INTERGOVERNMENTAL PANEL ON climate change
Working Group III – Mitigation of Climate Change

Chapter 14

Regional Development and Cooperation

Chapter:	14	
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Chapter 14: Regional Development and Cooperation

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Executive Summary

1. **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. [14.1.2, 14.4.1]

2. **Regions can be defined in many different ways depending upon the context.** Mitigation challenges are often differentiated by regions based on their levels of development. For the analysis of 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 OECD90 (Japan, Aus, NZ) (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 Sub-Saharan African (SSA), 5 in South Asia (SAS), 9 in South-East Asia and Pacific (PAS), and one each in Latin America and Caribbean (LAM) and the Middle East and North Africa (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]

1. **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]

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]

3. **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]

4. **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]

5. **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 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]

6. **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 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]

7. **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]

8. **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 GEF is much more balanced than that of the CDM. [14.3.7]

9. **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]

10. **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]

11. **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 supra-national regional bodies to enforce binding agreements on mitigation. [14.4.2, 14.4.3]

12. **Even in areas with deep regional integration, economic mechanisms to promote mitigation (including the EU-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 Clean Development Mechanism, 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]

13. **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]

14. **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]

15. **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 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]

16. **Regional development banks play a key role in climate mitigation financing** (*medium confidence*). The regional development banks, the World Bank, the United Nations system, other multilateral institutions and the 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]

17. **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 greenhouse gas (GHG) 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 Fourth Assessment Report (AR4). Its discussion of policies, instruments and cooperative agreements (AR4 Working Group III, 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 of the 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 greenhouse gas emissions, underscoring significant differences in socio-economic contexts, energy endowments, consumption patterns, development pathways, and other underlying drivers that influence greenhouse gas emissions and therefore mitigation options and pathways (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 co-operation, 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 European Union (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 (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 OECD90 members (Japan, Aus, NZ) (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 assessment models (IAMs). 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 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 trade-offs 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 (McCarthy et al., 2001).

Figure 14.1shows 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.

Lastly, 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.

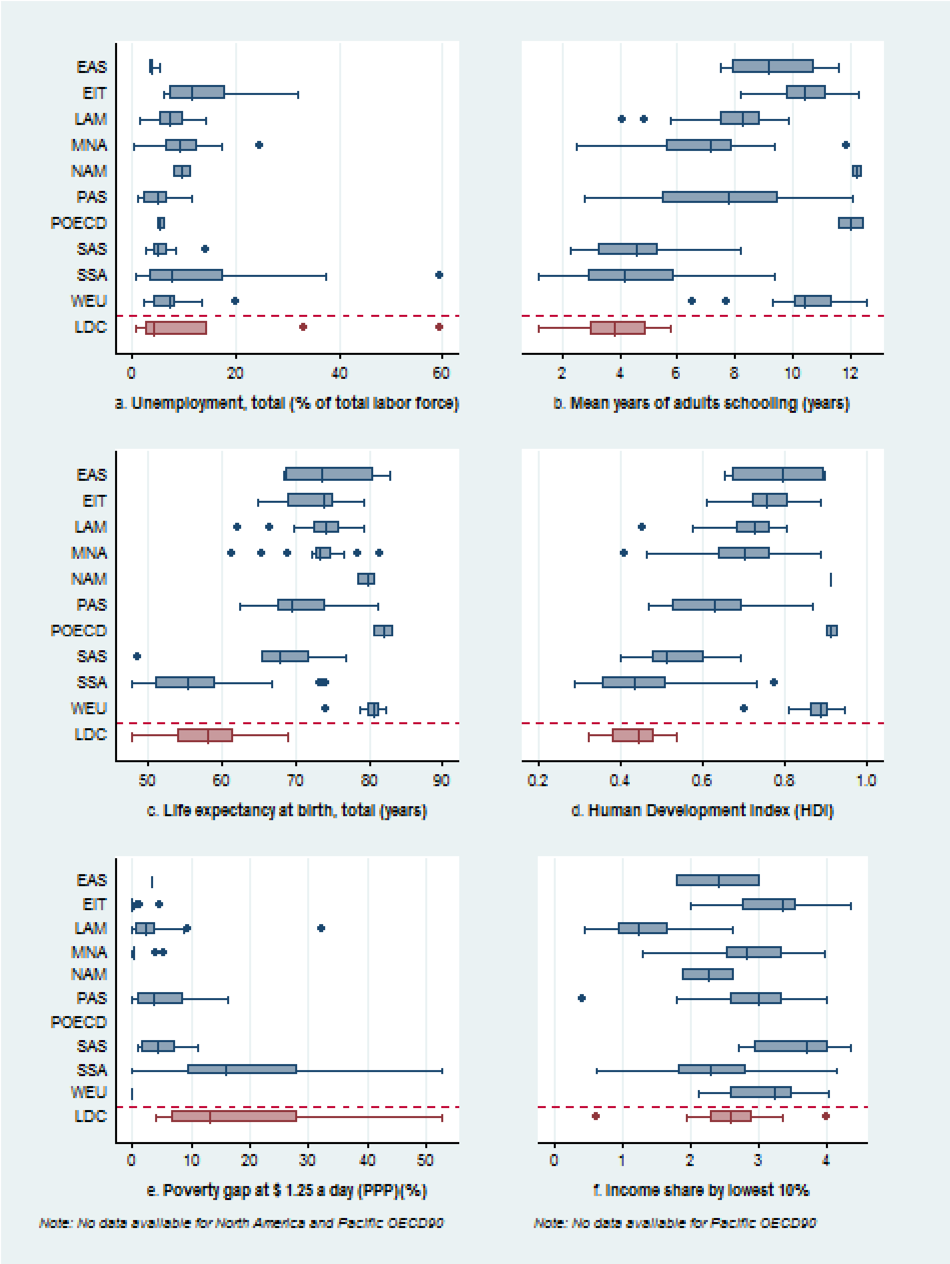

Figure 14.1. Social provisions enabling regional capacities to embrace mitigation policies. In the box plot, the left hand side of the box represents the first quartile (percentile 25) whereas the right hand side represents the third quartile (percentile 75). The vertical line inside the box represents the median (percentile 50). The left line outside the box denotes the lowest datum still within 1,5 interquartile range (IQR) of the lower quartile, and the right hand side line outside the box represents the highest datum still within 1,5 IQR of the upper quartile. The dots denote outliers. Source: (UNDP, 2010; World Bank, 2011). Statistics refer to the year 2010 or the most recent year available.

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 Chapter 13.9 discusses inter-regional technology transfer mechanisms which could help foster this process, there is an emerging literature which 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 climate-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-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.

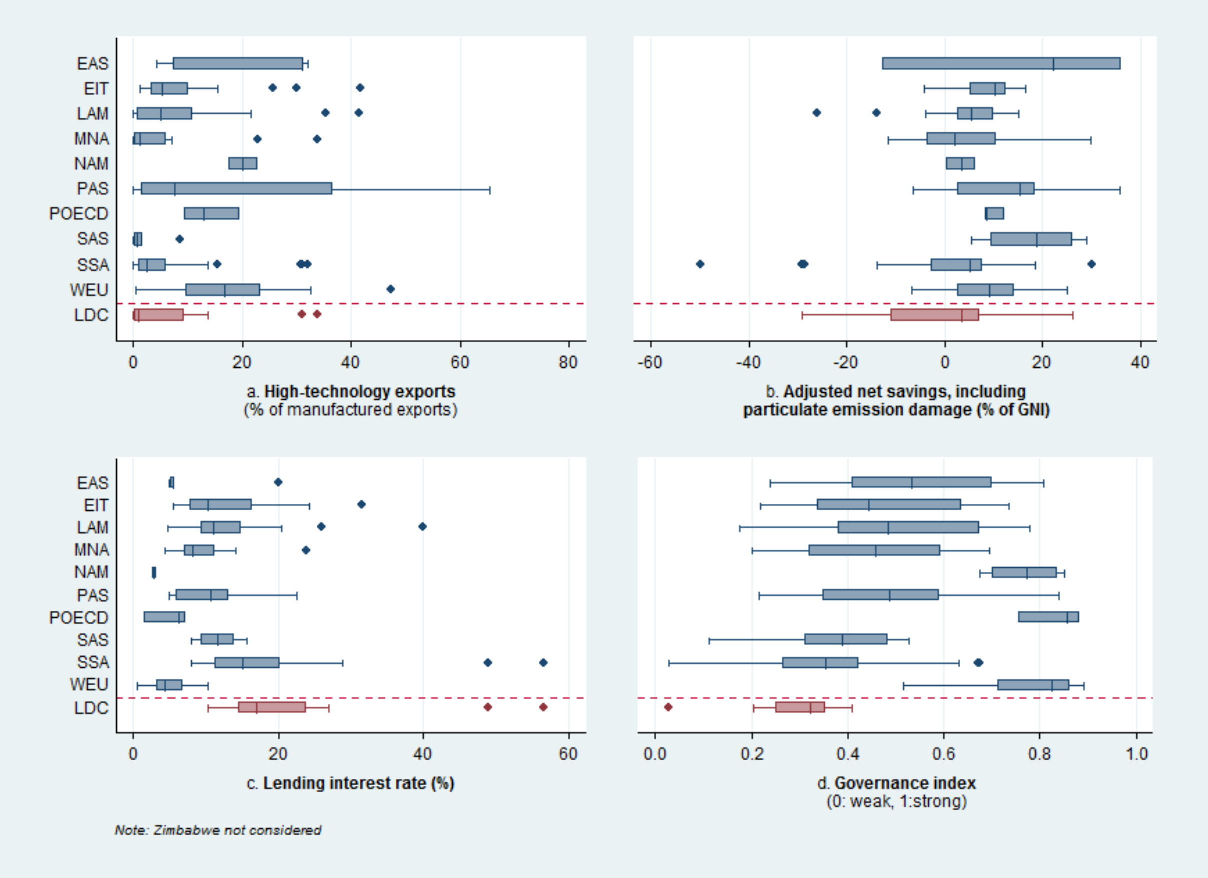

Figure 14.2. Economic and governance provisions enabling regional capacities to embrace mitigation policies. In the box plot, the left hand side of the box represents the first quartile (percentile 25) whereas the right hand side represents the third quartile (percentile 75). The vertical line inside the box represents the median (percentile 50). The left line outside the box denotes the lowest datum still within 1,5 interquartile range (IQR) of the lower quartile, and the right hand side line outside the box represents the highest datum still within 1,5 IQR of the upper quartile. The dots denote outliers. Source: (UNDP, 2010; World Bank, 2011). Statistics refer to the year 2010 or the most recent year available.

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 Assessment Models (IAMs) on the regional distribution of costs of mitigation pathways as well as regional modeling exercises that compare IAM 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 our 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, 2013). 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 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 IAM 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 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 Section 1.3 and 6.3) and reached around 49-50 $GtCO_2$-eq in 2010 (IEA, 2012a; JRC/PBL, 2012; Peters et al., 2013), see Annex II.8). In 1990, Economies in Transition (EIT) was the world's highest emitter of GHG emissions at 19% of global total of 37 $GtCO_2$-eq, followed by North America (NAM, 18%) and Western Europe(WEU, 12%) and East Asia (EAS, 12%), with the rest of the world emitting less than 40%. By 2010, the distribution had changed remarkably. EAS became the major emitter with 24% of the global total of 48 $GtCO_2$-eq (excluding international transport; (IEA, 2012a; JRC/PBL, 2012)). 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 Least Developed Countries including countries from several regions) over the period from 1990 to 2010, broken down along three drivers: Emissions intensity (emissions per unit of 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.

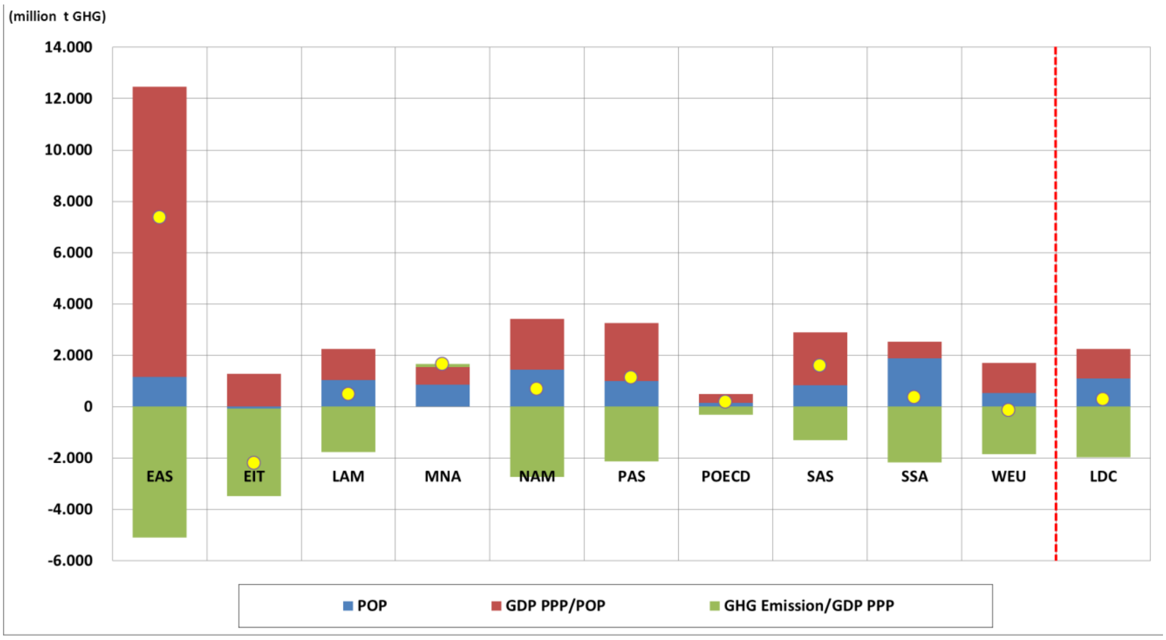

Figure 14.3. Decomposition of drivers for changes in GHG emissions (excluding international transport) in different world regions from 1990-2010 (LMDI method according to (Ang, 2004). The yellow dots indicate changes of GHG emissions(1990-2010) and the bars, which are divided by three colours, show the impacts on GHG emission changes drawn by the Population, GDP per capita and GHG emission per GDP. For example, the yellow 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 Gt CO2-eq, which are indicated by blue, red and green bars respectively. Data sources: GHG emission data from (IEA, 2012a; JRC/PBL, 2012), see Annex II.8, GDP ppp from (World Bank, 2013a), and population data from (United Nations, 2013).

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 20.1% of the world's population, but accounted for 39% of global GHG emissions, while other regions with 79.9% 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 23.2% (SAS) emits 6.8%. One of the important observations from Figure 14.4a is that some regions such as SSA (Sub Saharan Africa) and PAS (South-East Asia and Pacific) 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 14.4b). 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).

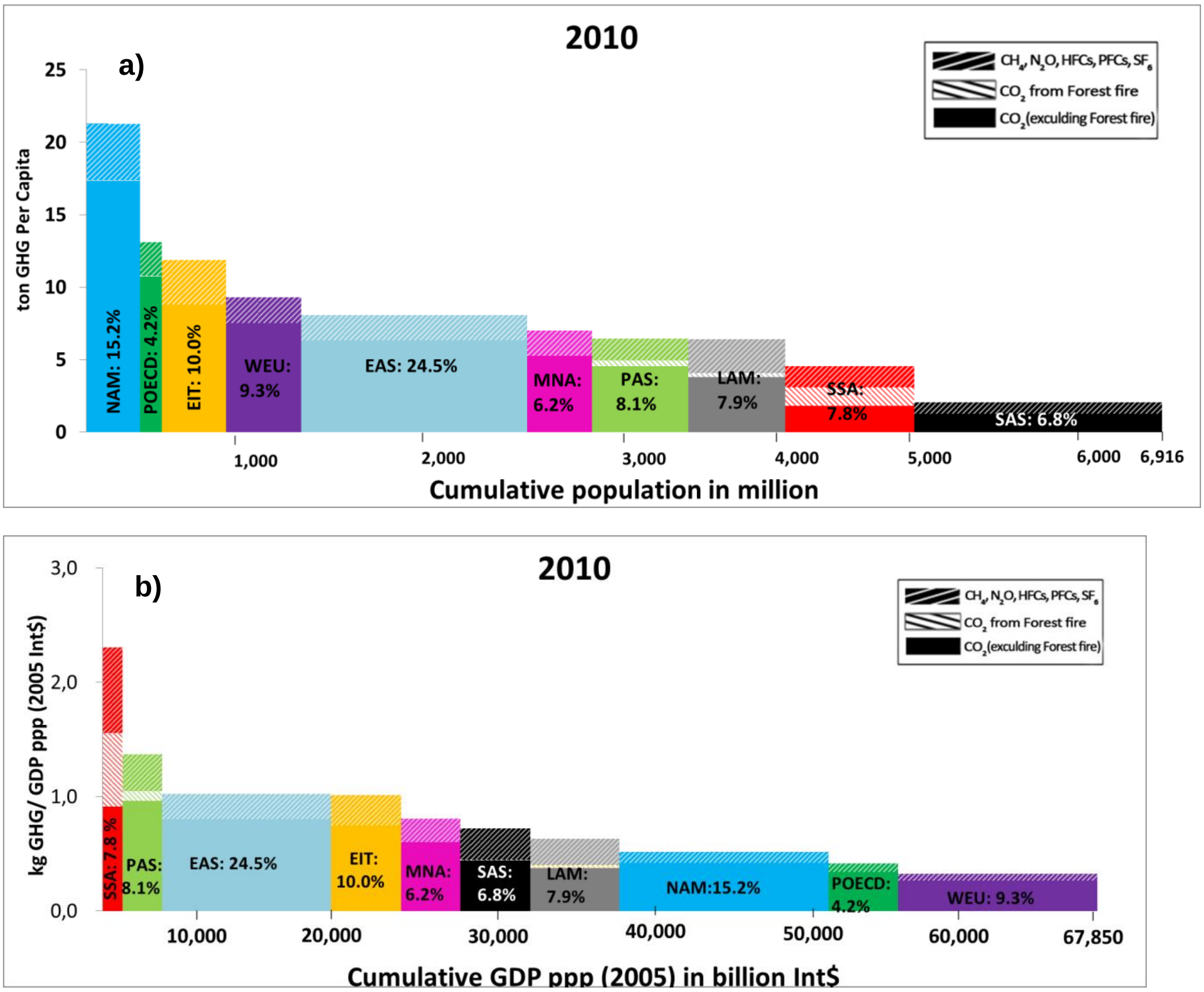

Figure 14.4. Distribution of regional GHG emissions (excluding international transport) in relation to population and GDP: cumulative distribution of GHG emissions per a) capita and b) GDP. The percentages in the bars indicate a region's share in global GHG emissions. Data sources: GHG emission data from (IEA, 2012a; JRC/PBL, 2012), see Annex II.8, GDP ppp from (World Bank, 2013a), and population data from(United Nations, 2013).

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 Gt-CO_2 in EAS, which is equivalent to roughly half of the global net increase of CO_2 emissions from fossil fuel combustion.

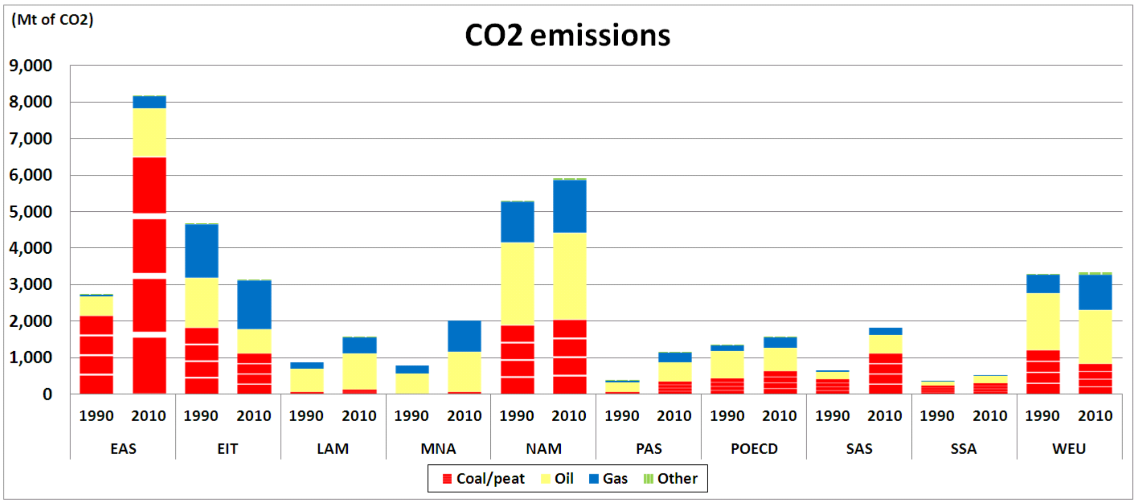

Figure 14.5. CO2 emissions by sources and regions. Data source: (IEA, 2012)

These observations are in line with findings in the literature emphasizing the transformation of energy use patterns over the course of economic 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 Gt CO2 eq. 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 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 CO2 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 14.6a). Carbon intensities of GDP tended to decrease constantly for most regions as well as for the globe (Figure 14.6b).

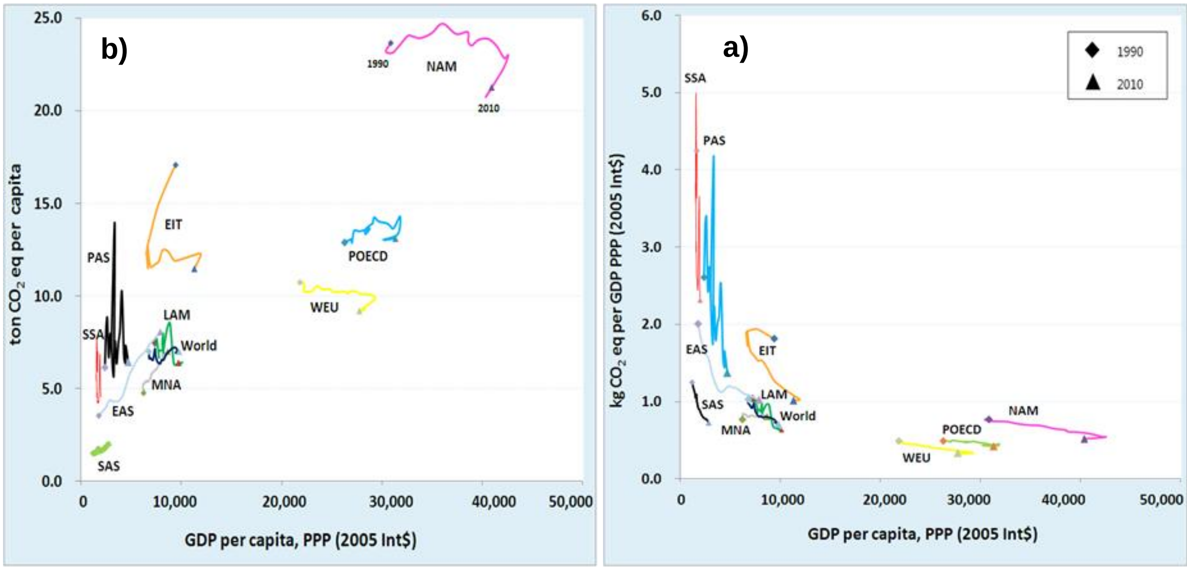

Figure 14.6. Relationship between a) CO2 emissions per capita and GDP per capita, and b) CO2 emissions per GDP and GDP and per capita (1990-2010). Data sources: CO_2 emission data from (IEA, 2012a; JRC/PBL, 2012), see Annex II.8, GDP ppp from (World Bank, 2013a),and population data from (United Nations, 2013).

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 1.3 – 1.5 billion people — over 20% of the global population — lack access to electricity in 2009 (IEA, 2010a, 2013; *World Development Indicators 2012*, 2012; Pachauri et al., 2012, 2013; Sovacool et al., 2012) and nearly 2.5 – 3 billion lack access to modern cooking energy options (Zerriffi, 2011; Sovacool et al., 2012; Rehman et al., 2012). There is considerable regional variation as shown in Table 14.1, with electricity access being particularly low in Sub-Saharan Africa, followed by South Asia.

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

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, 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 Development Indicators 2012*, 2012).

The lack of access to electricity is much more severe in rural areas of LDCs (85%) and SSA (79%)(IEA, 2010a; 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 a million premature deaths are attributed to household cookfuel'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).

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 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 above (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 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, 2010b) 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 which explores four possible low-carbon development pathways for China (Wang and Watson, 2008).

Regional modeling exercises have also examined different mitigation pathways in the energy sector in different regions. For example, EMF28 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 AME for Asia it will involve a greater switch to natural gas with 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, 1998a; Dantas, 2011a; 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 be region(IEA, 2012b, p. 20; OECD, 2012, p. 201; 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 represent 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). IMF (2013)reports that in MNA as well as EIT, pre-tax energy subsidies are very high as a share of GDP. Also in South Asia, energy subsidies are substantial, and there are also some subsidies in Latin America and Sub Saharan Africa where they are concentrated among fuel exporters(IMF, 2013).Similar data on pre-tax subsidies is available from the 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, 2012b).

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 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 (United Nations, 2009), 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)and Figure 14.4 above). In SSA the per capita carbon emissions remained unchanged in the past four decades (JRC/PBL (2012), IEA (2012), see Annex II.8), while the urbanization level of the region almost doubled (United Nations, 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 14.7a). 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).

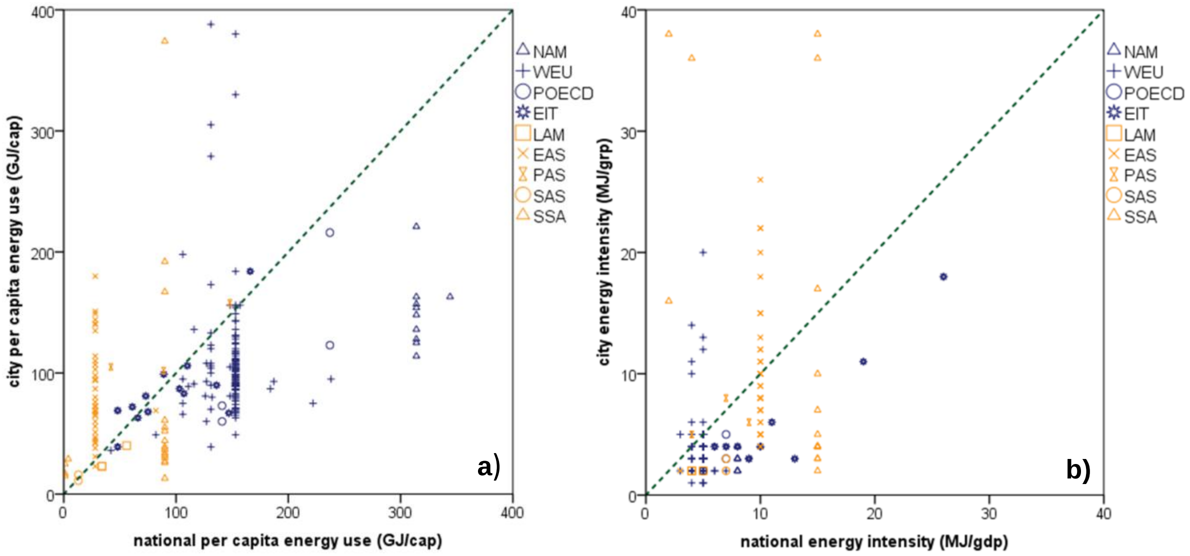

Figure 14.7. a) Per capita energy use and b) energy intensity in cities compared with the national average by regions, 2000. The per capita energy use of cities represented by a dot above the green line is higher than the national average; otherwise, is lower than the national average. Data sources: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

Per capita energy consumption in cities of developing countries is shown to be generally lower (Figure 14.7a). At the same time, studies reveal that cities in developing regions have significantly higher energy intensity than cities in developed regions (Figure 14.7b). 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 US 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 US 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; United Nations, 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 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 IPCC 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 UN Urbanization Prospects(UNDP, 2005), 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 environmental-friendly technology, the same urbanization trend generates a much smaller impact (1.5 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 1.5 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 East Asia (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).

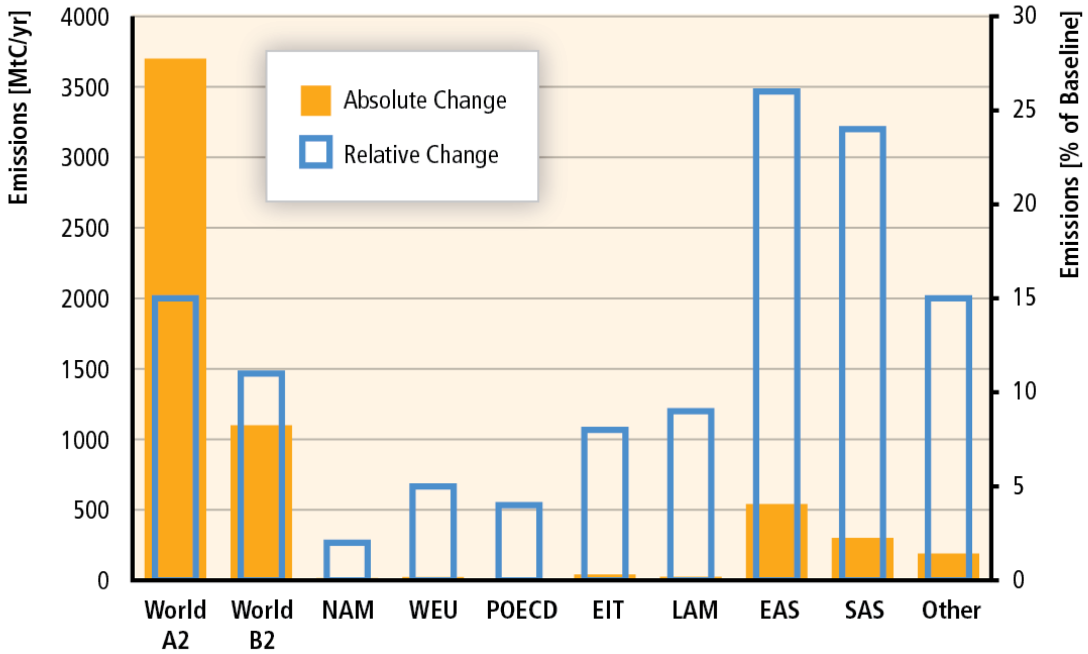

Figure 14.8. Impact of Urbanization on Carbon Emissions in 2100 for the World under SRES A2 and B2 Scenarios and by Regions only under SRES B2 Scenario. This figure is based on (O'Neill et al., 2010), data for NAM from the US, POECD from Japan, EIT from Russia, LAM from Mexico and Brazil, EAS from China, SAS from India, and other from Indonesia. The urbanization scenario follows UN Urbanization Prospects (United Nations, 2005), 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 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.

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: (a) 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 (b) 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 modeling 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 East Asia and South Asia grew by almost 5- 6% annually from 2.5 to 6.5Gt and from 0.8 to 2.0Gt, 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. (Data source: 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 South East Asia, South Asia and East Asia 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 0.63t to 0.57t. (Data source: Peters et al. (2011))

Methodologies, datasets and modeling 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 MRIO method and economic and emissions (from fossil fuel combustion) data derived from 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 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, East Asia was the largest net emission exporter (1,102 Mt) in 2007, with total exported production emissions (1,520 Mt) accounting for 27% of total production emission (5,692 Mt), while imported consumption emissions (418 Mt) accounted for less than 10% of total consumption emissions (4,590 Mt). OECD countries are the major destinations of export products in East Asia. For example, North America and Western Europe account for 34% and 29% of East Asia's total exported production emissions, respectively. The share of embodied emissions in Chinese exports to annual Chinese emission 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 emission 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 emission in China may be over-estimated by more than 60% if the distinction between processing exports and normal exports is not made. In contrast, Western Europe was the largest net emission importer (870 Mt) in 2007, with total exported production emissions (457 Mt) accounting for 16% of total production emission, while imported consumption emissions (1,327 Mt) accounted for 36% of total consumption emissions.

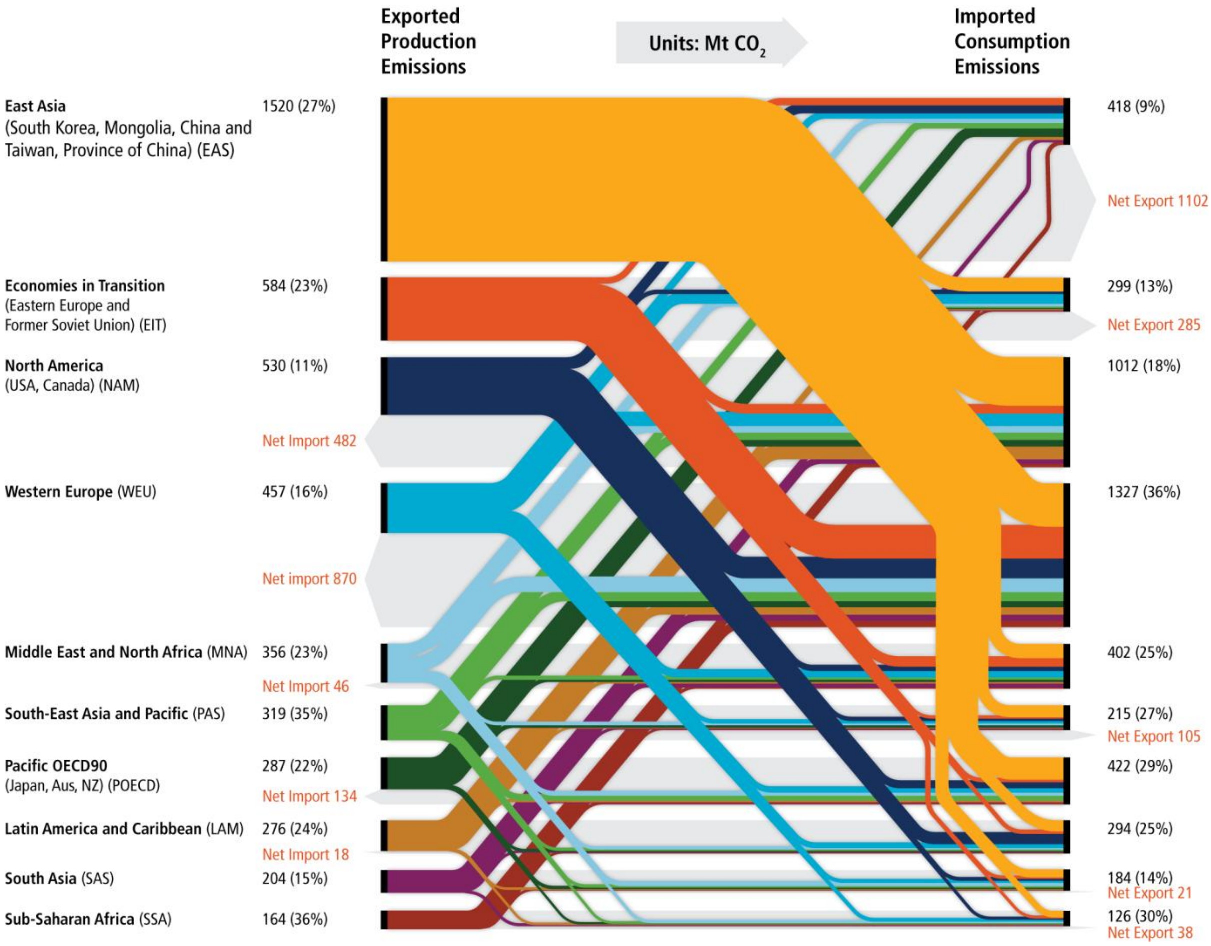

Figure 14.9. Net transfer of CO_2 emissions (from fossil fuel combustion only) between World regions in 2007 using the MRIO method. Flow widths represent the magnitude of emissions (in Mt CO_2) released by left-hand-side regions that have become embodied (along global supply chains) in the goods and 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 Gt CO_2 in 2007 (22.8 Gt from industry and a further 3.7 Gt from residential sources).The analysis is performed using multi-regional input-output model and emissions data derived from GTAP Version 8 database, as explained and presented by Andrew and Peters (2013) .

Figure 14.10 demonstrates (using the EEBT method) that the embodied CO_2 emissions in international bilateral trade between the 10 world regions have grown by 2.5Gt during 1990 – 2008. Considering exports, half of global growth is accounted for by exports from East Asia (1226 Mt CO_2), followed by exports from Middle East & North Africa and South Asia with 20% (510 MtCO_2) and 12% (290 Mt CO_2) of global growth, respectively. North America has increased imports by 621 Mt, with the three Asian regions providing 75% of the increase. Although Western Europe observed positive import flows increase by 610Mt, it also saw a decrease of 268 Mt in some bilateral trade connections, primarily from Eastern Europe & former Soviet Union (257 Mt).

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, East Asia, South-East Asia and Pacific, and Latin America & Caribbean have increased their imported emissions by 260 Mt, 242 Mt and 212 Mt, respectively. Over half of the growth in East Asia and Latin America & Caribbean 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 South-East Asia & Pacific and South Asia. 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.

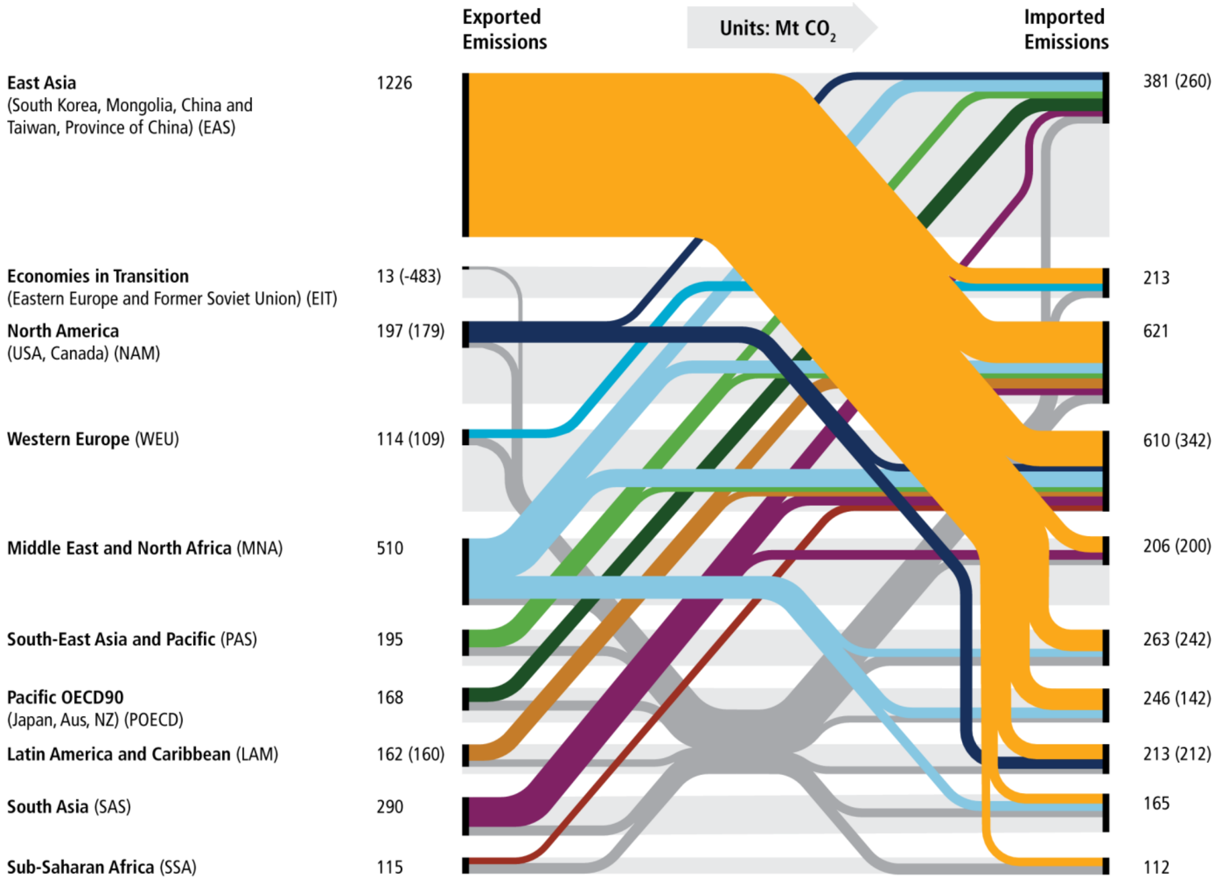

Figure 14.10. Growth in bilateral traded CO_2 emissions between world regions from 1990 to 2008: Flow widths represent the growth in bilateral traded emissions (in Mt CO_2) between 1990 and 2008, exported from left-hand-side region and imported by right-hand-side region. Flows representing a growth greater than 30 Mt CO_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 Mt CO_2), to EAS (-121 Mt CO_2), to POECD (-80 Mt CO_2) and to other regions (-15 Mt CO_2). Total growth in inter-region traded emissions between 1990 and 2008 is found to be 2.5 Gt CO_2 (this does not include intra-region traded emissions, e.g., between US 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).

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 in order to assess how global emissions would change in reaction to a change of imported emissions (Jakob and Marschinski, 2013).

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 Sub-Saharan Africa, Asia and

Pacific 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 Asia and Pacific and North America, 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.

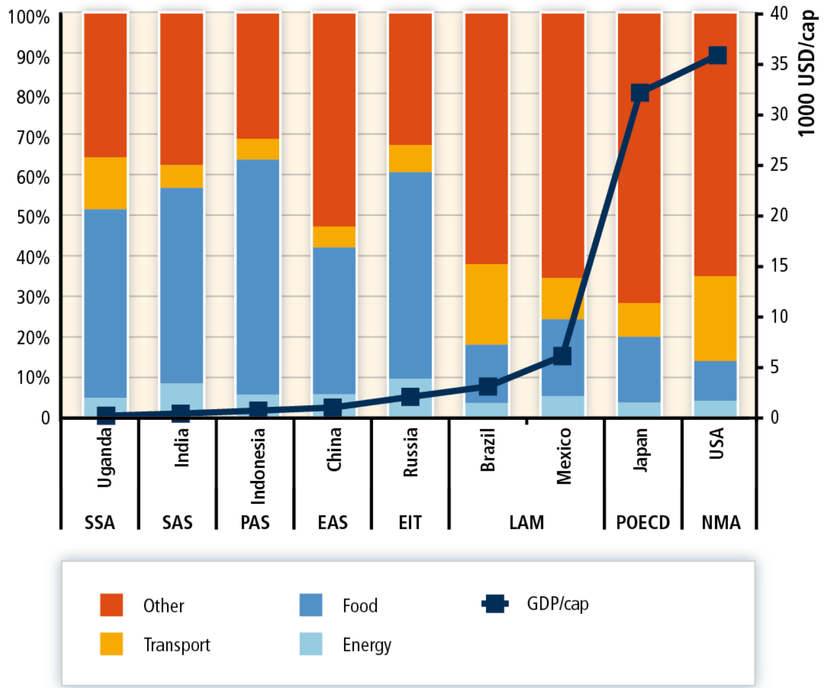

Figure 14.11. Expenditure share of households and per capita income, 2001. Household expenditure share is based on (Zigova et al., 2009; O'Neill et al., 2010). Per capita GDP is from World Bank Development Indicators (World Bank, 2011).

14.3.5 Agriculture, Forestry and Other Land Use (AFOLU) Options for Mitigation

Emission of GHGs in the AFOLU sector increased by 20% from 9.3 Gt CO_2-eq/yr in 1970 to 11.2 Gt CO_2-eq/yr (Figure 5.18) in 2010, and contributed about 22% to the global total in 2010 (JRC/PBL (2012), IEA (2012), see Annex II.8). Over this period, the increase in the Agriculture sub-sector was 35%, from 4.2 Gt CO_2-eq/yr to 5.7 Gt CO_2-eq/yr, and in the Forest and Other Land Use (FOLU) sub-sector it rose from 5.1 Gt CO_2-eq/yr to 5.5 Gt CO_2-eq/yr (Section 5.3.5.4; see also Sections 11.2 and 11.3 for more detailed sector specific values). AFOLU emissions have been relatively more significant in non-OECD90 regions, dominating for example total GHG emissions from Middle East and Africa (MAF) and Latin America (LAM) regions[2] (see Section 5.3.1.2 and Figure 5.6, Section 11.2 and 11.3, Figures 11.5 and 11.7). In the LDCs, more than 90% of the GHG emissions from 1970-2010 were

[2] These belong to the so called five RCP regions which include ASIA, OECD90, Latin America (LAM), Middle East and Africa (MAF), and Reforming Economics (REF). The ten regions used in this chapter further disaggregate OECD90 (POECD, NAM, POECD), MAF (MNA and SSA), and ASIA (EAS, SAS, PAS).

generated by AFOLU (Figure 5.20), and emissions grew by 0.6% per year over the past 4 decades (Box 5.2).

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 (Figure 11.6 and 11.7). For the period 1750-2011, cumulative CO2 fluxes have been estimated at 660 ($\pm$ 293) Gt CO2 based on the model approach of Houghton (2003, updated in (Houghton, 2012)), while annual emissions averaged 3.8 $\pm$ 2.9 $GtCO_2\ yr^{-1}$ 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 $GtCO_2\ yr^{-1}$) and LAM (1.2 $GtCO_2\ yr^{-1}$) compared to MAF (0.56 $GtCO_2\ yr^{-1}$), OECD (0.21 $GtCO_2\ yr^{-1}$) and REF (0.12 $GtCO_2\ yr^{-1}$(Houghton, 2003; Pongratz et al., 2009; Hurtt et al., 2011; Pan et al., 2011; Lawrence et al., 2012); these are means across 7 estimates, noting that in OECD and REF 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 greenhouse gas 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 REF 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; (Taylor et al., 2009; Hurtt et al., 2011; Lawrence et al., 2012) show different combinations of land cover change (cropland and grazing land) and wood harvest as developed by four integrated assessment models and harmonised 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 CO2 flux and climate change vary substantially across different Earth System Models (Brovkin et al., 2013). Furthermore, as shown by Popp et al. (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 11.20).

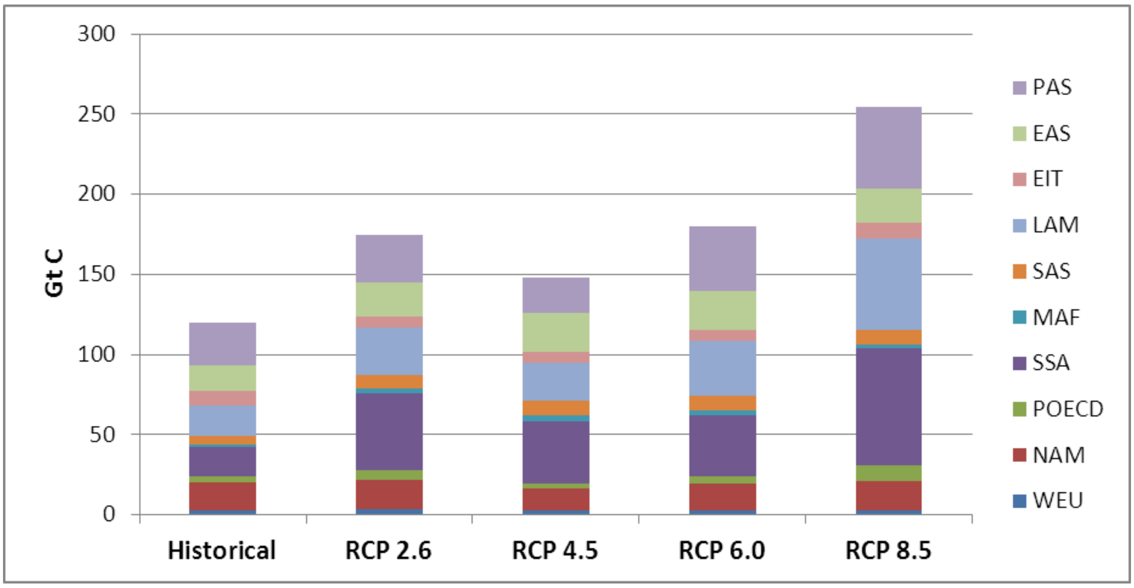

Figure 14.12. Regional Emissions of CO_2 from Agriculture, Forestry and Other Land Use. The four Representative Concentration Pathways (RCPs) developed for this Assessment Report explore the implications of a broad range of future greenhouse gas concentration trajectories, resulting in a range of radiative 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.

Mitigation options in the AFOLU sector mainly focus on reducing GHG emissions, increasing carbon sequestration, or using biomass to 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 in order 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 RCP regions and all AFOLU measures, ASIA shows the largest economic mitigation potential, both in forestry and agriculture, followed by LAM, OECD90, MAF and REF. Reduced deforestation dominates the forestry mitigation potential in LAM and MAF, but shows very little potential in OECD90 and REF. Forest management, followed by afforestation, dominate in OECD90, REF 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 OECD90 (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 RCP4.5 implying the most ambitious reductions. Reducing the gap between technical potential and realized GHG 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 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 (González-Zeas et al.; Cooper et al., 2008).

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, 1998b; Davison et al., 2000; Lee and Kim, 2001; Perkins, 2003; Gallagher, 2006; Ockwell et al., 2008; Walz, 2010; Watson and Sauter, 2011a; 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, 1998b; Perkins, 2003; Unruh and Carrillo-Hermosilla, 2006; Watson and Sauter, 2011a; 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, 2011b). The increasing specialization in global markets can make it increasingly difficult for developing countries to gain access to external knowledge (Watson and Sauter, 2011c). 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, 1998b; Dantas, 2011b; 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, 2011a). 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 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.

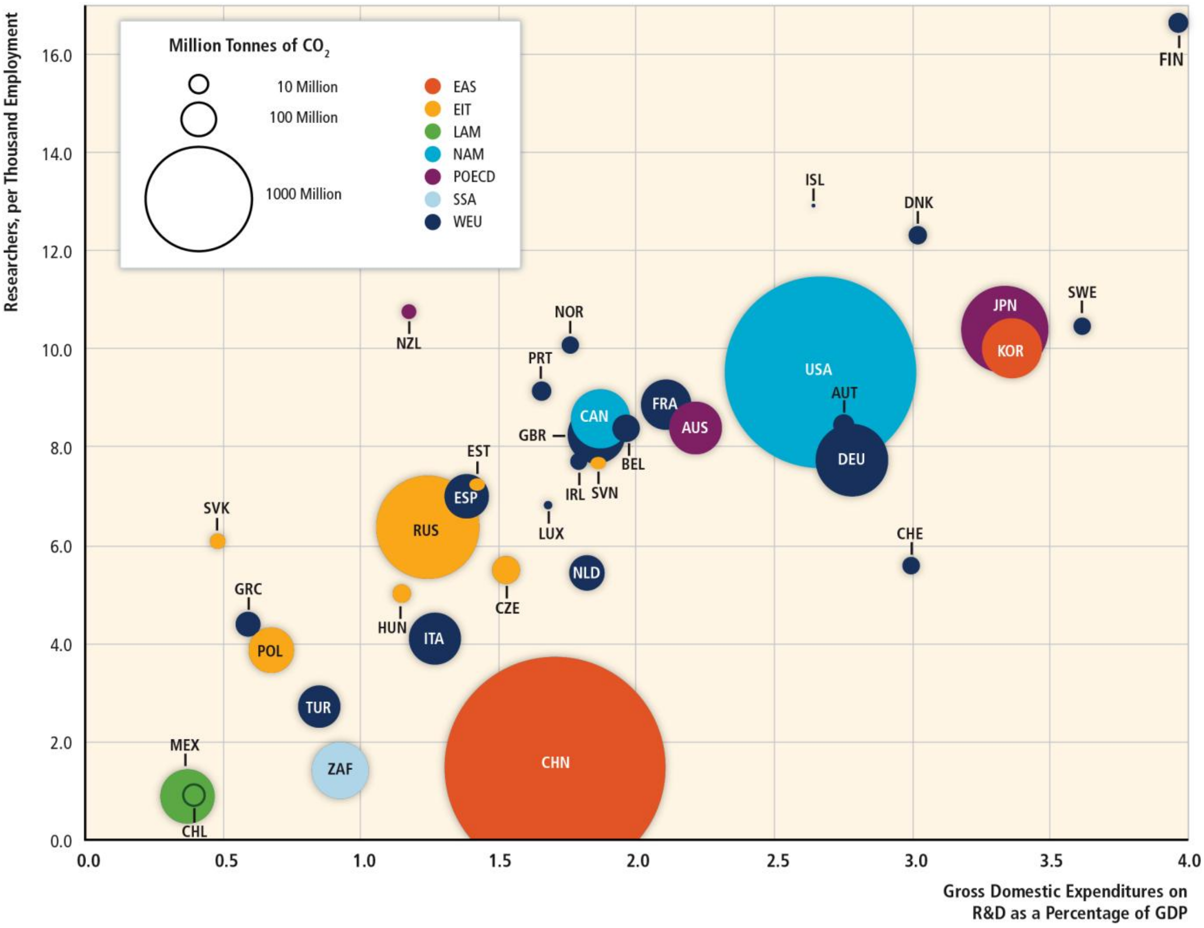

Figure 14.13. Emissions Contribution and Innovative Capacity: Regional Comparison. Source: Data on researchers and R&D expenditures as percentage of GDP from the OECD Main Science and Technology Indicators Database (OECD, 2011b); CO2 from fossil fuels are for 2009 (IEA, 2011).

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 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 NREL and 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 UNFCCC at COP 17 as part of the Cancun Agreements. The CTCN, confirmed during COP 18 in Doha, is jointly managed by UNEP and 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.

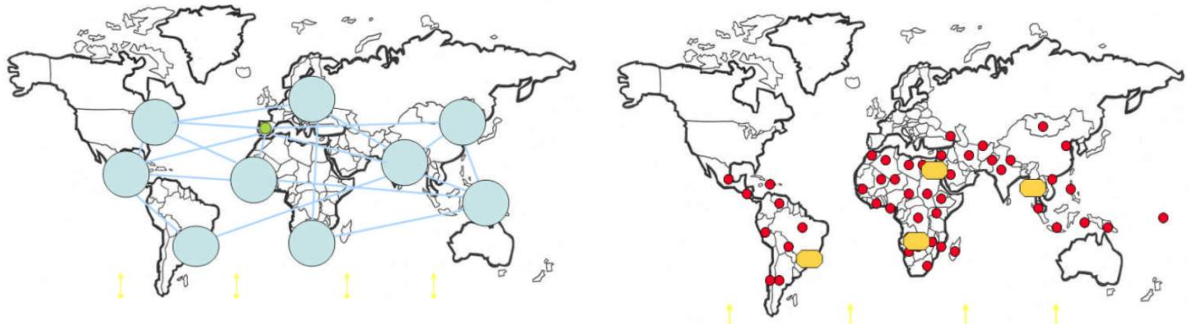

Figure 14.14. Options for Regionally-Coordinated Climate Technology Networks. Map on the left illustrates a network of climate technology RD&D centers (blue circles) with a small secretariat (green circle); map on the right illustrates a network of climate technology RD&D centers with national hubs (red dots) and regional centers (yellow shapes). Source: (Cochran et al., 2010, pp. 35–36).

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 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). Here, we assess regional differences in use of public finance instrument 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 the last two years (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. Her 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.

For CDM programmes of activities that allow bundling an unlimited number of projects, the distribution differs markedly. According to the UNEP Riso Centre (2013), SSA's share is ten times higher than for ordinary CDM projects, while EAS and SAS's share are a third lower. LAM'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 Joint Implementation (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.

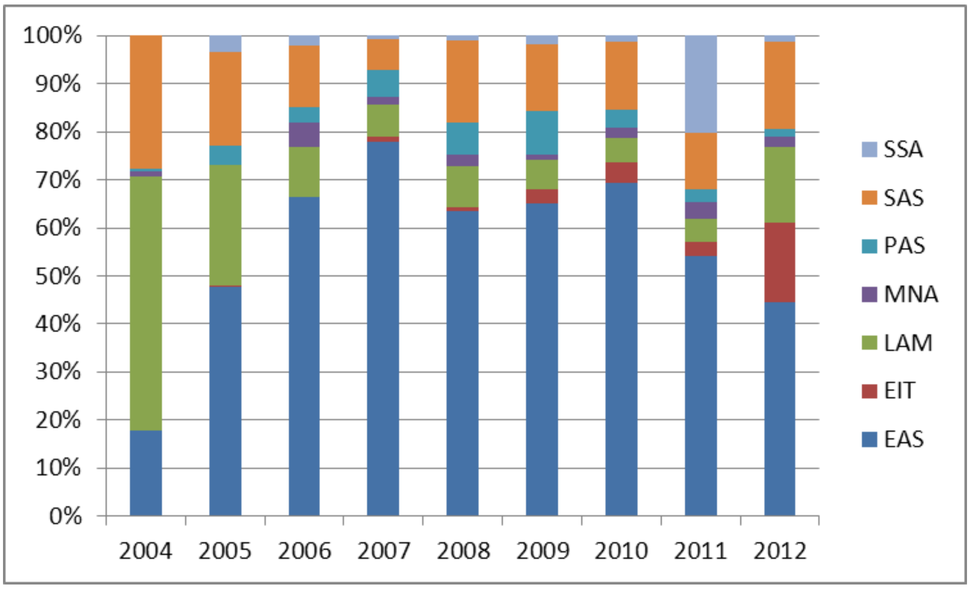

Figure 14.15. Regional Distribution of Pre-2013 Credit Volumes for Annual CDM Project Cohorts Raw data source: (UNEP Risoe Centre, 2013)

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 (3.1 billion $ in total) 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 $ funds pledged by September 2011, 53% came from Asia, 37% from Europe, 9% from North America and 1% from Australasia. Of 3.1 billion $ 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 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).36 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+ initiative 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 promote sustainable forest management (den Besten et al., 2013) (see also chapter 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.

In what follows, we distinguish 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 trade-offs and synergies between adaptation, mitigation and development at the regional level. Questions addressed in this chapter are 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 Chapter 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 greenhouse gas- 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 chapter 13).

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.

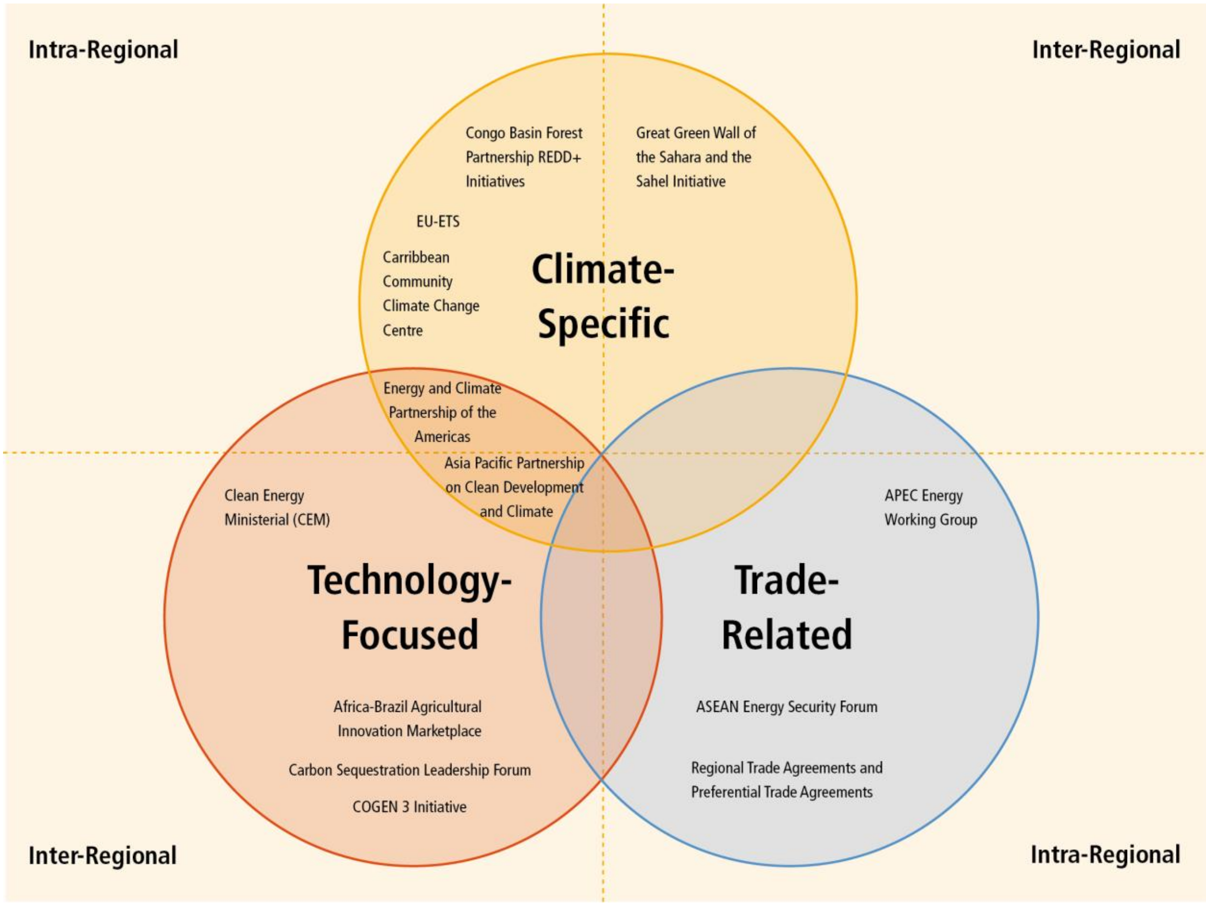

Figure 14.16. Typology of regional agreements with mitigation implications. Figure includes selected regional agreements only, and is not comprehensive. While not all agreements fit into the typology presented in this diagram, many do.

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 they survey, 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 Ch. 15 for a discussion of such instruments), only emission trading systems have been applied on a regional scale: the EU Emissions Trading Scheme (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 US and provinces in Canada and now includes just California and Quebec (see Chapter 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 supra-national 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 one could add regional collaboration in the framework of the UNFCCC (e.g. the CG 11 of Eastern European countries in transition or the African Group). An evaluation of these initiatives follows below.

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 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 30 €, which was unexpected by analysts, and in the 2005-2007 pilot phase triggered emission reductions estimated from 85 Mt CO_2(Ellerman and Buchner, 2008) up to over 170 Mt CO_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 t CO_2 p.a.) 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 Mt CO_2 and an allowance surplus for the entire 2008-2012 period.

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 : (i) the financial and economic crises (Neuhoff et al., 2012; Aldy and Stavins, 2012), (ii) the change of offset regulations (Neuhoff et al., 2012), (iii) the interaction with other policies (Fankhauser et al., 2010; Van den Bergh et al., 2013), and (iv) 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 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 Mt CO_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 stabilized prices until late 2011. Nonetheless, since then the price has again dropped and the surplus has reached approximately 2 billion tonnes /CO_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 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 then in turn generated pressure on the price of EU allowances (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 which share of the price decline is due to expansion of renewable energy and improvement of energy efficiency. Chapter 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 €/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 (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. Some studies indeed find that pricing carbon would decrease oil wealth(Haurie and Vielle, 2011).[3] These findings are consistent with the literature which was reviewed in AR4. 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. Several studies suggest that the effect of climate policies on oil wealth and export revenues is found to be negative in most studies(McCollum et al.; IEA, 2009; Haurie and Vielle, 2011; Bauer et al., 2013a; b; Tavoni, 2013). However, some studies find that climate policies would increase oil export revenues of mainstream exporters by pricing carbon-intensive unconventionals out of the market (Johansson et al.; Persson et al., 2007; Brandt, 2012). See also Section 6.3.6.6.

In what follows, 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 (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 towards 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 renewable energy sources (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 energy efficiency

[3]See also Chapter 13 for a discussion on how the carbon market and a burden sharing regimes could be used to offset the possible decrease in export revenue for fossil exporters.

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 Mt CO_2-eq 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 energy efficiency 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 energy efficiency 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.

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); 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 energy efficiency 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.

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 GHG 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. Via 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)).

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 (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 (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 (e.g. (Zarsky, 2010; Nyatichi Omambi et al., 2012)).

Regional cooperation on energy efficiency standards and labeling

Standards and labels (S&L) for energy efficient products are useful in accelerating market transformation towards more energy efficient technologies. Energy efficiency standards and labeling programs help, for instance, reducing consumption of fossil fuels (e.g. diesel) for electricity generation. Also, when applied to biomass-based cook stoves, standards and labels help decreasing the use of traditional biomass for cooking (Jetter et al., 2012). Standards and labeling 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 Labeling 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 standards and labeling throughout EU member states and harmonization efforts on energy efficiency standards and labeling between the U.S, Canada and Mexico as 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 ECOWAS regional initiative on energy efficiency standards and labeling (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 adaption 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 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 European Union (EU), the North American Free Trade Agreement (NAFTA), the Southern Common Market (MERCOSUR), the Association of Southeast Asian Nations (ASEAN) and the Common Market of Eastern and Southern Africa (COMESA). RTAs 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. (2011) argue that PTAs can include provisions on establishment of emissions trading schemes (ETSs) with mutual recognition of emissions allowances (i.e. linking national ETSs in a region) and carbon-related standards. In promoting climate 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 processes and production methods (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 climate 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 Chapter 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 trade-offs 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 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 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 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 Association of Southeast Asian Nations (ASEAN) is a particularly active region in organizing initiatives focused on energy technology cooperation that may contribute to climate 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 (Phillipine DOE, 2012). 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 (Phillipine DOE, 2012). 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 greenhouse gases and air pollutants (USAID, 2007; UNESCAP, 2008; Cabalu et al., 2010; IEA, 2010a; b). 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, 2010b).

The Asia-Pacific Economic Cooperation (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).

The Economic Community of West African States (ECOWAS) regional energy program aims to strengthen regional integration and to boost growth through market development in order 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. ECOWAS has recently expanded further energy access initiatives, that were launched by The Regional Centre for Renewable Energy and Energy Efficiency (ECREEE) (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 and 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 climate 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 Chapter 13 (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 climate 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 capture and sequestration 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 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, 2012).

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 Regional arrangements for a discussion of specific regional institutions). Development finance institutions channeled an estimated USD 76.8 billion (2010 USD) 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 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 USD 9 to 12 billion in 2006, and projected that these flows would surpass USD 15 billion by 2020 ((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 USD 52.8 million in 2006 (Buchner et al., 2011).

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, 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, labeling, 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 trade-offs 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 AR5. In most chapters a 5-region classification is used that is consistent with the integrated assessment models (IAMs): OECD90, 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 OECD90 members (Japan, Aus, NZ) (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 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 greenhouse gas emissions, underscoring significant differences in socio-economic contexts, energy endowments, consumption patterns, development pathways and other underlying drivers that influence greenhouse gas 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 pay 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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