and Asselt, 2009; McGee and Taplin, 2009) and encouraged voluntary action (Heggelund and Buan, 2009).

Another technology agreement that brings together clean energy technology experience from different regions is the Clean Energy Ministerial (CEM). The CEM convenes ministers with responsibility for clean energy technologies from the world's major economies and ministers from a select number of smaller countries that are leading in various areas of clean energy (Clean Energy Ministerial, 2012). The first CEM meeting was held in Washington in 2010. The 23 governments participating in CEM initiatives are Australia, Brazil, Canada, China, Denmark, the European Commission, Finland, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, Norway, Russia, South Africa, Spain, Sweden, the United Arab Emirates, the United Kingdom, and the United States. These participant governments account for 80 % of global GHG emissions and 90 % of global clean energy investment (Clean Energy Ministerial, 2012).

A smaller agreement that focused on a broad range of mitigation technologies, the Sustainable Energy Technology at Work (SETatWork) Program, was comprised of two years of activities that ran from 2008 to 2010. SETatWork developed partnerships between organizations in the EU, Asia, and South America focused on implementing the EU ETS through identifying CDM project opportunities and transferring European technology and know-how to CDM host countries (European Commission, 2011a).

Other inter-regional technology cooperation initiatives and agreements focus on specific technology areas. For example, multiple initiatives focus on the development or deployment of carbon dioxide capture and storage (CCS) technologies, including the Carbon Sequestration Leadership Forum (CSLF), the European CCS Demonstration Project Network, The Gulf Cooperation Council CCS Strategic Workshop, and the Global Carbon Capture and Storage Institute.

14.4.3.3 South-South technology cooperation agreements

There are increasingly more examples of technology cooperation agreements among and between developing countries, often in the context of broader capacity building programs or agreements to provide financial assistance. One example is the Caribbean Community Climate Change Centre; which coordinates the Caribbean region's response to climate change and provides climate change-related policy advice and guidelines to the Caribbean Community (Caribbean Community Climate Change Center, 2012). Larger countries such as China and Brazil have taken an active role in promoting South-South cooperation. For example, China has served as a key donor to the UNDP Voluntary Trust Fund for the Promotion of South-South Cooperation, and United Nations Educational, Scientific and Cultural Organization (UNESCO) is working with the China Science and Technology Exchange Centre, which is part of China's Ministry of Science and Technology, to develop a network for South-South cooperation on science and technology to Address Climate Change (United Nations Development Programme: China, 2005; UNESCO Bejing, 2012). The Brazilian Agricultural Research Corporation has established several programs to promote agricultural and biofuel cooperation with Africa, including the Africa-Brazil Agricultural Innovation Marketplace, supported by Brazilian and international donors (Africa-Brazil Agricultural Innovation Marketplace, 2012).

Other South-South programs of cooperation that do not focus on climate change explicitly still may encourage climate related technology cooperation. For example, the India, Brazil, South Africa (IBSA) Trust Fund implements South-South cooperation for the benefit of LDCs, focusing on identifying replicable and scalable projects that can be jointly adapted and implemented in interested developing countries as examples of best practices in the fight against poverty and hunger. Projects have included solar energy programs for rural electrification and other projects with potential climate change mitigation benefits (UNDP IBSA Fund, 2014).

14.4.3.4 Lessons learned from regional technology agreements

A review of regional climate technology agreements reveals a complex landscape of cooperation that includes diversity in structure, focus, and effectiveness. While all of the regional agreements discussed above vary in their achievements, the strength of the regional organization or of the relationships of the members of the partnership also vary substantially. This has a direct implication for the effectiveness of the cooperation, and for any emissions reductions that can be attributed to the program of cooperation.

Well-coordinated, regionally based organizations, such as ASEAN, have served as an effective platform for cooperation on clean energy, because such programs build upon a strong, pre-existing regional platform for cooperation. Since most regional organizations coordinate regional activity rather than govern it, most of these regional energy and climate technology agreements focus on sharing information and knowledge surrounding technologies, rather than implementing actual projects, though there are exceptions. Since many countries are involved in multiple regional agreements, often with a similar technical focus, it can be difficult to attribute technology achievements to any specific agreement or cooperation initiative.

Because of the large number of intra-regional climate technology agreements with different types of membership structures and motivations, it is very difficult to draw general lessons from these types of initiatives. Since intra-regional technology agreements rarely build upon existing regional governance structures, their efficacy depends both on the commitment of the members, as well as the resources committed. The prominence of regionally coordinated agreements in other arenas, including environmental protection and trade, suggests that regions will play an increasingly important role in climate-related cooperation in the future. Experience with regional climate cooperation thus far suggests that building upon pre-existing regional groupings and networks, particularly those with strong economic or trade relationships, may provide the best platform for enhanced regional climate change cooperation.

14.4.4 Regional mechanisms for investments and finance

14.4.4.1 Regional and sub-regional development banks and related mechanisms

Regional institutions, including the regional multilateral development banks and the regional economic commissions of the United Nations, play an important role in stimulating action and funding for mitigation activities (see Section 16.5.1.2 for a discussion of specific regional institutions). Development finance institutions channeled an estimated 76.8 billion USD_{2010} in 2010/2011 (Buchner et al., 2011).

Appropriate governance arrangements at the national, regional, and international level are an essential pre-requisite for efficient, effective, and sustainable financing of mitigation measures (see Chapter 16). The Report of the Secretary-General's High-Level Advisory Group on Climate Change Financing recommended that the delivery of finance for adaptation and mitigation be scaled up through regional institutions, given their strong regional ownership. It also found that regional cooperation provides the greatest opportunity for analyzing and understanding the problems of, and designing strategies for coping with, the impact of climate change and variability (United Nations, 2010).

There are few aggregated estimates of the split of finance by type of disbursement organization available (see Chapter 16). A regional breakdown of the recipients of Multilateral Development Bank (MDB) climate finance based on the OECD Creditor Reporting System (CRS) database shows that recipients are primarily located in Asia (26 %), Latin America and the Caribbean (23 %) and Europe/Commonwealth of Independent States region (19 %) (Buchner et al., 2011).

14.4.4.2 South-South climate finance

There are limited data available to accurately quantify South-South climate finance flows, and many studies have pointed to a need for more accessible and consistent data (Buchner et al., 2011). One study that tracked overall development assistance from countries that are not members of the OECD Development Assistance Committee (DAC) estimated flows of 9.66 billion to 12.88 billion USD_{2010} (9 to 12 billion USD_{2006}) and projected that these flows would surpass 15 billion USD by 2010 (ECOSOC, 2008; Buchner et al., 2011). Brazil, India and China, the 'emerging non-OECD donors', are playing an increasingly important role in the overall aid landscape, and these countries also have programs to provide climate-related assistance to developing countries (Buchner et al., 2011). The share of GEF contributions that come from developing countries was estimated to total 56.6 million USD_{2010} (52.8 million USD_{2006}) (Ballesteros et al., 2010).

14.5 Taking stock and options for the future

A key finding from this chapter is that currently there is a wide gap between the potential of regional cooperation to contribute to a mitigation agenda and the reality of modest to negligible impacts to date. As shown in the discussion on climate-specific as well as climate-relevant regional cooperation, the ability to use existing regional cooperation for furthering a mitigation agenda, by pursuing a common and coordinated energy policy, embodying mitigation objectives in trade agreements in urbanization and infrastructure strategies, and developing and sharing technologies at the regional level, is substantial. In principle, in many regions the willingness to cooperate on such an agenda is substantial. In the absence of an increasingly elusive global agreement, such regional cooperation may provide the best alternative to furthering an ambitious mitigation agenda. Also, if a global agreement emerges, such regional cooperation could prove vital for its implementation.

At the same time, the reality is one of very low mitigation impacts to date. Even in areas of deep integration where multiple instruments for mitigation have been put into place, progress on mitigation has been slower than anticipated. This is largely related to a political reluctance to pursue the multiple policy instruments with sufficient rigor. The challenge will be to drastically increase the ambition of existing instruments while carefully considering the positive and negative interactions between these different policies. For regions where deep regional integration is not present yet, the experience from the EU suggests that only after a substantial transfer of sovereignty to regional bodies can an ambitious mitigation be pursued. Such a transfer of sovereignty is unlikely in most regions where the regional cooperation processes are still in early stages of development. Alternatively, regional cooperation on mitigation can build on the substantial good-will within regions to develop voluntary cooperation schemes in the fields outlined in the chapter that also further other development goals, such as energy security, trade, infrastructure, or sustainable development. Whether such voluntary cooperation will be sufficient to implement ambitious mitigation measures to avoid the most serious impacts of climate change remains an open question.

14.6 Gaps in knowledge and data

While there is clear evidence from the theoretical and empirical literature that regional mechanisms have great potential to contribute to mitigation goals, there are large gaps in knowledge and data related to the issues covered in this chapter. In particular, there are gaps in the literature on:

- The quantitative impact of regional cooperation schemes on mitigation, especially in terms of quantifying their impact and significance. While some of the mechanisms, such as the EU-ETS are well-studied, many other cooperation mechanisms in the field of technology, labelling, and information sharing have hardly been analyzed at all.

- The factors that lead to the success or failure of regional cooperation mechanisms, including regional disparities and the mismatch between capacities and opportunities within and between regions. This research would be useful to determine which cooperation mechanisms are suitable for a particular region at a given stage of development, resource endowment, a given level of economic and political cooperation ties, institutional and technical national capacities and heterogeneity among the participating countries.

- Synergies and tradeoffs between mitigation and adaptation. In addition, it would be important to understand more about capacity barriers for low-carbon development at the regional level, including on the costs of capital and credit constraints. There is also very little peer-reviewed literature assessing the mitigation potential and actual achievements of climate-relevant regional cooperation agreements (such as trade, energy, or infrastructure agreements).

- The empirical interaction of different policy instruments. It is clear that regional policies interact with national and global initiatives, and often there are many regional policies that interact within the same regions. Not enough is known to what extent these many initiatives support or counteract each other.

14.7 Frequently Asked Questions

FAQ 14.1 How are regions defined in the AR5?

This chapter examines supra-national regions (i.e., regions in between the national and global level). Sub-national regions are addressed in Chapter 15. There are several possible ways to classify regions and different approaches are used throughout the IPCC Fifth Assessment Report (AR5). In most chapters, a five-region classification is used that is consistent with the integrated models: OECD-1990, Middle East and Africa, Economies in Transition, Asia, Latin America and the Caribbean. Given the policy focus of this chapter and the need to distinguish regions by their levels of economic development, this chapter adopts regional definitions that are based on a combination of economic and geographic considerations. In particular, this chapter considers the following 10 regions: East Asia (China, Korea, Mongolia) (EAS); Economies in Transition (Eastern Europe and former Soviet Union) (EIT); Latin America and Caribbean (LAM); Middle East and North Africa (MNA); North America (USA, Canada) (NAM); South-East Asia and Pacific (PAS); Pacific OECD-1990 members (Japan, Australia, New Zealand) (POECD); South Asia (SAS); sub-Saharan Africa (SSA); Western Europe (WEU). These regions can readily be aggregated to other regional classifications such as the regions used in scenarios and integrated assessment models (e.g., the so-called Representative Concentration Pathways (RCP) regions), commonly used World Bank socio-geographic regional classifications, and geographic regions used by WGII. In some cases, special consideration will be given to the cross-regional group of Least Developed Countries (LDCs), as defined by the United Nations, which includes 33 countries in SSA, 5 in SAS, 8 in PAS, and one each in LAM and MNA, and which are characterized by low incomes, low human assets, and high economic vulnerability.

FAQ 14.2 Why is the regional level important for analyzing and achieving mitigation objectives?

Thinking about mitigation at the regional level matters for two reasons. First, regions manifest vastly different patterns in their level, growth, and composition of GHG emissions, underscoring significant differences in socio-economic contexts, energy endowments, consumption patterns, development pathways, and other underlying drivers that influence GHG emissions and therefore mitigation options and pathways [14.3]. We call this the 'regional heterogeneity' issue.

Second, regional cooperation, including the creation of regional institutions, is a powerful force in global economics and politics—as manifest in numerous agreements related to trade, technology cooperation, transboundary agreements relating to water, energy, transport, and so on. It is critical to examine to what extent these forms of cooperation have already had an impact on mitigation and to what extent they could play a role in achieving mitigation objectives [14.4]. We call this the 'regional cooperation and integration issue'.

Third, efforts at the regional level complement local, domestic efforts on the one hand, and global efforts on the other hand. They offer the potential of achieving critical mass in the size of the markets required to make policies, for example, on border tax adjustment, work, in creating regional smart grids required to distribute and balance renewable energy.

FAQ 14.3 How do opportunities and barriers for mitigation differ by region?

Opportunities and barriers for mitigation differ greatly by region. On average, regions with the greatest opportunities to bypass more carbon-intensive development paths and leapfrog to low-carbon development are regions with low lock-in, in terms of energy systems, urbanization, and transport patterns. Poorer developing regions such as sub-Saharan Africa, as well as most Least Developed Countries, fall into this category. Also, many countries in these regions have particularly favorable endowments for renewable energy (such as hydropower or solar potential). At the same time, however, they are facing particularly strong institutional, technological, and financial constraints to undertake the necessary investments. Often these countries also lack access to the required technologies or the ability to implement them effectively. Given their urgent need to develop and improve energy access, their opportunities to engage in mitigation will also depend on support from the international community to overcome these barriers to invest in mitigation. Conversely, regions with the greatest technological, financial, and capacity advantages face much-reduced opportunities for low-cost strategies to move towards low-carbon development, as they suffer from lock-in in terms of energy systems, urbanization, and transportation patterns. Particularly strong opportunities for low-carbon development exist in developing and emerging regions where financial and institutional capacities are better developed, yet lock-in effects are low, also due to their rapid planned installation of new capacity in energy and transport systems. For these regions, which include particularly Latin America, much of Asia, and parts of the Middle East, a reorientation towards low-carbon development paths is particularly feasible. [14.1, 14.2, 14.3]

FAQ 14.4 What role can and does regional cooperation play to mitigate climate change?

Apart from the European Union (with its Emissions Trading Scheme and binding regulations on energy and energy efficiency), regional cooperation has, to date, not played an important role in furthering a mitigation agenda. While many regional groupings have developed initiatives to directly promote mitigation at the regional level—primarily through sharing of information, benchmarking, and cooperation on technology development and diffusion—the impact of these initiatives is very small to date. In addition, regional cooperation agreements in other areas (such as trade, energy, and infrastructure) can influence mitigation indirectly. The effect of these initiatives and policies on mitigation is currently also small, but there is some evidence that trade pacts that are accompanied by environmental agreements have had some impact on reducing emissions within the trading bloc. Nonetheless, regional cooperation could play an enhanced role in promoting mitigation in the future, particularly if it explicitly incorporates mitigation objectives in trade, infrastructure, and energy policies and promotes direct mitigation action at the regional level. With this approach regional cooperation could potentially play an important role within the framework of implementing a global agreement on mitigation, or could possibly promote regionally coordinated mitigation in the absence of such an agreement. [14.4]

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