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

Chapter 14

Regional Development and Cooperation

Chapter:	14	
Title:	Regional Development and Cooperation	
(Sub)Section:	All	
Author(s):	CLAs:	Shardul Agrawala, Stephan Klasen
	LAs:	Roberto Acosta Moreno, Leonardo Barreto-Gomez, Thomas Cottier, Alba Eritrea Gámez-Vázquez, Dabo Guan, Edgar E. Gutierrez-Espeleta, Leiwen Jian, Yong Gun Kim, Joanna Lewis, Mohammed Messouli, Michael Rauscher, Noim Uddin, and Anthony Venables
	CAs:	Kateryna Holzer, Peter Lawrence, Axel Michaelowa, Victoria Schreitter
Support	CSAs	Iris Butzlaff, Nicole Grunewald
Remarks:	Second Order Draft (SOD)	
Version:	1	
File name:	WGIII_AR5_Draft2_Ch14.docx	
Date:	19 February 2013	Template Version: 8

Table of changes

No	Date	Version	Place	Description	Editor
1	07.11.2012	01		SOD	Iris
2	10.12.2012	01		SOD (new compiled)	Iris
3	18.12.2012	01		SOD	Nicole
4	08.01.2013	01		SOD (included Dabo's part)	Iris
5	31.01.2013	01		Almost SOD	Nicole
6	01.02.2013	01		SOD	Iris

COMMENTS ON TEXT BY TSU TO REVIEWER: This Chapter has been allocated 40 template pages, currently it counts 55 pages (excluding this page and the bibliography), so it is 15 pages over target. Reviewers are kindly asked to indicate where the chapter could be shortened.

Chapter 14: Regional Development and Cooperation

Contents

Executive Summary

1. Regions matter for greenhouse gas (GHG) emissions and the achievement of mitigation objectives for two distinct reasons:

   1.1. First, regions manifest vastly different patterns in the level, growth and composition of GHG emissions. This underscores significant differences in socio-economic contexts, energy endowments, consumption patterns, development pathways, and other underlying drivers of GHG emissions, and therefore in the mitigation options and pathways that regions face (Sections 14.1 and 14.2 , high agreement, robust evidence). We call this the 'regional heterogeneity' issue.

   1.2. Second, most literature finds that regional cooperation, including the creation of regional institutions, has been a powerful force in global economics and politics. This is manifest in numerous agreements related to trade and technology cooperation, as well as trans-boundary agreements related to water, energy, transport, etc. (medium agreement, robust evidence). This chapter examines the extent to which these forms of cooperation have already had an impact on mitigation and to what extent they could play a role in achieving mitigation objectives (Section 14.3). We call this the 'regional cooperation issue'.

2. This chapter only examines supra-national regions (sub-national regions are examined in Chapter 15). Patterns of regional heterogeneity are examined using ten world regions that are defined based on economic and geographic proximity: Latin America and Caribbean (LAM); North America (USA, Canada) (NAM); East Asia (China, Taiwan, Korea, Mongolia) (EAS); Western Europe (WEU); Pacific OECD90 (Japan, Aus, NZ) (POECD); Sub Saharan Africa (SSA); Middle East and North Africa (MNA); South Asia (SAS); Economies in Transition (Eastern Europe and former Soviet Union) (EIT); South-East Asia and Pacific (PAS). Regional cooperation, meanwhile, is examined through actual examples that bear upon mitigation objectives, which do not typically conform to the above mentioned world regions.

Regional Heterogeneity

3. It is widely recognized that mitigation challenges differ dramatically by region. 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 and the build-up of industries. Their mitigation challenge relates to choosing among development paths with different mitigation potentials. Due to their low-carbon intense economies and geographical endowments, these countries have more opportunities to leapfrog to low-carbon development paths. Emerging countries in South and East Asia (and possibly Latin America), which are further along the way of carbon-intensive development, have greater capacity 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 quickly installing new capacity, but they will also face lock-in effects once decisions have been made. In industrialized countries the opportunities to leapfrog are small and the main challenge will be to drastically re-orient existing development paths towards lower carbon intensity of production and consumption. This shows that opportunities for mitigation differ greatly by region, with poorer regions generally offering greater opportunities to leapfrog to low-carbon development paths (high agreement, medium evidence). This heterogeneity across regions is reflected in the results of the regional modeling exercises on transformation pathways that are reviewed in this chapter.

4. Most literature suggests that opportunities for low-carbon development (including renewable energy options, low-carbon urbanization and low-emission land use) are typically very costly in terms of capital, skills, technology and institutional quality (medium agreement, medium

evidence). Poorer developing regions, including most Least Developed Countries (LDCs), are generally very poorly endowed with these factors, so their ability to seize these opportunities is limited and costs of delaying installing new capacities are substantial. While the mismatch between opportunities and capacities varies across sectors and countries, it implies that in a business as usual scenario many developing regions cannot implement low-carbon development strategies (medium agreement, medium evidence). At the same time, some regions face mitigation options with low or even negative cost, e.g. related to removing energy subsidies or reducing deforestation.

5. As a result, successful mitigation strategies that aim towards low-carbon development in poorer developing countries will have to tackle capacity issues. These relate to technology development and transfer, financial transfers, capacity building and measures to support institutional quality. The literature suggests that there is only limited evidence that to date this is happening effectively and to the extent required (medium agreement, medium evidence).

6. An extensive literature has emerged on the integration of climate change policies into sustainable development policies, including on possible synergies and trade-offs between mitigation and adaptation at conceptual and sectoral levels. However, at present there is not enough literature to assess these possible synergies and trade-offs in sufficient depth at a regional level. Moreover, some examples in the literature indicate difficulties to achieve the possible benefits of these interlinkages. This confirms the need of specific national, regional and international policies and actions to help harnessing mitigation and adaptation synergies (medium agreement, limited evidence).

Regional Cooperation

1. Many regional cooperation structures have initiatives to address mitigation challenges. Some have moved very far in setting clear and binding mitigation goals and targets. Due to its advanced stage of regional integration, the European Union – with the EU Emissions Trading Scheme (ETS) and various directives related to mitigation – has gone furthest in putting binding mechanisms in place to achieve mitigation objectives; in other regions, there are also some initiatives related to mitigation that have not gone as far in terms of binding commitments.

2. Based on the current assessment, most literature suggests that climate-specific regional cooperation agreements have not played an important role in addressing mitigation challenges to date (medium agreement, medium evidence). To some extent this is not surprising, given the level of regional integration and issues related to the transfer of sovereignty to supra-national regional bodies. Even in areas with deep regional integration, mechanisms to promote mitigation (including the EU-ETS) have not been as successful as anticipated in achieving intended mitigation objectives (high agreement, robust evidence). Nonetheless, theoretical models and past experience suggest that there is substantial potential to increase the role of climate-specific regional cooperation agreements (high agreement, medium evidence). In this context it is important to consider carbon leakage of regional initiatives and ways to address it; a subject that is discussed controversially in the literature (medium agreement, medium evidence).

3. Climate-specific regional cooperation using regulation-based approaches, including EU directives on energy efficiency, renewable energy, and biofuels, have had some impact on mitigation objectives, although there is more potential than has been realized (medium agreement, medium evidence).

4. In addition, non-climate-related modes of regional cooperation could have significant implications for mitigation, even if mitigation objectives are not a component of current policies and agreements (medium agreement, medium evidence).

5. Forms of regional cooperation with non-climate-related objectives but possible mitigation implications, such as trade agreements, cooperation on technology transfer, and cooperation on infrastructure and energy, have to date also had negligible impacts on mitigation.

6. Going forward, regional mechanisms have some potential to contribute to mitigation goals. In particular, these mechanisms have provided different models of cooperation between countries on mitigation, 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 (medium agreement, medium evidence).

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 existing modes of regional cooperation, ranging from regional initiatives focused specifically on climate change (such as the emissions trading scheme of the EU) to regional trade agreements and 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 14.3 will examine current development patterns and goals and their emission implications at the regional level. In this context, this section will discuss the issues of energy and development, urbanization and development, and consumption and production patterns in the context of development. Section 14.3 will also examine opportunities and barriers for low carbon development by examining policies and mechanisms for such development in different regions and the different sectors. It will also analyze issues surrounding technology transfer, investment and finance. Section 14.4 will then evaluate existing regional arrangements and their impact on mitigation, including climate-specific as well as climate-relevant regional initiatives. In this context, examples of links between mitigation, adaptation and development will be discussed. Also, the experiences of technology transfer and leapfrogging will be evaluated. Lastly, Section 14.5 will formulate policy options.

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 actors in the policy arena.

We should note from the outset that there 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

Thinking about mitigation at the regional level matters for two reasons. First, as detailed in Section 14.3 , mitigation challenges differ greatly by region. This is particularly the case for the interaction between development/growth opportunities and mitigation policies, which are closely linked to resource endowments, achievement in human development, 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.

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 risks associated with the need to adapt to climate change, 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, given 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, 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.

There is a second reason why regions matter. For many decades, regional integration has been a powerful force in the global economy and politics, and has brought opportunities for cooperation, resource sharing, etc. 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 to promote a carbon trading scheme. Others have focused on trade integration, which might have repercussions on the mitigation challenge. Many regional initiatives have also been supported by regional development and aid initiatives. It will be critical to analyze to what extent these regional activities have been able to effectively promote mitigation activities and what options exist to build on platforms of regional cooperation to achieve mitigation objectives.

This report will treat regions in two ways: as aggregations of countries to highlight the heterogeneous nature of the mitigation challenge, and as actors of cooperation and integration that could further promote mitigation. The first part of the chapter will adopt the first view, while the second half (starting with Section 14.4) will focus on regional cooperation and its potential effect on mitigation activities.

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. As the focus of the chapter will be on development and mitigation, developing country regions will be discussed in greater detail, as the range of challenges and opportunities are greater and less studied in the overall report. We will also include a discussion that emphasizes the particular challenges of Least Developed Countries (LDCs) (according to the official United Nations classification). As the interaction between development and mitigation is also a challenge for industrialized countries, this group of countries will also be examined.

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: Latin America and Caribbean (LAM); North America (USA, Canada) (NAM); East Asia (China, Taiwan, Korea, Mongolia) (EAS); Western Europe (WEU); Pacific OECD90 members (Japan, Aus, NZ) (POECD[1]); Sub Saharan Africa (SSA); Middle East and North Africa (MNA); South Asia (SAS); Economies in Transition (Eastern Europe and former Soviet Union, EIT); South East Asia and Pacific (PAS). These regions can, with very minor deviations, readily be aggregated to regions used in scenarios and integrated assessment models (IAMs) (e.g. the so-called RCP regions). They are also consistent with commonly used World Bank socio-geographic 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 defines regions itself. The LDC region is orthogonal to the above regional definitions and includes countries from SSA, SAS, PAS and LAM.

FAQ 14.1. How are regions defined in the AR5?

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. 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. We provide a more disaggregated view, which considers economic similarity and geographic proximity. This chapter considers the following 10 regions: Latin America and Caribbean (LAM); North America (USA, Canada) (NAM); East Asia (China, Taiwan, Korea, Mongolia) (EAS); Western Europe (WEU); Pacific OECD90 (Japan, Aus, NZ) (POECD); Sub Saharan Africa (SSA); Middle East and North Africa (MNA); South Asia (SAS); Economies in Transition (Eastern Europe and former Soviet Union) (EIT); South-East Asia and Pacific (PAS). 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.

[1] In some parts of the report, POECD is referred to as JPAUNZ. This will be standardized in later versions.

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 concerns relate 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 in societies (McCarthy et al., 2001).

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, mitigation challenges and the associated mitigation/development trade-offs differ greatly by region. This is particularly the case for the interaction between development/growth opportunities and mitigation policies, which are closely linked to resource endowments, achievement in human development, 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.

Second, for many decades regional integration has been a powerful force in the global economy and politics. From loose free trade areas in many developing countries to deep integration involving monetary union in parts of 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 (within or outside the framework of a global agreement). Some regions, most notably the EU, already cooperate to promote a carbon trading scheme and to devise regional policies on renewable energy and biofuels. Others have focused on trade integration, which might have repercussions on the mitigation challenge. Many regional initiatives have also been supported by regional development and aid initiatives. It will be critical to analyze to what extent these regional activities have been able to effectively promote mitigation activities and what options exist to build on platforms of regional cooperation to implement mitigation actions.

Figure 14.1 shows that regions differ greatly in development outcomes such as education, human development, unemployment and poverty. Generally, levels of education (Figure 14.1b), life expectancy (Figure 14.1c), poverty, and the Human Development Index (Figure 14.1d) are particularly low in SSA and LDCs. Unemployment (Figure 14.1a) is quite high in SSA, LDCs, MNA, and EIT, making employment-intensive economic growth a high priority there (Fankhaeser 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. 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 difficult 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.

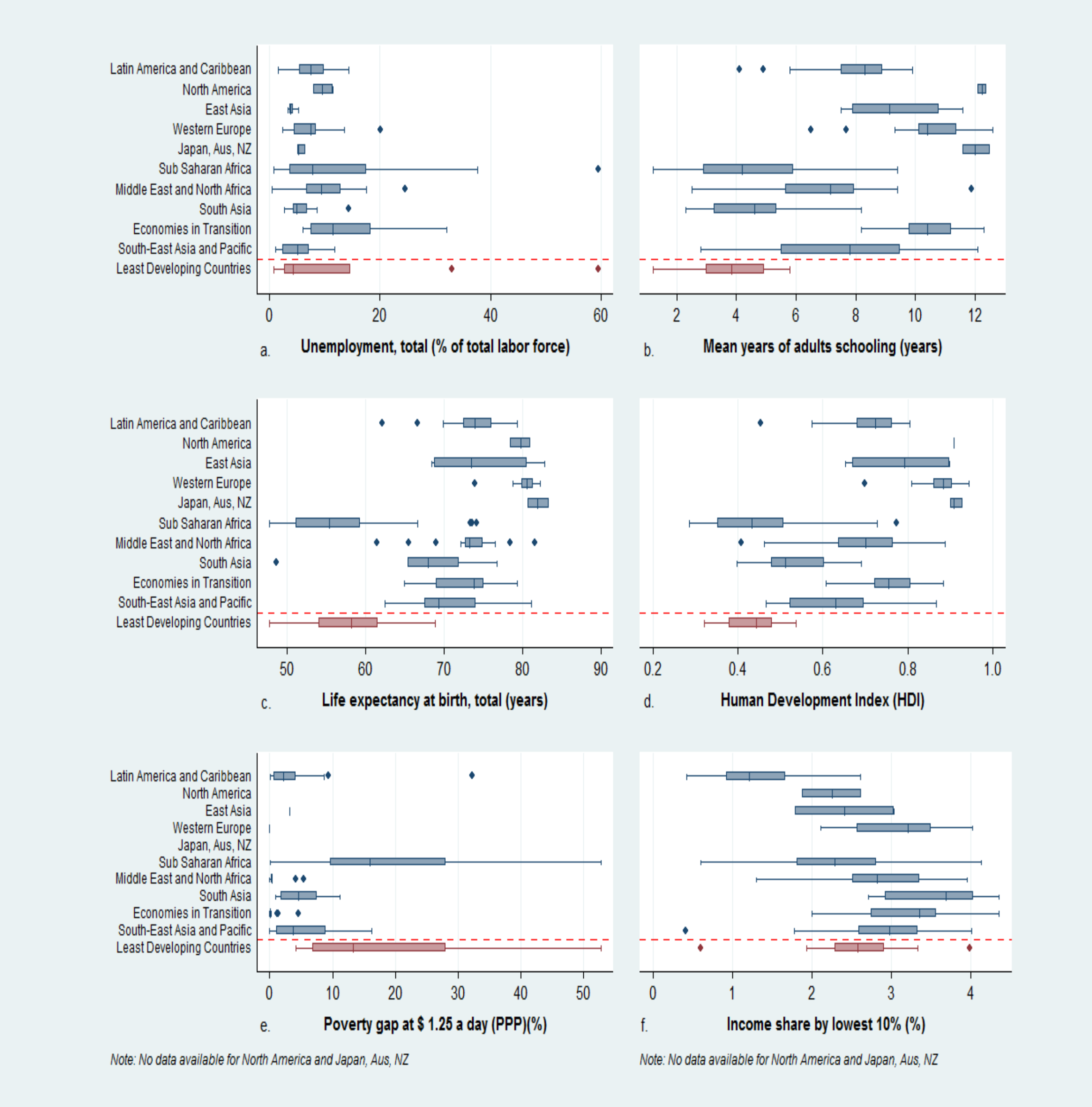

Figure 14.1. Social provisions enabling regional capacities to embrace mitigation policies

Note: 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 absorb new technologies

Developing and adopting low-carbon technologies might be one way to address the mitigation challenge. However, the capacity to innovate 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.

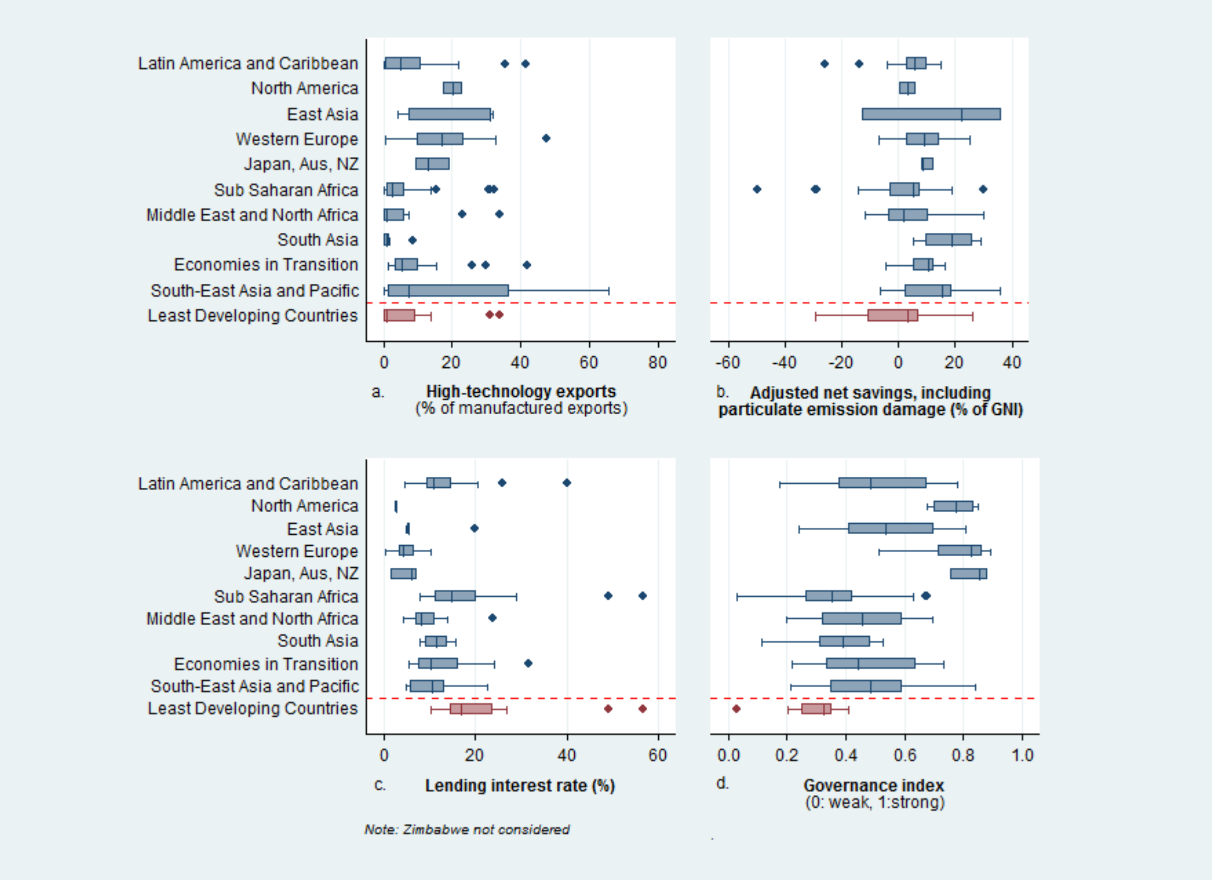

Figure 14.2. Economic and governance provisions enabling regional capacities to embrace mitigation policies

Source: (UNDP, 2010; World Bank, 2011). Statistics refer to the year 2010 or the most recent year available.

14.1.3.2 Other regional advantages and challenges

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 mitigation.

Conversely, there are different natural opportunities to promote mitigation activities. As discussed by Collier and Venables (2012a), it is particularly Africa which 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 financing and governance challenges are addressed. This may require international support.

In sum, regions differ greatly in their current state of development, levels of well-being, and ability to undertake mitigation efforts. Given these regional differences, the structure of multi-national or multi-regional environmental agreements affects their chance of success (Karp and Zhao, 2010). In this regard, 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). 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) and therefore put the sustainability of development at risk.

14.2 Development Trends and their Emission Implications at the Regional Level

14.2.1 Overview of Trends in GHG Emissions and their Drivers by Region

Global GHG emission has increased rapidly over the last two decades, from 37.7Gt CO_2 in 1990 to 47.7Gt CO_2 in 2008. In 1990, Economies in Transition (EIT) was the world's highest emitter of GHG emissions at 18.9% of global total of 37.7Gt CO_2, followed by North America (NAM, 17.9%) and Western Europe (WEU, 12.6%) and East Asia (EAS, 12.2%), with the rest of the world emitting less than 40%. By 2008, the distribution had changed remarkably. EAS became the major emitter with 23.5% of the global total of 47.7Gt CO_2. The rapid increase in emission 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 over the period from 1990 to 2008, broken down along three drivers: Emissions intensity, 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. The population growth also affected the emission growth but increase of GHG emission intensity per GDP contributed to lowering the growth rate of GHG emission. These tendencies are more or less similar in most of regions with some exceptions.

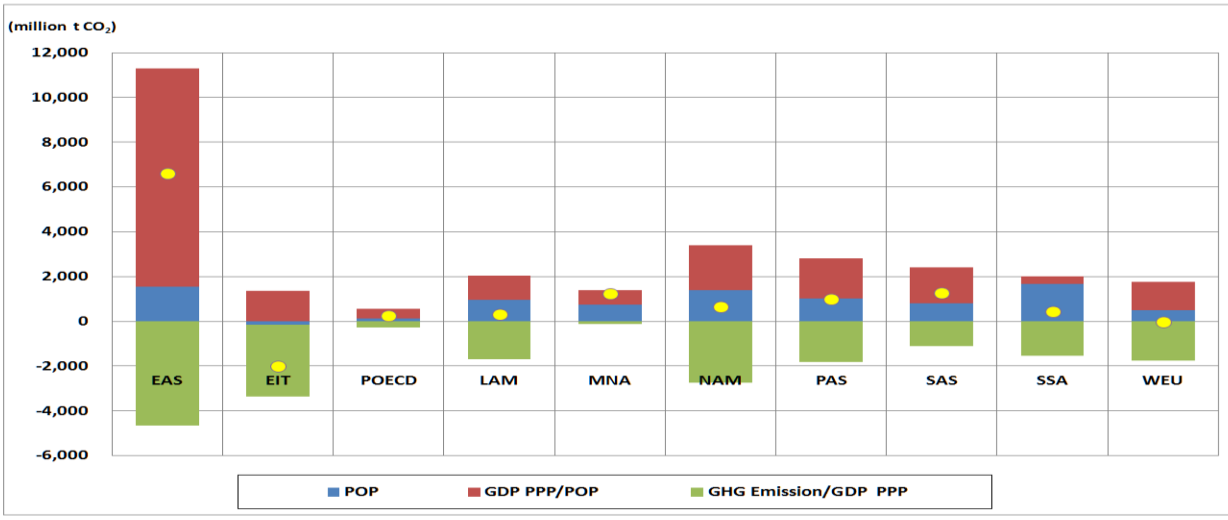

Figure 14.3. Decomposition of drivers for GHG emissions in different world regions

Note: The yellow dots indicate changing amounts of GHG emissions (1990-2008) and the bars, which are divided by three colors, show the increasing GHG emissions drawn by the Population, GDP per capita and GHG emission per GDP.

Source: GHG emission data from (Emission Database for Global Atmospheric Research (EDGAR) v4.2, 2011) and GDP ppp from (IEA, 2011).

Other ways to look at heterogeneity of regional GHG emissions are relative to the size of total population, the size of the overall economy and in terms of sources of these emissions. These elements are shown in the two panels of Figure 14.4. In 2008, NAM, POECD (Japan, Australia and New Zealand), EIT and WEU, taken together, had 20.5% of the world's population, but accounted for 40.7% of global GHG emissions, while other regions with 79.5% of population accounted for 59.3% of global emissions. The contrast between the region with the highest per capita GHG emissions (NAM) and the lowest (SAS: South Asia) is more pronounced: 5.1% of the world's population (NAM) emits 15.5%, while 22.6% (SAS) emits 6.4%. One of the important observations from Figure 14.4 (left panel) is that some regions such as SSA (Sub Saharan Africa) and PAS (South-East Asia and Pacific) have lowest levels of per capita emissions of CO_2 from non-forestry sources even though they have GHG emissions per capita that are comparable to other regions.

The cumulative distribution of emissions per GDP shows a strikingly different feature from the distribution of emissions relative to population (right panel of Figure 14.4). The four regions with highest per capita emissions, NAM, POECD, EIT 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 countries.

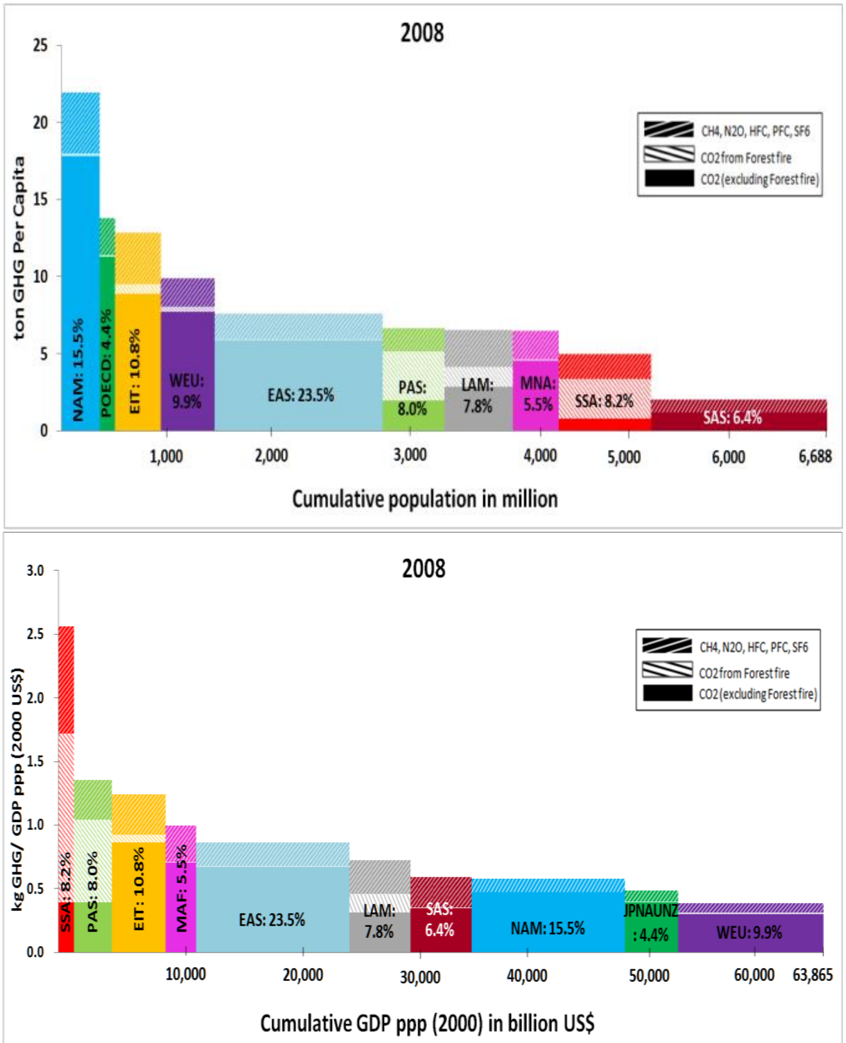

Figure 14.4. Distribution of regional GHG emissions in relation to population and GDP.

Note: The percentages in the bars indicate a regions share in global GHG emissions.

Data Source: GHG emission data from (Emission Database for Global Atmospheric Research (EDGAR) v4.2, 2011) and GDP ppp from (IEA, 2011).

14.2.2 Opportunities and Barriers for Low Carbon Development: Evidence from Regional Modeling Results

Global implications of mitigation scenarios are discussed in Chapter 6. In addition to the global studies, several multi-model exercises have explored regional approaches to mitigation. US EMF 22 (Fawcett et al., 2009) and US EMF 24 (Clarke, 2013) studies have evaluated a set of transitional scenarios for the U.S.A. Asian Modeling Exercise (AME) has addressed the scenarios for Asia (Calvin et al., 2012). EU EMF 22 (Böhringer et al., 2009) and EU EMF 28 (Knopf, De Cian, et al., 2013) focused on the European Union. While most attention of the global studies has been on the implications for the 21st century, most of the focus of the regional studies has been on the role of technologies and policy designs through 2050.

The US EMF 22 exercise addressed the following questions for the U.S. emission reduction paths to 2050: (1) what are the costs of different levels of emissions reductions? (2) How will the reductions be allocated across time? (3) How will reductions be allocated across sectors? And (4) what are the implications of climate policy for the energy producers and consumers? The costs of different levels of action can be measured in different ways and they vary across models. The study evaluated the household consumption loss. The annual average of the 2020 through 2050 per household consumption impacts in net present value terms translate the average impact of the emissions limits in future years on household consumption into an equivalent loss of household consumption today. Costs measured in this way range between $30 and $262 in the least-stringent scenario (keeping emissions constant to 2050), and between $606 and $1210 in the most stringent scenario (about 80% reduction in emissions in 2050 relative to 1990). Emissions reductions tend to increase over time as allowance prices rise, old existing capital stock retires, and technology advances. The models in the EMF 22 have shown that in the U.S. allowances are banked in the early years and that this bank is drawn down in the later years of the policy.

By design, a cap-and-trade system does not require equal emissions reductions from all sectors. Instead, the marginal cost of abatement is equalized across sectors, and sectors that have the most low-cost abatement opportunities provide the greatest amount of abatement. All of the models participating in the EMF 22 study show that in each of the scenarios analyzed, emissions reductions in the electricity sector are greater than those in the transportation sector. The imposition of climate policy substantially changes the U.S. energy system. All models show a substantial move towards low-carbon technologies, particularly within the electricity sector. By 2050, between 39% and 62% of total primary energy comes from low carbon sources in the mid-range policy scenario (50% reduction in emissions in 2050 relative to 1990) compared to between 12% and 28% in the reference (no policy) scenario. Low-carbon technologies play a greater role in the electricity sector, and their share of generation in the mid-range scenario is between 79% and 97% in 2050, compared to between 24% and 40% in the reference scenario.

The range of additional issues analyzed include: the effects of technology availability on costs and GHG reductions (Kyle et al., 2009; Paltsev et al., 2009); the importance of the assumptions about economic growth and technology costs (Paltsev et al., 2008; Blanford et al., 2009); the implications of the availability of offsets (Tuladhar et al., 2009); impacts on trade and emissions leakage (Ross et al., 2009); and the impact of complementary policies (Goettle and Fawcett, 2009).

The US EMF 24 exercise focused on technology strategies for the U.S. GHG emissions reduction. The main questions that are addressed are: (1) what would the U.S. energy system transition look like in a path of achieving 50% reduction in GHG emissions by 2050; (2) what are the potential implications of transportation and electric sector regulatory approaches?; and (3) how might the technological improvements and technological availability influence the energy transition?

The AME is a coordinated comprehensive scenarios analysis experiment across 23 models that addressed the development of Asia with and without climate policy. Asia contributed 44% to global energy consumption, 60% to world population, and about 50% to global CO_2 emissions in 2010.

Hence future development patterns in Asia are important to climate change and mitigation, yet are equally challenging to derive given the various demographic, economic, cultural and institution factors underlining their evolution. Baseline emissions pathways across the models in the comparison have indicated wide variations, particularly for emerging Asian economies, driven by differences in projections of income growth and the decline of energy intensity rates (Blanford et al., 2012). This uncertainty around baseline emissions has a first order impact on near term abatement requirements by Asian economies to meet a long-term global target. The observed variations in baseline scenarios and emissions across models have significant effects on mitigation costs and regional abatement potentials. In the baseline, models in the comparison exercise project a 1.5 to 3-fold increase in global emissions between 2005 and 2050, with the global per-capita emissions increasing to 4.8-7.9 tCO_2/year in 2050 on average and to 9-13 and below 2 tCO_2/year for China and India, respectively.

Under a cost-effective implementation of a 550ppm stabilization scenario, the model comparisons suggest that China, India, and Indonesia reduce emissions substantially below baseline trajectory. These results indicate that under a globally harmonized emission pricing policy the rapidly growing economies of Asia would assume a disproportionally high share of emission abatement, which underscores the importance of addressing burden sharing and compensation schemes when considering mitigation efforts by these countries.

Differences in mitigation potentials across regions in the AME are also explained by differences in fuel mix and technology patterns during the transition (Clarke et al., 2012). Yet, beyond some intuitive results such as the large proportion of low-carbon technologies deployed in Asia under mitigation scenarios and the relative lack of CCS in regions without substantial reservoir capacity such as Japan and Korea, there is no consistent technology story on Asia to tell across the models in the exercise. The absence of meaningful variations across regions in technology type and deployment is also a result of the use of a uniform instrument for mitigation across models and the lack of explicit representation of social, political, and institutional factors shaping the transition and national policy choices in the considered scenarios. On urbanization patterns, the results from the Asian modeling comparison exercise have shown large distributional impacts of urbanization with and between regions along the simulated economic pathways, but little impacts on CO_2 emissions and radiative forcing (Grieshop et al., 2011).

The scope of AME was further extended to compare the effects of national climate policies and measures that are currently being discussed or implemented in Asia. For the mitigation pledges under the Copenhagen Accord, the model comparison indicated that most of the models agreed that there is no need for new climate policy in India to achieve its pledge whereas for China a carbon price of \$30/t CO_2 in 2020 is sufficient to reach its target of reducing emission intensity by 40-45% in 2020 relative to 2005 (Calvin et al., 2012). In addition to the Copenhagen Accord the AME scenarios have explicitly explored the feasibility of emissions pathways consistent with 2^0 centigrade global stabilization target. The AME results demonstrate Asia's vital role in achieving this stabilization target, but also raises the challenge to come up with policy framework and implementation mechanisms that can align climate policy with regional development objectives in what came to be known as Low Carbon Society (LCS) development (Kainuma et al., 2012). Comparative assessment of modeling results under AME for Japan, China, India, Korea, and Nepal showed LCS options in these countries include energy efficiency, low-carbon energy supply, material recycling, and low-carbon infrastructure and that the deployment of these options requires a combination of taxes, subsidies, and technology transfer policies. AME has also contributed to the literature of climate mitigation co-benefits in Asia. Examples of AME studies that explored this issue are Dowling and Russ (2012), Shrestha and Shakya (2012), Van Ruijven et al. (2012), and Van Vliet et al. (2012). These papers find that mitigation leads, among others, to reduced energy imports and reduced air pollution.

The European Union (EU) commitments of reducing greenhouse gas (GHG) emissions to 80-95% below 1990 levels by 2050 are evaluated in several studies. EMF22 (Böhringer et al., 2009) has evaluated the short-term policies to achieve the 20-20-20 targets on the basis of a model comparison with 3 models. If implemented at the lowest possible cost, the 20% emissions reduction would lead to a welfare loss of 0.5–2.0% by 2020. Second-best policies increase costs. The models differ greatly in the detail of their results. The models agree, however, that the distortions introduced by total EU package imply a substantial welfare loss over and above the costs needed to meet the climate target.

The EMF28 model comparison project (Knopf, De Cian, et al., 2013) contributes to the recent debate on the EU long-term energy and climate policies until 2050. This model comparison is the first one to relate its results to those of the Energy Roadmap presented by European Commission in 2011 (European Commission, 2011a). In that context, the analysis compares a reference scenario where the EU reaches 40% GHG reduction by 2050 with a mitigation scenario in which GHG emissions are reduced by 80%.

The models suggest that reaching the ambitious targets of 80% GHG reduction by 2050 is possible: all models except one found a solution. The abatement costs indicate increasing costs with the level of ambition, while the benefits of mitigation have not been evaluated here. For 80% GHG mitigation, implementation is leading to only moderate GDP losses of less than 1% until 2030 and numbers slightly above 2% for 2040. However, in some models there is a sharp increase in costs after 2040 up to 10% GDP losses, while in some other models costs continues to increase roughly linearly.

EMF28 concludes that the short-term targets for 2020 with 20% GHG reduction are not consistent with the cost-minimizing pathways to the long-term target of 80% GHG reduction. Therefore, to facilitate the long-term transformation, a clear indication of binding targets for the period beyond 2020 would help investors to take the right strategic decisions. In addition, with setting targets for 2030 the EU would give a credible signal for their willingness to contribute to the global mitigation effort. Model results show that a 40% GHG reduction target for 2030 could be in line with the long-term endeavor of 80% reduction and is a kind of no-regret option.

Results on technologies for 80% mitigation can be summarized as following:

- A high level of energy efficiency is realized;
- biomass use shows a more than 3-fold increase between 2050 and 2010; non-biomass-renewables are also increased considerably; all renewable energies together will make up nearly 50% of the electricity generation (model mean); among non-biomass-renewables wind is the most important one with an 7-fold increase up to 2050 and reaching a similar deployment level as nuclear, while solar PV only reaches a limited share;
- Nuclear is constant or only moderately increasing over time, but continues to make an important contribution in the electricity sector;
- CCS is used to some extent but is not mandatory to reach the targets.
- As (intermittent) renewables, such as wind and solar PV, will contribute a major share to a future energy system with a share of 27% by 2050 (model median), balancing options are required. This would mean the development of long-term and medium-term storage options and/or the expansion of the European electricity grid and the increase of interconnectors between Member States (analyzed in (Von Hirschhausen and Holtz, 2013) with an analysis of infrastructure requirements).

In general, EMF28 supports the findings of the EC Energy Roadmap 2050.

Part of this model comparison also focused on the question of how the international climate regime may affect achieving European ambitions, i.e. investigating unilateral actions vs. a joint global mitigation strategy. De Cian et al. (2013) come to the conclusion that when the global CO_2 market opens up, the EU would operate as a buyer, suggesting a steeper MAC compared to other regions. Global trade reduces EU MAC significantly.

In the AMPERE model comparison on EU unilaterally vs. joint global action Schwanitz et al. (2013) study how badly or well it is when the EU starts stringent climate policies right away, hoping that the others will be inspired at some point.

In an analysis that goes deeper on a Member State level of the EU, Knopf et al. (2013) conclude that national preferences, potentials, and history and therefore the transformation strategies at Member State level differ substantially from the aggregated European energy mix e.g. of the Energy Roadmap of the European Commission. Comparing model results with the National Renewable Energy Action Plans (NREAPs) and national Roadmaps shows that models indeed capture national differences but that solar PV is considerable lower in the models. They argue that national preferences and policies and measures can have a considerable influence on the technology mix and should get more attention in order to facilitate the European energy transformation.

In general, regional studies have found that the costs of climate stabilization for an individual region will depend on the baseline development of regional emissions and energy use, the mitigation requirement, the emissions reduction potential of the region, and terms of trade effects of climate policy, particularly in the energy markets.

14.2.3 Energy and Development

14.2.3.1 Energy as a driver of regional emissions

Rapid growth in final energy consumption is occurring in many developing countries. Consequently, energy-related GHG emissions in developing country regions such as EAS, MNA and PAS in 2008 were more than double the level of 1990, while the GHG emission in EIT decreased by around 30%. The composition of energy consumption also varies by region. Oil is the dominant type of 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. A particularly strong increase of the share of electricity occurred in EAS, from 7.6% to 18.8% between 1990 and 2008. PAS and SAS also experienced the growth of electricity share from 6.2% and 6.9% to 12.3% and 12.1% respectively over the same period. The share of electricity, the most convenient energy to use, is highest in POECD, followed by the high-income regions NAM and WEU.

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 2008 has come from coal, followed by gas and oil. In this period, CO_2 emissions from coal grew by 3,767 Mt-CO_2 in EAS, which is equivalent to roughly half of the global net increase of CO_2 emissions from fossil fuel combustion. Oil is the dominant source of emissions in WEU, NAM, MAF and LAM, while coal has the largest share in EAS and SAS.

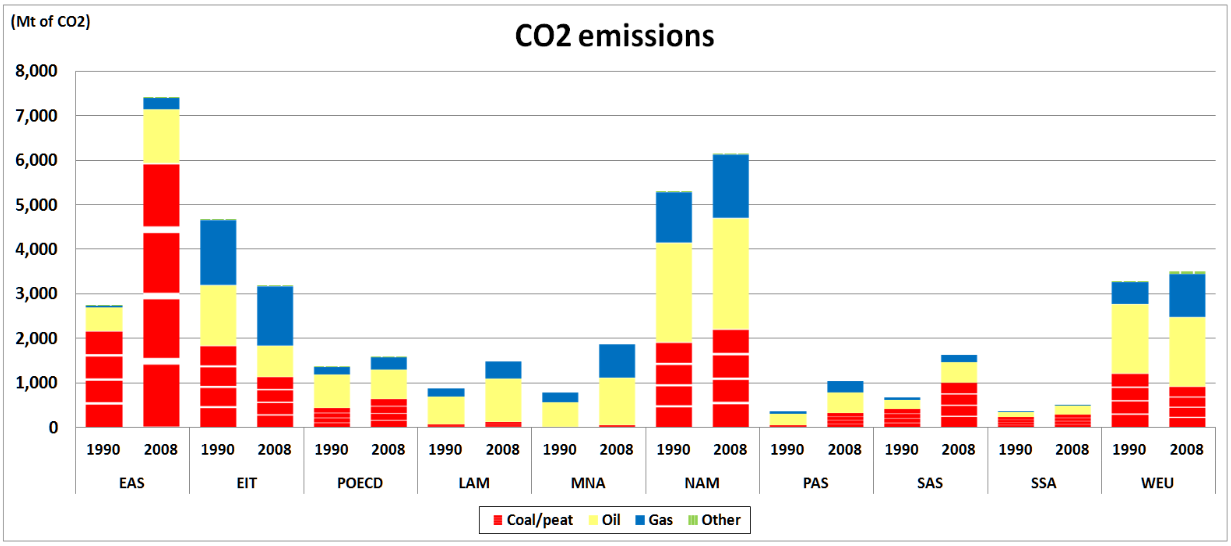

Figure 14.5. CO2 emissions by sources and regions

Source: (IEA, 2011)

Figure 14.6 shows the relationship between GHG emissions and development measured using per capita income levels. Individual regions have different starting levels and different directions and magnitudes of changes. It is hard to find a tendency of decreasing per capita emissions, regionally as well as globally. Developed regions (NAM, WEU, POECD) appear to have grown with stable per capita emissions, with NAM having much higher levels of per-capita emissions throughout. Carbon intensities of GDP tend to decrease constantly for most of regions as well as for the globe.

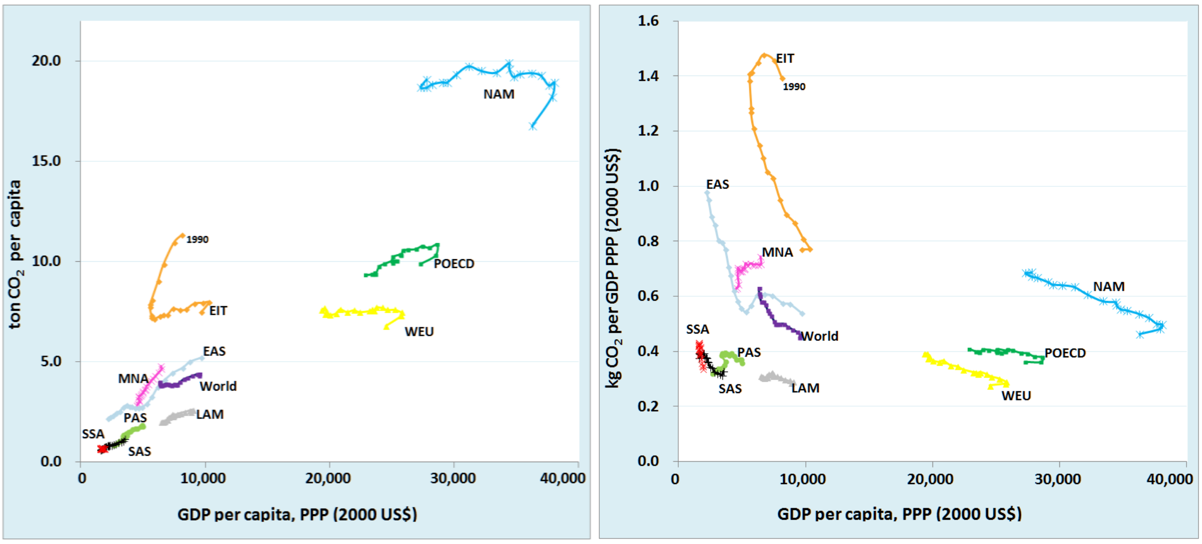

Figure 14.6. Relationship between emissions per capita and GDP per capita (1990-2009)

Data Source: (IEA, 2011)

Despite rising incomes and rising energy use, lack of access to modern energy services remains a major constraint to economic development in many countries and regions (Johnson and Lambe, 2009). About 1.4-1.5 billion people — over 20% of the global population — lack access to electricity in 2009 (International Energy Agency, 2010) and nearly 3 billion lack access to modern[2] cooking

[2] Modern fuels include natural gas, liquefied petroleum gas (LPG), diesel and renewables such as bio-diesel and bio-ethanol (Bazilian et al., 2012).

energy options (Zerriffi, 2011; Rehman et al., 2012). There is considerable variation in regard to energy access in countries and regions as shown in Table 14.1.

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 (JP, AUS NZ)	*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, North Korea, Macao, Burundi, Cape Verde, Central African Republic, Chad, Equatorial Guinea, Gambia, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Rwanda, Sierra Leone, Somalia, South Sudan, Swaziland, Djibouti, Malta, Turkey, West Bank and Gaza, Bhutan). For OECD and EIT, no data are listed but presumed to be 100% access; these are recorded in italics. Source:(World Bank, 2012).

The energy access situation is dismal in the LDCs (Chaurey et al., 2012). Of the world's 'energy poor'[3], 95% live in Asia and SSA (Rehman et al., 2012). Africa has the lowest electrification rate in the world at 26% of households, implying that nearly 550 million people in the continent are without access to electricity (Agbemabiese et al., 2012). SAS and PAS are characterized by high density populations with about 59.2% and 37.8%, respectively, of their total populations not yet having access to electricity (Urmee et al., 2009). This low access to electricity is compound by the fact that people rely on low quality biomass energy sources which results in indoor air pollution and about 1.5 million deaths per year – mostly women and children (Agbemabiese et al., 2012).

Rural areas in developing countries are suffering more than urban areas in terms of energy access as 41% of rural population do not have electricity access, compared to 10% of the urban population in developing countries (UNDP, 2009). The lack of access to electricity is much more severe in rural areas of LDCs (87%) and SSA (86%), especially compared to 41% in developing countries (UNDP, 2009). Table 14.2 shows the number of people without access to electricity in urban and rural areas. The greatest challenge is in SSA, where 79% of the rural population has no electricity access; this is the highest regional lack of electricity access in the world (International Energy Agency, 2010).

Although there are numerous factors that limit the expansion of access to energy services, the goal of achieving universal access to energy services by 2030 is taking shape (Hailu, 2012). To this end, about half of all developing countries (68 out of 140) have established targets for access to electricity (UNDP, 2009; Hailu, 2012).

While there are no fundamental technical obstacles preventing universal energy access, access is restricted due to a lack of effective institutions, good business models, transparent governance, and appropriate legal and regulatory frameworks (Bazilian et al., 2012). For example, innovation in energy access is necessary as conventional technologies and developing approaches cannot be relied

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

upon to eliminate energy poverty in Africa (Agbemabiese et al., 2012). In fact, when one accounts for not only the lack of access to modern sources of heating, cooking and lighting, but also productive energy, mechanical power, and mobility and transport, the number of those confronting energy poverty grows even higher (Sovacool et al., 2012). Energy access is beginning to acquire an important place in public policy debates at the national level (Sokona et al., 2012), and regions can play an equally important role.

Table 14.2: Number of People (Urban and Rural Areas) Lacking Access to Electricity in 2009 (million)

Region	Rural (%)	Urban (%)	Total Population
Africa	79	21	587
Developing Asia	90	10	799
China	100	0	8
India	94	6	404
Other Asia	85	15	387
Latin America	87	13	31
Developing countries*	85	15	1438
World**	85	15	1441

Source: (Kaygusuz, 2012) *includes Middle East countries, **includes OECD and transition economies

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

The above discussion shows that there are significant differences in opportunities and challenges for low-carbon development in the energy sector at the regional level. These differences arise from existing 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 (i.e. those within the region or country being studied) indicate the opportunity cost of different inputs. They affect the viability of different technologies and are therefore a guide to decision making. These local prices vary across regions and countries, and 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 features. First, they depend on the natural advantage of the region. For example, while some regions (such as SSA) are abundantly endowed with hydro or solar potential, others are less so. 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. Developing regions are, to varying degrees, scarce in all of these types of capital. Borrowing costs for developing countries are generally high, making it difficult to finance capital-intensive projects. Households and small enterprises find it difficult to access credit, and when they do may face borrowing costs in excess of 30-40% pa (see Section 14.2.7). Low levels of education and skill retard the adoption of new techniques and impede the operation and maintenance of technical equipment. Lack of government regulatory capacity creates barriers (a high shadow price) on running large scale or network investments that require a sophisticated legal and regulatory framework.

A number of features of energy production interact with local costs and thereby determine the extent of uptake of different technologies in different regions. In general, the high capital intensity of many renewable technologies (IEA, 2010a) makes them relatively expensive in many capital scarce developing economies. Skill requirements encounter shortages, particularly in developing countries (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 hydro, 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. State run 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. Third, if scale economies are very large, there are cross-border issues. For example, Africa is fragmented into small economies that have had difficulty agreeing cross-border power arrangements (see Section 14.3).

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. Discount rates (i.e. rates of social time preference) are high. Further delay in anticipation of future technical progress is therefore particularly expensive in developing regions.

While advanced countries may have better capacity to undertake mitigation, they also face a greater degree of lock-in in their energy systems that might imply higher costs. On the other hand, many developing countries may be able to leapfrog towards low carbon development, if they manage to build the financial and institutional capacity to implement such choices.

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. As can be seen in Table 14.3, energy subsidy levels vary substantially be region. In particular, in the MNA region as well as Economies of Transition, energy subsidies are very high in absolute terms (per person) and 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. Reducing those subsidies would reduce the carbon-intensity of growth and save scarce fiscal resources; this issue, as well as the political economy or fuel subsidies and fuel taxation, are discussed in more detail in Chapter 15.

Table 14.3: Average Energy Subsidies by Region in 2011

Region	Average subsidization rate (%)	Subsidy ($/person)	Total subsidy as share of GDP (%)
North America	0.00	0.00	0.00
Western Europe	0.00	0.00	0.00
Latin America and Caribbean	4.68	40.28	0.47
POECD (JPAUNZ)	0.00	0.00	0.00
Economies in Transition	10.14	114.26	3.05
Middle East and North Africa	30.05	799.78	4.22
East Asia	1.76	19.44	0.14
South Asia	15.38	23.00	1.84
South-Eastern Asia and Pacific	2.91	19.86	0.44
Sub-Saharan Africa	1.29	2.46	0.07

Note: We assume the subsidies to be zero for those countries for which the IEA does not report any subsidy rates. The averages are not weighted. Source: (IEA, 2012)

14.2.4 Urbanization and Development

14.2.4.1 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). Accompanying the changes in industrial structure and economic development, urbanization increases fossil fuel consumption and CO_2 emissions (Jones, 1991). 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).

Due to the regional variations in the relationship between urbanization, economic growth and industrialization, the impact of urbanization on carbon emissions differs remarkably across regions. 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. In SSA the per capita carbon emissions remained unchanged in the past four decades, while the urbanization level of the region almost doubled. 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 carbon emissions of developing countries are significantly lower than in developed countries, both in urban areas and the whole country (Figure 14.7 left panel). On the other hand, per capita emission of cities in developing regions is usually higher than the national average, while the relationship is reversed in developed regions (Grubler, forthcoming; Kennedy et al., 2009). 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. 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 (Martínez-Zarzoso and Maruotti, 2011).

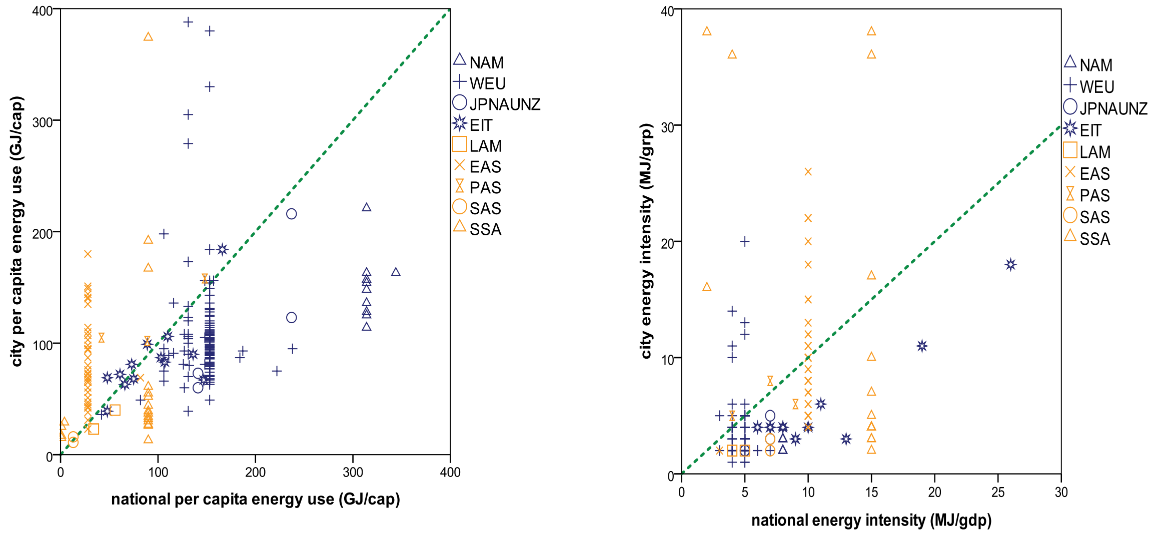

Figure 14.7. Per Capita Energy Use (left panel) and Energy Intensity (right panel) in Cities Compared with the National Average by Regions, 2000

Note: 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 (Grubler, forthcoming); (2) national energy data is from IEA energy balances (IEA, 2010b).

Studies reveal that developing regions and their cities have significantly higher energy intensity than developed regions (Figure 14.7, right panel). This is although their per capita energy consumption is generally lower, and 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. The energy intensities in cities of a country at any given urbanization level can differ substantially. Important factors that contribute to the varying energy intensities across cities are the different patterns and forms of urban settlements (Burchell et al., 1998) (see Chapter 12 for 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 (Kahn, 2000). Suburbanization in the US may also contribute to increasing residential fuel consumption and land use change (Bento et al., 2005).

14.2.4.2 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 all occur in cities of developing regions (United Nations, 2009). 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 (Jiang and O'Neill, forthcoming), these regions have great opportunities to develop energy-saving and resource-efficient urban settlements. For instance, if the African and Asian population increasingly grows 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, the same urbanization trend 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. The contribution from the already very urbanized NAM, Europe, developed Asia and Pacific, and LAM is limited. 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, while a growing urban population in developing regions will inevitably pose significant challenges to global mitigation, 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.

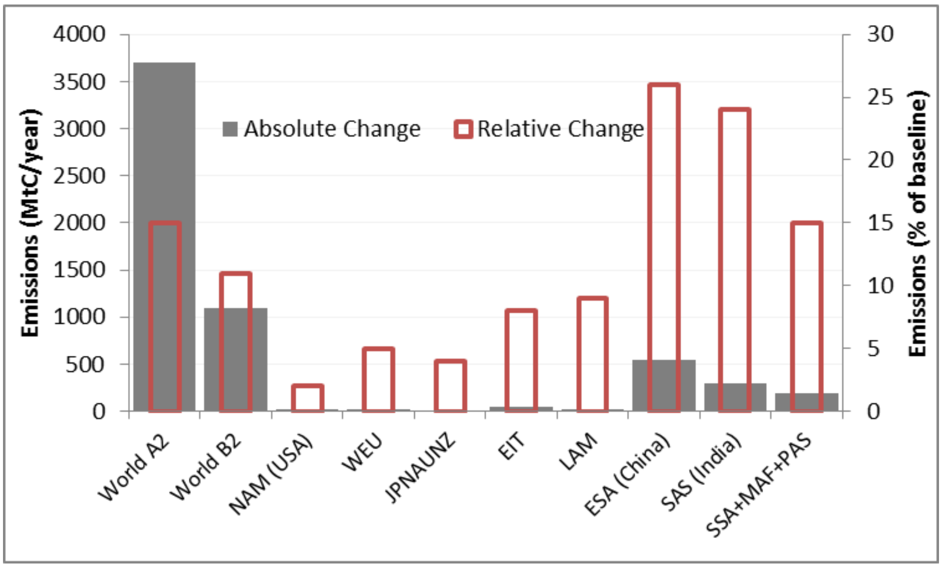

Figure 14.8. Impact of Urbanization on Carbon Dioxide Emissions in 2100 for the World under SRES A2 and B2 Scenarios and by Regions under SRES B2 Scenario

Note: This figure is based on (O'Neill et al., 2010). 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.

14.2.5 Consumption and Production Patterns in the Context of Development

Recall from Chapter 5, the difference between production and consumption accounting methods are: the former identifies the place where emissions occur and the latter investigates the driving forces of emissions discharged.

14.2.5.1 Consumption as a driver of regional emissions growth

Researchers have argued that the consumption-based accounting method (Peters, 2008) can provides a better understanding of the common but differentiated responsibility between countries in different economic development stages (Peters and Hertwich, 2008; Davis and Caldeira, 2010; Peters et al., 2011; Steinberger et al., 2012; Lenzen, Moran, et al., 2012). Consequently, a great 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, Marland, et al., 2012; Wiebe et al., 2012). Reviews of modelling international emission transfers are provided by Wiedmann et al. (2007), Wiedmann (2009) and Peters et al. (2012).

Methodologies, datasets and modelling techniques vary between studies, producing uncertainties of estimates of consumption-based emissions and measures of emissions embodied in trade. First, there are two methods in allocating embodied emission in trade - the emissions embodied in the bilateral trade (EEBT) method; and (b) the multi-region input-output (MRIO) method (see Chapter 5 for method description). In summary, the EEBT method considers domestic supply chains only and answers questions such as “how much of East Asian emissions are from the production of exported goods and services”? The MRIO method enumerates global supply chains and thus only considers imports to final consumers with trade in intermediate consumption calculated endogenously. The MRIO method answers questions like, “what are the global emissions from household consumption in North America”? Second, there are different datasets in constructing MRIO models and associated emission datasets. Many researches have used the Global Trade Analysis Project (GTAP) database version 7.1 (Narayanan and Walmsley, 2008) to construct MRIO table representing the world economy in 2004 (Hertwich and Peters, 2009). Recent MRIO modelling development includes WIOD - world input-output database (Timmer et al., 2012) and Eora MRIO database (Lenzen, Kanemoto, et al., 2012). Their modelling data sources are based on national input-output tables from different countries. WIOD provides a homogenised production sector (35 industries) for all 40 regions while Eora has kept the same industry sectors as national input-output tables for the 187 included countries and regions. Third, among models, various construction techniques have been applied. These include production sector aggregation and disaggregation (Lenzen, 2011; Lindner et al., 2012); avoid double counting in re-export / re-import (Dietzenbacher et al., 2012); price and deflation (Dietzenbacher and Hoen, 1998; Dietzenbacher and Wagener, 1999); and multiplier effects (Dietzenbacher, 1995) and balancing (Rey et al., 2004; Lenzen et al., 2009, 2010).

During the period 1990 – 2008, the consumption emissions of East Asia and South Asia regions grew in parallel by almost 5% - 6% annually from 2.5 to 6.5Gt and from 0.8 and 2.0Gt, respectively. The other developing regions observed a steadier growth rate in consumption emissions of 1% - 2.5% per year. Flourishing global trade, especially trade between developing countries, largely drives this growth. The transfer of emissions via traded products between developing countries grew at 21.5% annually during 1990 – 2008.

Per capita consumption emissions in developed regions are far larger than the average level of developing countries. However due to great lifestyle disparities within developing regions, 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, the average consumption emissions have increased 72%, 74% and 120% in South East Asia, South Asia and East Asia respectively. The growth is projected to be further accelerating (Hubacek et al., 2007; Guan et al., 2008). Per capita consumption emissions in least developed country regions have relatively small changed, which is a result of minimal improvements in their lifestyle. It is worth to mention that the per capita consumption emission in Sub-Sahara Africa has slightly decreased from 0.63t to 0.57t due to population growth.

14.2.5.2 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. If we focus 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 percentage values 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. 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). Producing exports have driven half of emission growth in China (Guan et al., 2009). 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.

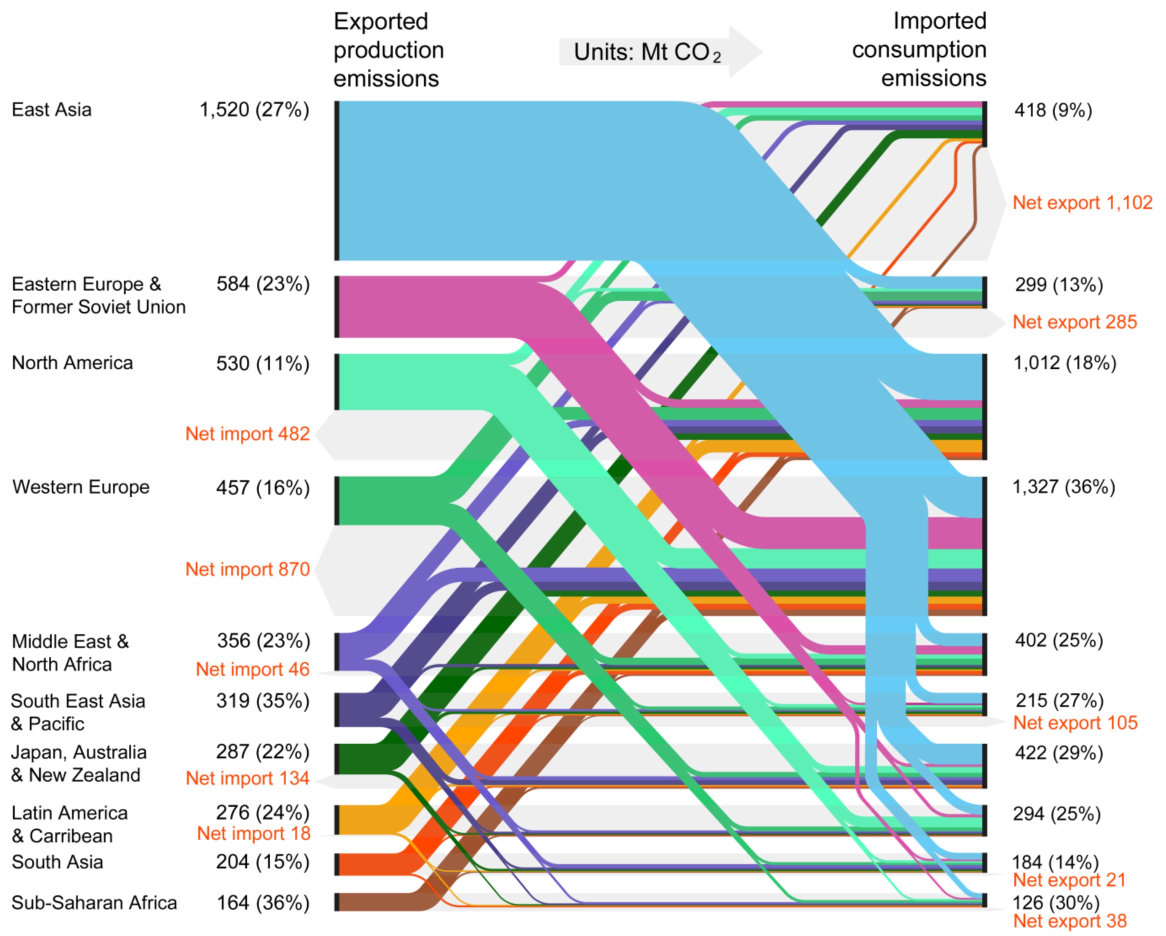

Figure 14.9. Net transfer of CO2 emissions (from fossil fuel combustion) between World regions in 2007 using MRIO method. Flow widths represent magnitude of emissions (in Mt CO2) released by left-hand-side regions that have become embodied (along global supply chains) in the good and services consumed by right-hand-side regions. Figures for total exported production emissions and total imported consumption emissions are given, and the difference between these two measures shown as either a net export or net import emissions transfer. Percentage figures on left-hand-side indicate total exported emissions as percentage of total industry production emissions, while percentage figures on right-hand-side indicate total imported emissions as percentage of total industry consumption emissions Analysis performed using multi-regional input-output model and emissions data derived from GTAP Version 8 database. Data reports global CO2 emissions of 26.5 Gt CO2 in 2007 (22.8 Gt from industry and a further 3.7 Gt from residential sources).

Figure 14.10 demonstrates (using the EEBT method) that the embodied CO_2 emissions in international bilateral trade between 10 aggregate world regions has grown by 2.5Gt during 1990 – 2008. Considering exports, half of global growth is accounted for by exports from East Asia (1366 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 global total. For example, the top three developing regions in terms of imported emissions are East Asia, South-East Asia and Pacific, and Latin America & Caribbean, which 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.

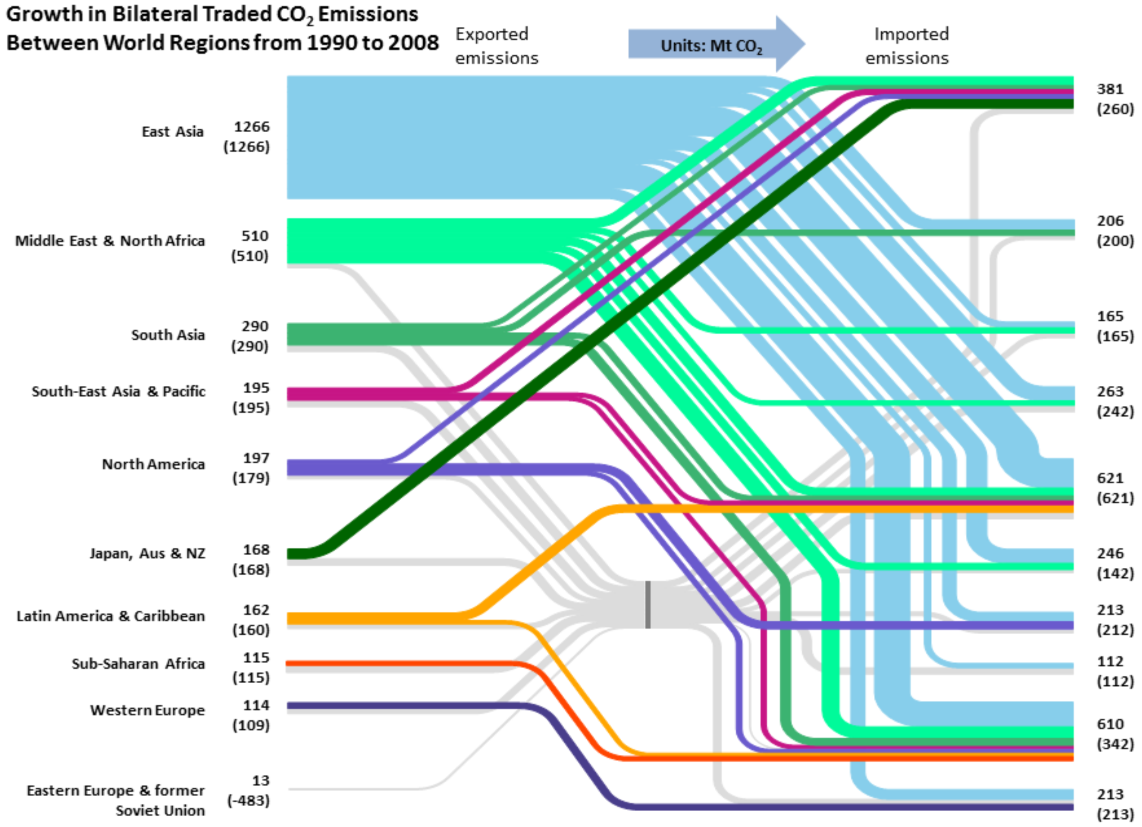

Figure 14.10. Growth in bilateral traded CO2 emissions between world regions from 1990 to 2008 (using EEBT method): Flow width represents growth in bilateral traded emissions (in Mt CO2) between 1990 and 2008, exported from left-hand-side region and imported by right-hand-side region. Flows representing growth greater than 30 Mt CO2 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 given. Bracketed figures give net growth in exported/imported emissions for each region after trade connections exhibiting negative growth (not shown in diagram) have been accounted for. Total growth in inter-region traded emissions between 1990 and 2008 is found to be 2.5 Gt CO2 (this does not include intra-region traded emissions, e.g., between US and Canada). Trade connections exhibiting significant negative growth include: Eastern Europe & former Soviet Union to Western Europe (-267 Mt CO2), to East Asia (-121 Mt CO2), and to Japan, Aus & NZ (-80 Mt CO2).

Taking the above analysis a step further, Figure 14.11 breaks the aggregate (MRIO-based) regional emissions transfers down to the level of industry sectors for the largest regional importer of embodied emissions – Western Europe (Chart A)– and the largest exporter of embodied emissions – East Asia (Chart B) – in 2007.

For example, Western Europe's Metal Production & Products (MtPP) sector emits 76 Mt CO_2, with 34% (26 Mt CO_2) of these production emissions ultimately embodied, via global supply chains, in the final goods and services consumed by other regions (i.e., are exported from Western Europe). Meanwhile, Western Europe's final consumption of goods and services entailed the release of 140 Mt CO_2 from the Metal Production & Products sector globally, with 64% (90 Mt CO_2) of these consumption emissions being emitted beyond Western Europe's borders. In comparison, the export share of East Asia's Metal Production & Products sector is very similar (33%), but at only 11% East

Asia's import share of Metal Production & Products emissions is significantly lower than Western Europe's.

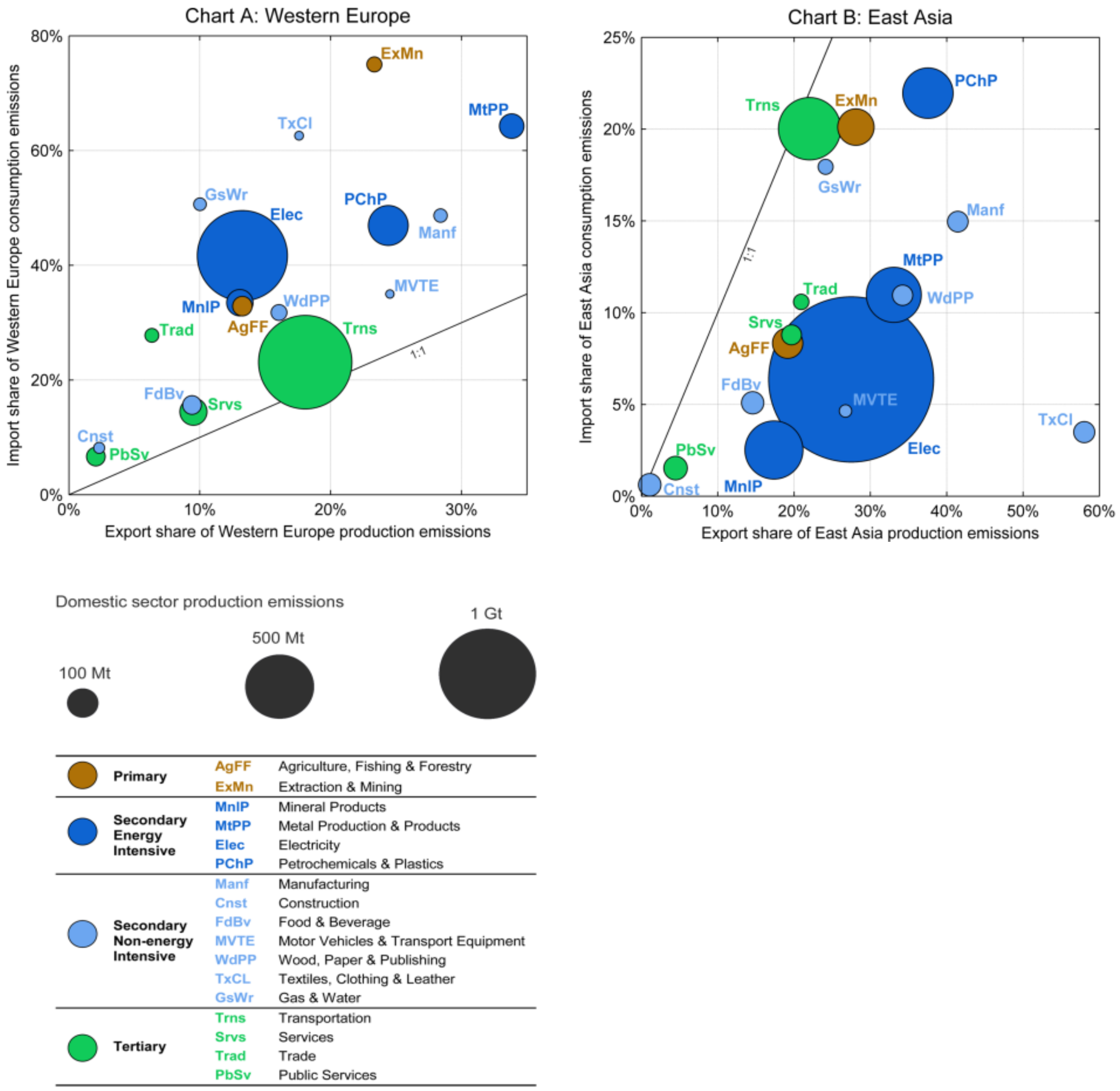

Figure 14.11. Heterogeneity of regional embodied emissions transfers across different industry sectors in 2007.

Note: Coordinates of circular markers in Chart A indicate the relationship between the export share and import share of Western Europe's production and consumption emissions respectively for individual sectors. The area of each marker represents the magnitude of that sector's Western Europe production emissions, providing an indicator of the relative importance of different sectors. Similarly, Chart B presents the same relationships for the East Asia region. Different marker colours are used to group sectors by broad industry category – primary, secondary energy intensive, secondary non-energy intensive and tertiary industries. It should be noted that while the marker area scale is common across both charts (to aid comparison); the x- and y-axis scales differ. A line representing equal import and export share is shown in each chart.

For Western Europe, each sector falls above the line representing equal export and import share; hence the region can be considered a net importer of emissions for each individual sector. The opposite is true for East Asia, which is shown to be a net exporter of emissions for every sector. In general, Figure 14.11 indicates that primary and secondary industries (both energy and non-energy intensive) typically exhibit a relatively high import share for Western Europe and a relatively high export share for East Asia. Tertiary industries tend to exhibit relatively balanced export and import shares for both regions.

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

As discussed, there is a growing discrepancy between production and consumption-based emissions. This is most likely related to changing structures of international trade, although carbon leakage associated with efforts to curb emissions in industrialised countries can play a role here as well. In any case, it is related to the fact that demand for emission-intensive goods has not been reduced as much as production of emission-intensive goods in industrialised countries. This relates to consumption patterns and life styles in rich countries.

Climate change analysis and policies pays increasing attention to importance of consumption (Nakicenovic and Swart, 2000; Michaelis, 2003). Analysis of household survey data from different regions shows that with improving income levels, households spend increasing larger amount of the income on energy intensive goods (Figure 14.12) (O'Neill et al., 2010). Indeed, there is substantial regional heterogeneity in consumption patterns. Households in Sub-Saharan Africa, Asia and Pacific have much lower income level than the more developed regions, and spend much larger share of the smaller income on food and meeting other basic demands. Households in the more developed Asia and Pacific and North America, on the other hands, enjoys much higher affluence and spend larger share of their income on transportation, recreation and other purposes. With economic growth and improving income, however, households in the less developed regions are very likely to westernizing 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. In poorer regions there might be more opportunities for such changes as there are fewer lock-in effects to high-emission consumption patterns. To the extent that carbon leakage contributes to this increasing discrepancy between production and consumption-based emissions, border-tax adjustments can be one tool to manage this issue in the absence of a global agreement on mitigation. This is discussed in more detail below.

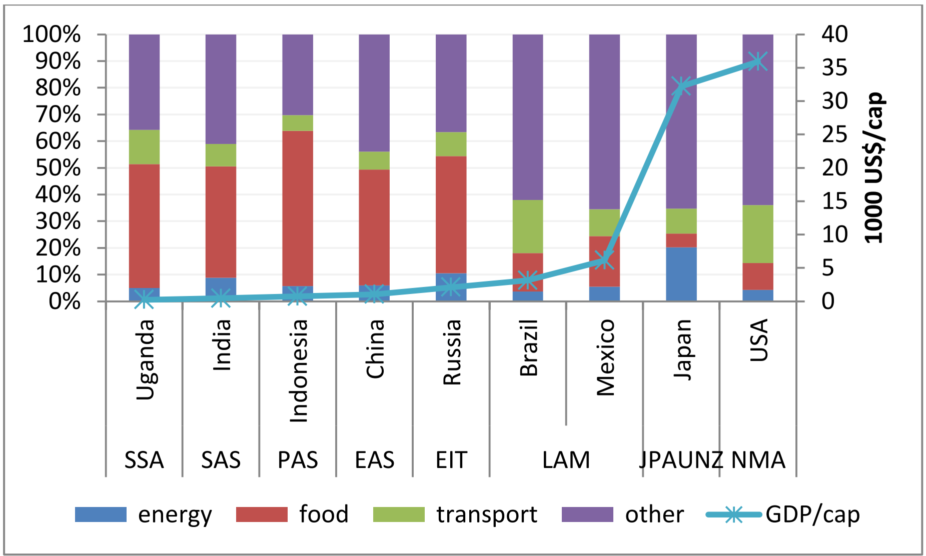

Figure 14.12. Expenditure share of households and per capita income, 2001

Note: 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).

14.2.6 Agriculture and Land Use Options for Mitigation

As discussed in Chapter 11, land use change contributes to about one third of global GHG emissions, and is in turn affected by climate change (Smith et al., 2007). Non-Annex I countries, which are source to 74% of total agricultural emissions, are to expect the largest rates of increase in emissions. By 2030, the fastest regions will be EAS (95%), POECD (62%), MNA (50%), NAM (49%) and SAS (46%) (Smith et al., 2007). Since general development conditions affect 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., 2011). This poses challenges in terms of those regions' vulnerability from climate change and their prospects of mitigation actions and low carbon development from agriculture and land use changes. Under an A1B scenario, for the 2080s reduced land productivity is forecasted for Central America (-1), Northwest and Central Africa (-8), Middle East (-8), and particularly for South-East Asia (-18); whereas Australia (+1), North (+2) and South America (+1), and particularly Northern Europe (+15) would show the largest increase in productivity. Under scenario E1 the above-mentioned trend gets exacerbated particularly for the African continent and South-East Asia (Iglesias et al., 2011).

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 level from climate change, especially for regions such as South-East Asia and Africa, which is in need of technology and investment. Region-specific strategies are needed to allow for flexibility in the face of impacts and on the creation of synergies with development policies that enhance adaptive lower levels of risk. This is the case for NAM, Western and Eastern Europe, and POECD, but regions such as South East Asia, Central America and Central Africa are under more severe threat (Iglesias et al., 2011) (Figure 14.13).

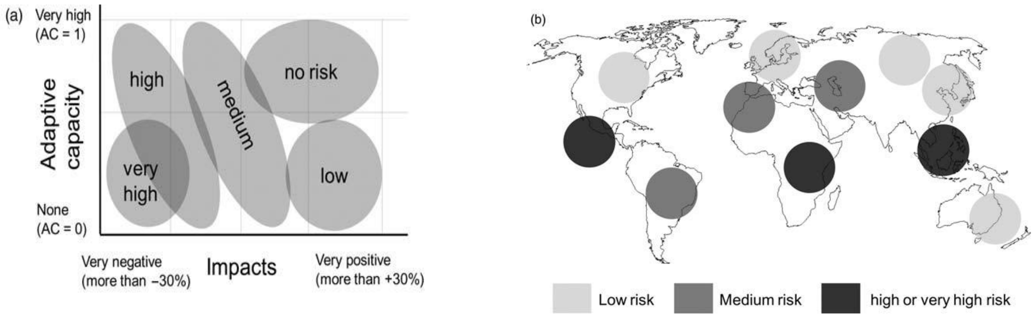

Figure 14.13. (left panel) Definition of risk profiles as determined by projected changes in productivity and levels of adaptive capacity. (right panel) Mapping of profiles as determined by projected changes in productivity and levels of adaptive capacity.

Source: (Iglesias et al., 2011).

Global estimates of changes during the period 1850-2005 in ecosystem carbon associated with land use and land cover change show that 65 Gt have been released into the atmosphere (Pongratz et al., 2009; Lawrence et al., 2012). These ecosystem carbon losses have been larger in SAS, EAS, SSA, and Latin America (Houghton, 2003; Pongratz et al., 2009; Hurtt et al., 2011; Pan et al., 2011; Lawrence et al., 2012), and were heavily influenced by the combined impact of land use changes, deforestation, and different agricultural patterns (Ramankutty and Foley, 1999; Hurtt et al., 2011; Foley et al., 2011; Lawrence et al., 2012) (Figure 14.14).

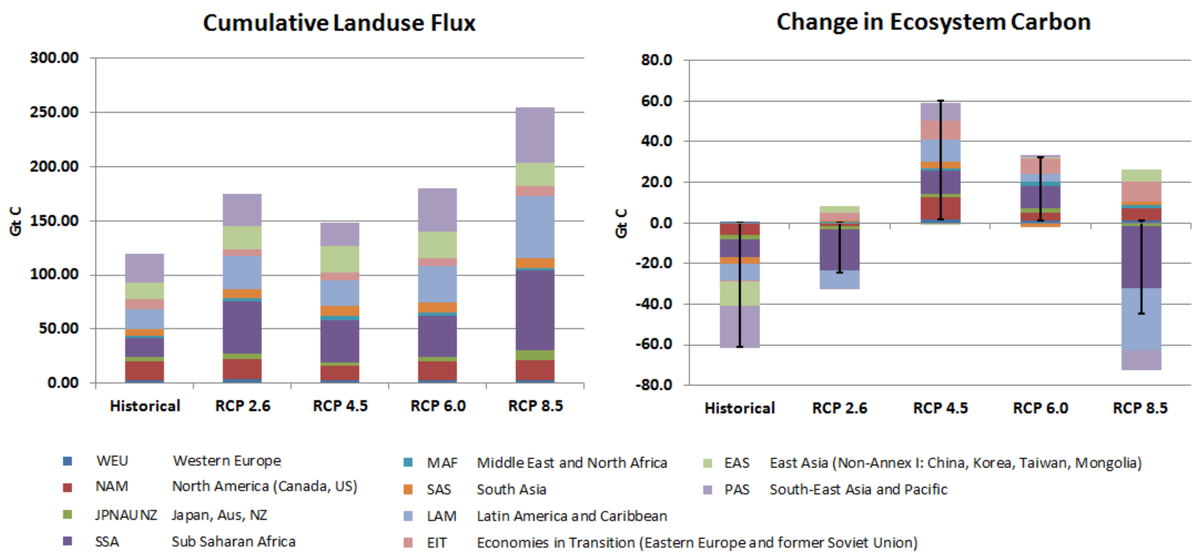

Figure 14.14. Regional Land Use Change

Note: RCP are the representative concentration pathways (Meinshausen et al., 2011).

Trajectories from 2006 to 2100 of the four Representative Concentration Pathways (RCPs) (Taylor et al., 2009; Hurtt et al., 2011; Lawrence et al., 2012) identified by WGII show different combinations of land cover change (cropping and grazing) and wood harvest in cumulative global land use fluxes and changes in global ecosystem carbon. RCP 8.5 (with 255 Gt C) resulted in a combined loss of ecosystem carbon of 49 Gt C in SSA, Latin America, and South East Asia, offsetting smaller gains in other regions. By contrast RCP 4.5 had the smallest cumulative land use flux of 148Gt C, which combined with reforestation results in a gain of ecosystem carbon of 61Gt C.

Although climate and non-climate policies at the national and international levels 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. Yet, 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).

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 (such as countries in SSA) are facing particularly strong institutional 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. Conversely, regions with the greatest technological, financial and capacity advantages face much reduced opportunities for low-cost strategies to move towards low-carbon development.

14.2.7 Leapfrogging, Technology Transfer and Low Carbon Development

The leapfrogging concept, i.e. the skipping of some generations of technology or stages of development, 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, 1998a; Davison et al., 2000; Lee and Kim, 2001; Perkins, 2003; Gallagher, 2006; Ockwell et al., 2008; Walz, 2010; Watson and Sauter, 2011; Doig and Adow, 2011).

The actual evidence for whether low carbon leapfrogging can or has already occurred, as well as specific models for low carbon development, are concepts that have been increasingly addressed in the literature reviewed in this section.

Most of the energy leapfrogging literature deals with the question of how latecomer countries can catch up with the energy producing or consuming technologies of industrialized countries (Goldemberg, 1998a; Perkins, 2003; Unruh and Carrillo-Hermosilla, 2006; Watson and Sauter, 2011; Lewis, 2012). Case studies of successful leapfrogging have shown that both the build-up of internal knowledge within a country or industry and the access to external knowledge are crucial (Lee and Kim, 2001; Lewis, 2007, 2011). In addition, the increasing specialization in global markets can make it increasingly difficult for developing countries to gain access to external knowledge (Watson and Sauter, 2011).

14.2.7.1 Examining low-carbon leapfrogging across and within regions

The strategies used by countries to leapfrog exhibit clear regional differences of particular relevance to this chapter. For example, many cases of successful 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, 1998a; Dantas, 2011a; Souza and Hasenclever, 2011).

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 (Katz, 1987; Lall, 1987, 1998; Kim, 1998; Lee and Kim, 2001; Watson and Sauter, 2011). While difficult to measure, absorptive capacity includes technological capabilities, knowledge and skills. It is therefore useful to examine regional differences across such technological capabilities, using metrics such as the number of researchers within a country, and total R&D invested. These metrics are investigated on a regional basis in Figure 14.15 along with the total CO_2 emissions footprint from energy use. This gives a sense of the magnitude of the climate mitigation challenge as well as the potential ability of different regions to leapfrog across regions.

14.2.7.2 Regional approaches to low-carbon development

The appropriateness of different low-carbon development pathways relies on a range of factors that may vary substantially from region to region, including the nature of different technologies and their appropriateness within different country contexts; the institutional architectures and related barriers and incentives that exist in regions, within different countries and in different regions within those countries; and the needs of different parts of society within and across countries. As a result, an appropriate low-carbon development pathway for a rapidly emerging economy like China may not be appropriate for countries in PAS or SSA due to differences in levels of development or in technological or institutional characteristics (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).

Low-carbon development pathways and roadmaps

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 by the Sussex Energy Group and the Tyndall Centre which explores four possible low-carbon development pathways for China (Wang and Watson, 2008).

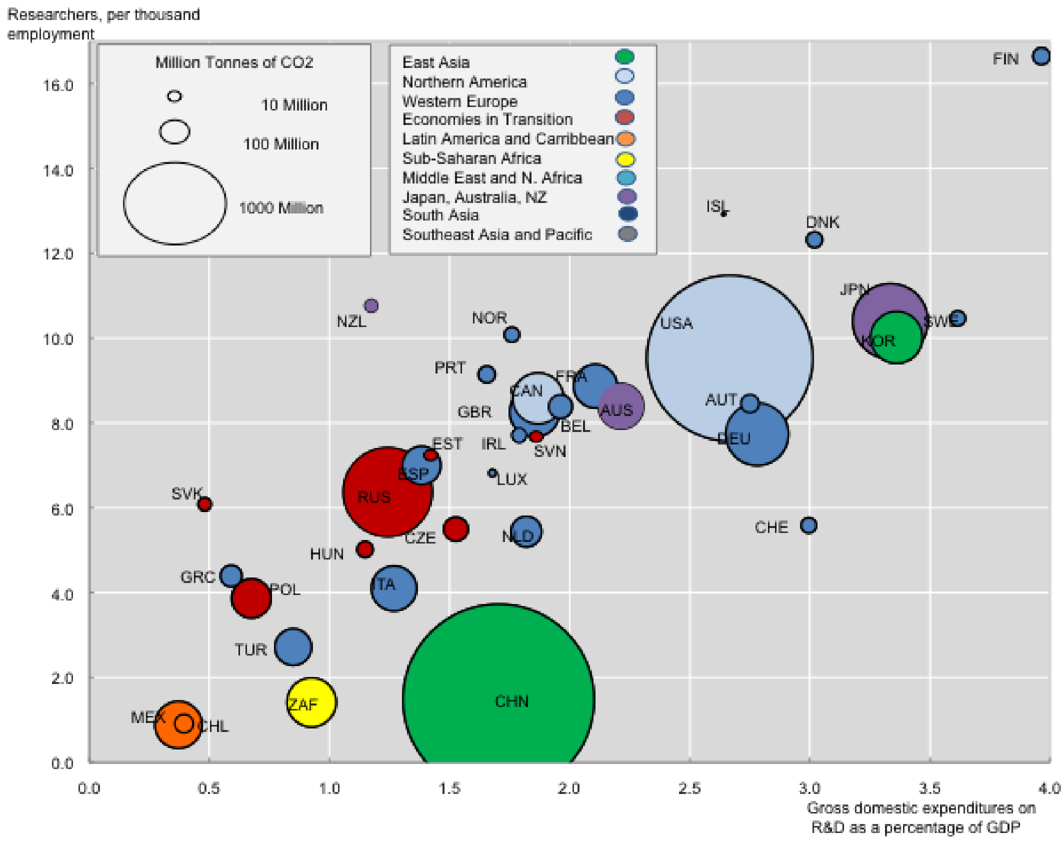

Figure 14.15. Emissions Contribution and Innovative Capacity: Regional Comparison

Source: Data on researchers and R&D expenditures as percentage of GDP from OECD, Main Science and Technology Indicators Database (OECD, 2011); CO2 from fossil fuels from the (IEA, 2011).

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 an abundance of 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, 1998b; Dantas, 2011b; 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).

Regional institutions for leapfrogging and low-carbon development

Many studies have proposed that regions could be used as a basis for establishing low-carbon technology innovation and diffusion centers (Carbon Trust, 2008). Such centers could “enhance local and regional engagement with global technological developments” and “catalyze domestic capacity to develop, adapt and diffuse beneficial innovations” (Carbon Trust, 2008). The idea of establishing a Climate Technology Center and Network has been embraced by the UNFCCC in its Technology Mechanism adopted at the COP 17.

In a report prepared for the United Nations Environment Program (UNEP) by NREL and ECN, several options for structuring climate technology centers and networks are presented that focus on establishing regionally based, linked networks (Cochran et al., 2010). The first option calls for centers to be organized regionally, with each focusing on sectors or technologies that are important and applicable to the region in which it is based. The second option calls for a network of national centers for market development with regionally based coordinating centers. These two options are illustrated in Figure 14.16.

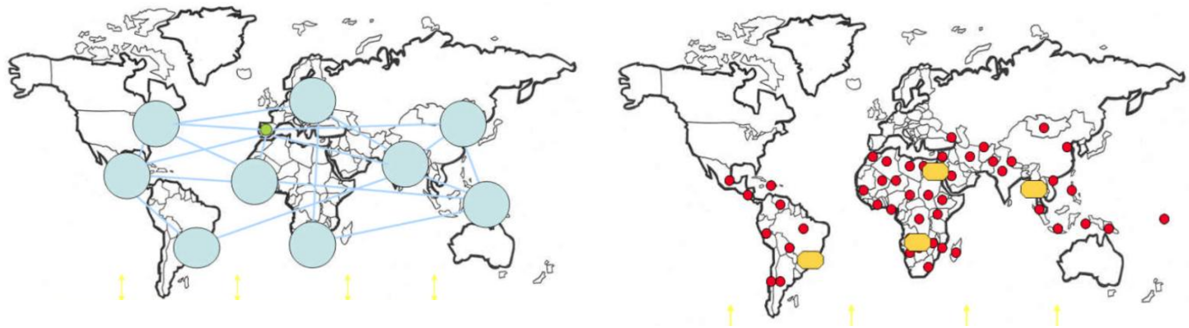

Figure 14.16. Options for Regionally-Coordinated Climate Technology Networks

Notes: 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).

14.2.8 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. 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. While public climate finance streams recently have averaged around 10 billion $ per year, annual investments through the CDM reached around $ 15-30 billion for CDM projects registered in 2009/2010 (UNEP Riso Centre, 2013). The general direction of flows is from North to South even if investment in mitigation in developing countries is increasing (Buen and Castro, 2012). (Miller, 2008) proposes to increasingly raise climate finance within advanced developing countries, as these have a capital surplus.

14.2.8.1 Overview of different streams of public and private financing

Stadelmann et al. (2011) estimate that in the years 2008-2010, 60-160 billion $ of private climate finance were flowing annually from industrialized to developing countries. For carbon market payments of 2 billion $ per year, data quality is good, while leveraged investments are estimated at 15-30 billion $ per year. For low carbon foreign direct investment estimated at 30-40 billion $ per year, as estimated by UNCTAC (2010) and investments leveraged by industrialized countries' public funds (20-90 billion $ per year), the uncertainties are much larger due to unclear definitions of mitigation benefits of foreign direct investments, uncertain climate benefits of public funds and wide ranges of public-private leverage ratios. Chapter 16 gives an overview on the landscape of current climate finance. Private finance contributes most with about 55 billion $ out of 97 billion $ in 2009/10. Private finance consists of direct equities and debt investments. Public finance contributes to another 21 billion $, which are leveraged by bilateral and multilateral banks (Buchner et al., 2011).

14.2.8.2 Participation in climate-specific policy instruments related to financing

Regional participation in different climate policy instruments varies strongly. It is often determined by the divide between Annex I and Non-Annex I countries, as specified in the UNFCCC, but some of the instruments differ substantially with regard to regional experiences within the group of Non-Annex B countries. Besides the Kyoto Mechanisms (as discussed in detail in the following section and in Chapter 13), the following will discuss some climate-specific programs with a regional view.

The CDM has developed a distinct pattern of regional clustering of projects and buyers of emission credits. Projects are concentrated in Asia (with the exception of its western parts) and Latin America. Africa and the Middle East are lagging behind. Credit buyers are concentrated in Western Europe (see Figure 14.17). This pattern has been relatively stable since 2006.

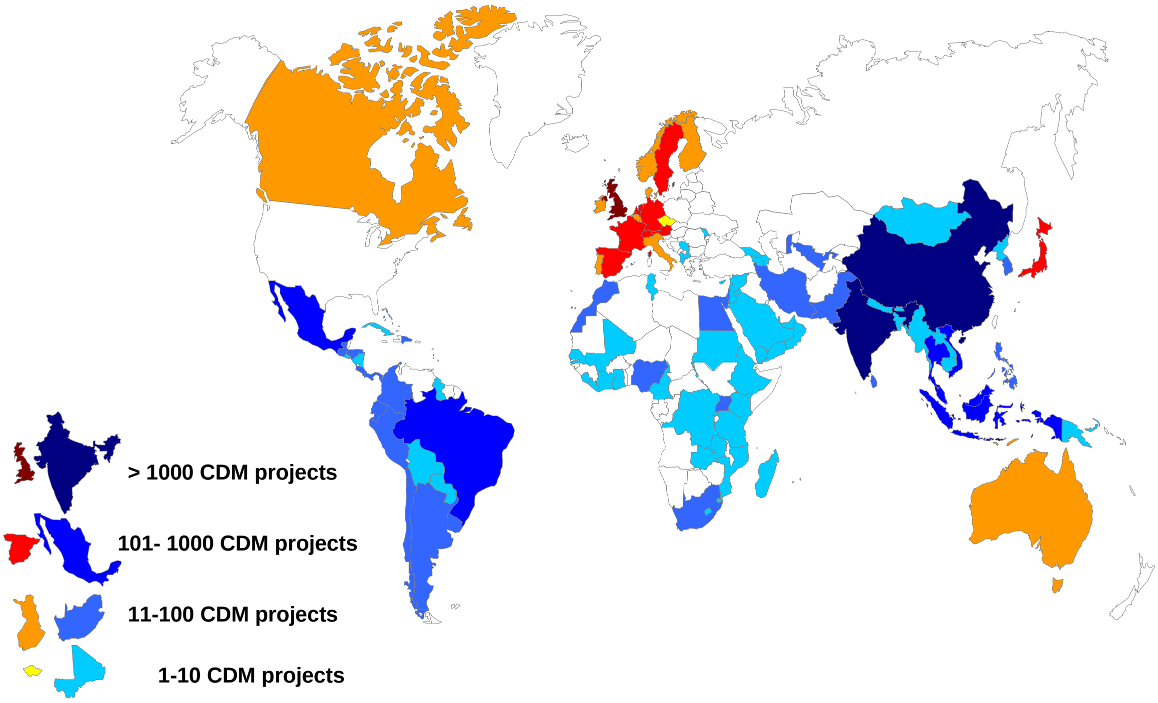

Figure 14.17. Regional Distribution of CDM Project Hosts (Blue) and Primary CDM Credit Buyers (Red) Data source: (UNEP Riso Centre, 2013)

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 the three parameters 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 program of activities that allow bundling an unlimited number of projects, the distribution differs markedly from standard CDM projects. According to the UNEP Riso Centre (2013), Africa's share reaches 25.6% (compared to 2.6% for all projects), while Asia reaches 57.9% (81.1% for all projects). Latin America stands at 15.7% (14.0%) and Europe so far is not represented (1.1%). The reason for this more balanced distribution is the higher attractiveness of small-scale projects that are appropriate for 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 countries in transition was not predicted by Oleschak and Springer (2007)'s list of most attractive JI countries. The shares have not shifted substantially over time.

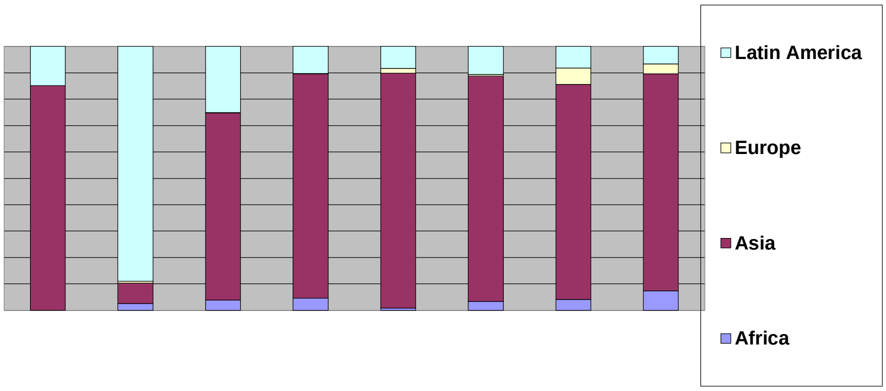

Figure 14.18. Regional Distribution of Pre-2013 Credit Volumes for Annual CDM Project Cohorts

Source: (UNEP Riso Centre, 2013)

Figure 14.18 shows the regional distribution of pre-2013 credit volumes for annual CDM project cohorts, including mitigation and adaptation, with a total finance volume. The regional distribution of the 880 climate change projects of the GEF (3.1 billion $ in total) is much more balanced than that of CDM projects in terms of project numbers, but project volumes are skewed in favor of Asia. Academic literature has evaluated reasons for 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 el al. (2009) assesses the 2008 climate finance flows from France, Germany and Japan as well as the European Investment Bank and finds that 64% of mitigation finance went to Asia and Oceania, 9% to Sub Saharan Africa, 8% to North Africa and the Middle East, and 5% to Latin America. With 11%, Eastern Europe had a surprisingly high share. Climate Funds Update (2013) provides data on pledges, deposits and recipients of the fast start finance pledged 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 the volume 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.

In terms of REDD, there were at least 79 REDD readiness activities and 100 REDD demonstration activities as of October 2009. Of these, the largest shares of REDD readiness and demonstration activities were implemented in Indonesia (7 and 15 respectively) and Brazil (4 and 13 respectively), countries widely agreed to have the greatest potential for reducing forest-based emissions (Cerbu et al., 2011).

Within the regions, countries have attracted varied amounts of REDD investment. Indonesia, located in the East Asia and Pacific Region, has the most number of REDD readiness activities (6). Also in the

East Asia and Pacific region, Vietnam and Papua New Guinea are both implementing 4 readiness, Lao PDR is implementing 3, Vanuatu 2, and Cambodia and Thailand 1 each. Paraguay and Guyana, in the Amazon region, are both implementing 5 readiness activities. Brazil is engaged in 4 readiness activities, while Colombia and Peru are engaged in 2 each. Madagascar, in East Africa, is also host to 5 readiness activities, while Tanzania is host to 3, and Ethiopia, Kenya and Uganda, 1 each. Central Africa, Democratic Republic of Congo and Cameroon are engaged in 4 national readiness activities each, Republic of Congo 2, and Central African Republic and Gabon 1 each. Costa Rica and Panama are engaged in 4 national readiness activities, Mexico 2, and Belize, Guatemala and Nicaragua 1 activity each. Meanwhile, Liberia (West Africa) is involved in 2 readiness activities and Ghana, 1, while Nepal (South Asia) is involved in 2 national readiness activities. Within the East Asia and Pacific region, Indonesia emerges as the most popular site for REDD demonstration activities with 15, followed by Papua New Guinea and the Philippines. Figure 14.19 provides a regional distribution of REDD projects.

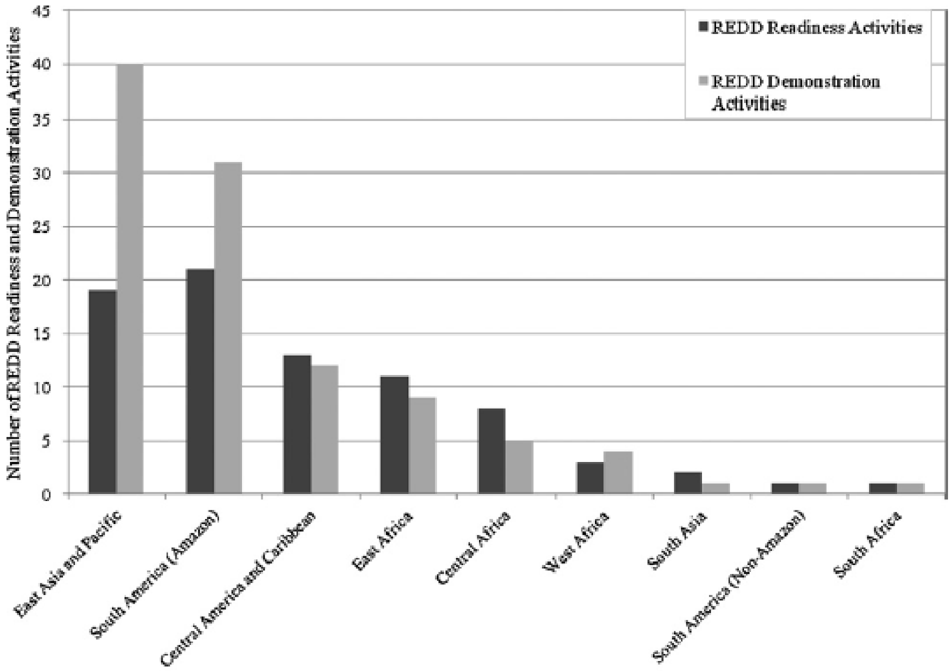

Figure 14.19. Regional Distribution of REDD

Source: (Cerbu et al., 2011)

REDD has the potential to tackle a good part of the 12-20% of emissions generated by the forest sector in tropical countries while simultaneously creating sustainable development benefits for communities. Given the results of this analysis, decisions surrounding the location of future REDD demonstration activities warrant careful consideration in order for REDD to avoid following in the CDM's footsteps.

14.3 Regional Cooperation and Mitigation: Opportunities and Barriers

14.3.1 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 regionally than globally, but also see the problem of fragmentation (Biermann et al., 2009; Zelli, 2011; Balsiger and VanDeveer, 2012). However, game-theoretic models suggest that several regional agreements are better than one global agreement with limited participation (Asheim et al., 2006; Osmani and Tol, 2010).

This section reviews regional mechanisms, what they have achieved in terms of mitigation and what they could achieve in future. When considering regional mechanisms, we distinguish between climate-specific and climate-relevant activities. Climate-specific regional initiatives are forms of cooperation at the regional level that are designed to address mitigation challenges. These include joint investment programs in low-carbon technologies, joint regional policies to regulate emissions, regionally implemented regimes to tax emissions, and regional cap-and-trade emissions trading schemes. Climate-relevant initiatives were launched with other objectives, but have potential implications for mitigation at the regional level. In this context, we examine regional trade agreements, which intend to promote trade across member countries but have impacts on GHG emissions and mitigation, and regional cooperation in energy issues, which has direct implications for mitigation. Moreover, there is a range of regional initiatives, often initiated from the regional trading blocs and sometimes from regional development banks, which aim to improve the coordination of policies in various fields, some of which can have mitigation implications. This section will also address trade-offs and synergies between adaptation, mitigation and development at the regional level.

When analyzing these regional mechanisms, one question is to what extent the existing schemes have had an impact on mitigation. A second question, which may be even more important, is to what extent these initiatives could be adjusted to have a greater mitigation potential in future. In fact, one key message of this chapter is that regional mechanisms could potentially become important platforms to organize regional initiatives for mitigation. Since this section focuses on the mitigation potential of regional cooperation, issues like well-being, equity, intra- and inter-generational justice will not be considered (see Chapter 3 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 a GHG should be charged the same implicit or explicit price. If this 'law of one price' is violated, mitigation efforts will be inefficient. Regarding regional cooperation, this implies 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 are inefficiently allocated.

External consistency is linked to the problem of GHG leakage (see Chapter 5). Suggestions to cope with leakage include border-tax adjustments (also discussed in Chapter 13), 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.

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 energy policies), 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, and many regional cooperation agreements in other areas (such as trade, energy, and infrastructure) influence mitigation indirectly, the effect of these initiatives and policies on mitigation is currently small. 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.

14.3.2 Existing Regional Cooperation Processes and their Mitigation Impacts

While there is ongoing discussion in the literature of the continued feasibility of negotiating and implementing an ever-larger set of global environmental agreements (see Chapter 13), a distinct set of studies has emerged, which examines international coordination through governance arrangements that aim at regional rather than universal participation (Table 14.4) (Balsiger and VanDeveer, 2010, 2012; Balsiger and Debarbieux, 2011; Elliott and Breslin, 2011). Much of the literature adopts a particular 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), it is highly likely that lessons can be learned from this broader set of regional environmental agreements in designing regional climate initiatives. However, this analysis is yet to be completed. Several regional environmental agreements have climate change components. For example, the Alpine Convention adopted the Action Plan on Climate Change in the Alps in March 2009 (Alpine Convention, 2009).

Table 14.4: Regional and Inter-Regional Environmental Cooperations

Distribution of Regional Environmental Cooperation, 1945–2005

World (Sub) Region	*Number of Arrangements Including at Least One Signatory from That Region*	*Of Which Regional*
Africa	707	391 (55.3%)
Americas	1,142	727 (63.7%)
Asia	1,058	577 (54.5%)
Europe	1,671	1,012 (60.6%)
Oceania	502	238 (47.4%)

Inter-regional Environmental Cooperation

UN World Regions Included in a Cooperative Arrangement	*Number of Arrangements*	*Of Which Regional*
1	1,201 (47.2% of n=2,546)	950 (79.1% of agreements in 1 UN world region)
2	826 (32.4%)	464 (56.2%)
3	156 (6.1%)	96 (61.5%)
4	56 (2.2%)	36 (64.3%)
5	307 (12.1%)	127 (41.4%)

Notes: The assessment is based on 2,546 multilateral and bilateral agreements and non-agreements concluded 1945–2005 (Mitchell, 2013). The delineation of world regions as used in this table is available at http://unstats.un.org/unsd/methods/m49/m49regin.htm. Source: (Balsiger and VanDeveer, 2012)

While lessons can be learnt from these more general environmental agreements, the next subsection will focus on agreements with specific mitigation objectives.

14.3.2.1 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). There are two regional emissions trading systems: 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. 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 could be defined. Most 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, or 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 emerged, such as the Asia-Pacific Partnership for Climate Change and one could theoretically add regional collaboration in the framework of the UNFCCC (e.g. the CG 11 of Eastern European countries in transition or the African Group). The evaluation of these initiatives follows below.

EU ETS and related initiatives

The EU ETS is a mandatory policy, which has evolved over a decade in strong interaction between the EU Commission, member state governments, and industry lobbies. 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 over 2 Bt of 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). According to Skjærseth and Wettestad (2009), from being an opponent of market mechanisms in climate policy as late as 1997 the EU become 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. 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. However, 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 as market inefficiency due to a bubble, exercise of market power or companies hedging against uncertain future emissions levels.

The release of the 2005 emissions data in 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). While a clampdown of the EU Commission on member states' allocation plan proposals for 2008-2012 reduced allocation by 10% (230 million t CO_2) 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. 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).

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 analysed intensively. Demailly and Quirion (2008) found 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.

The impact of target uncertainty for post-2012 on price formation has been assessed by Blyth and Bunn (2011), who see this as the major price driver. Chevallier (2009) finds only a limited influence of macroeconomic variables on prices. 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 behaviour. 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.

Anger et al. (2009) find that linking of the EU ETS with other trading schemes 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 can substantially reduce negative effects from a skewed allocation. 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. 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.

Interaction of the EU ETS with other mitigation policies has been discussed by (Del Río, 2010) for renewable energy and energy efficiency policies, by Sorrell et al. (2009) for renewable energy certificates, and by Kautto et al. (2012) for biomass energy. Most of this literature concludes that the EU ETS does not generate price signals that are high enough to mobilize renewable energy and energy efficiency investments, thus specific support policies are justified. On the other hand, these support policies drive the allowance price down due to a decrease in the demand of allowances.

The WCI was initiated in 2007 and is a bottom-up initiative consisting of US and Canadian states (see Chapter 13.7.1.2 for a detailed review). At its peak 11 jurisdictions were officially involved and committed to cap and trade: Arizona, California, Montana, Utah, New Mexico, Washington and Oregon in the United States, and British Columbia, Manitoba, Ontario, and Quebec in Canada. Another 16 jurisdictions had signed on as observers, but by 2012 only California and Quebec, as well as British Columbia remained remotely interested in trading and it is too early to tell whether this initiative will have a visible mitigation impact.

14.3.2.2 Climate change cooperation under regional trade agreements

Regional cooperation processes in areas not directly related to climate change can play an important role in climate change mitigation and adaptation. 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. RTAs aim to accelerate liberalization of trade in regions. 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).

As of January 2013, the WTO acknowledged 354 notifications of RTAs to be in force. This includes free trade agreements (FTAs) and customs unions (CUs) formed between two or more parties (WTO, 2011). Among them are also multilateral RTAs, such as the European Union (EU), the North American Free Trade Agreement (NAFTA), the Southern Common Market (MERCOSUR), the Association of Southeast Asian Nations (ASEAN), the Common Market of Eastern and Southern Africa (COMESA) and others. 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).

Trade diversion can lead to inefficiencies in the allocation of resources across sectors of the economy. Although the impacts of trade creation and trade diversion have not been analyzed theoretically with respect to their environmental impacts, conclusion by analogy implies ambiguity. Pollution intensive and green industries can be affected both ways by trade creation and trade diversion. Thus, the impact is an empirical issue. 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 14.2.5 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 PTAs have an impact on CO_2 emissions of member countries, and that emissions tend to converge (Baghdadi et al., 2012).

There is a potential to expand PTA environmental provisions to specifically cover climate policy concerns. One of the few existing examples of enhanced bilateral cooperation on climate change under PTAs relates to the promotion of capacity building to implement the CDM under the Kyoto Protocol provided for in Article 147 of the Japan-Mexico Agreement for the Strengthening of the Economic Partnership. Holmes et al. (2011) argue that PTAs can include provisions on establishment of 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). 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).

Regional trade agreements can also indirectly affect climate change through the way they redirect trade flows. If accompanied by environmental agreements, this can have further effects on mitigation. (Baghdadi et al., 2012) examine emission convergence in trading blocs and find evidence for such emissions convergence. If accompanied with an environmental agreement, such emission convergence appears to occur at a lower level of emissions, thereby contributing modestly to a mitigation objective.

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. Typically, declarations for regional action are made in the framework of economic cooperation agreements. However, in many cases, these declarations are not followed by concrete initiatives. Even if they do, there is a lack of systematic implementation, adequate financial support and monitoring. Nonetheless, some initiatives have materialized and are making progress.

Regional cooperation mechanisms take different forms depending, among others, on the degree of political cohesion in the region, the energy resources available, and the strength of economic ties between participating countries. Thus, cooperation mechanisms include:

- Adoption of regional overarching energy policies, strategies and targets;
- Establishment of regional institutions promoting the use of RES and EE potentials; and
- Coordination and harmonization of national policies and actions.

A number of barriers to regional cooperation remain to be solved. Overcoming these barriers requires efforts in a wide number of areas, such as:

- Garnering sustained political support for energy efficiency and renewable energy requires long-term efforts and substantial political skills;
- Building and strengthening institutions capable of implementing policies at the national and regional levels is a long-term process that needs to be tailored to specific regional circumstances; and
- Developing legislative and regulatory frameworks that are compatible across countries.

In what follows, some examples of existing regional cooperation mechanisms will briefly be 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).

Regional cooperation on renewable energy in the European Union

The legislative framework for renewable energy in the EU has been set up through several directives of the European Commission adopted by EU Member States (European Commission, 2001, 2003, 2009b). In the past, the European Commission issued two directives: one on the promotion of electricity from renewable sources and the second directive 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 set in motion a process of harmonization of a number of legal and regulatory aspects and required actions by EU member states to improve the growth, development and access to renewable energy (Haas et al., 2006, 2011; Harmelink et al., 2006). There was progress towards the targets in member states, 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 introduced a comprehensive 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 EU RES directive builds upon its two predecessors.

The RES Directive 2009/28/EC is part of the EU climate and energy package (European Commission, 2008). On the basis of model-based analysis, the European Commission (European Commission, 2011c) estimates that the implementation of the new RES directive 2009/28/EC 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 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. This, in its turn, reduces the carbon price in the EU ETS. Therefore, there is a need for coordination between RES and EE policies and the EU ETS in the future.

The implementation of the EU directives for renewable energy and the achievement of the national targets in the member states 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). Still, the EU directives for renewable energy have contributed to advance the introduction of RES in the member states by setting national targets and providing a common legislative framework at the EU level (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 establishes the adoption of the EU directives on electricity produced from renewable energy sources and on biofuels.

Analyses of the implementation of the acquis on renewables in the energy community contracting parties were conducted by EIHP (2007), Energy Community (2008), and IPA and EPU-NTUA (2010). These studies found that there has been some progress in implementing the directives, but that it has been dissimilar across Contracting Parties. Although potentials for renewable energies appear sizeable, barriers still abound. Thus, contracting parties need to implement concrete support measures before renewables can make an important contribution to the regional energy supply (Mihajlov, 2010; Karakosta et al., 2011; Tešić et al., 2011; Lalic et al., 2011). Several analyses ((EIHP, 2007; IEA, 2008; Energy Community, 2010; Mihajlov, 2010; Lalic et al., 2011) have recommended the introduction of a stable and comprehensive legislative framework as a key element for promotion of RES.

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 a harmonization of legal, policy and regulatory elements for the promotion of renewable energy and energy efficiency (Renner, 2009, p. 20). Through the legally binding Energy Community Treaty, the European Union has exported its legislative frameworks on renewable energy and energy efficiency to a neighboring region.

Power pools in Africa for energy resources sharing

Power pools have evolved as a form of regional cooperation in the electricity sector. Electricity interconnections and common markets in a region primarily serve the purpose of sharing least-cost generation resources and enhancing reliability of supply. In some cases, power pools provide opportunities for sharing renewable energy sources for electricity generation, notably hydropower, facilitating fuel switching away from fossil fuels (ICA, 2011; Khennas, 2012).

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 member countries. 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). Only the SAPP includes a non-negligible trade in energy. The main share of electricity demand in the region also occurs in South Africa, and is increasing at a rapid pace. One of the driving forces in SAPP is supplying demand growth in South Africa with hydropower generated in the northern part of the SAPP region. Although the bulk of new installed capacity will still remain coal-based, the share of hydropower in the SAPP could increase significantly. This way, the power pool can contribute to fuel switching from coal to hydropower (ICA, 2011).

Regional cooperation in hydropower

In principle, there is great potential to further regional cooperation in hydropower. The hydropower potential in several regions of the world, including Sub Saharan Africa and Asia, is substantial and only a small share has been exploited. At the same time, many hydropower projects pose difficult local environmental and social issues and often involve transboundary rivers, where political issues often prevent rapid progress on such projects (Van Edig et al., 2001; Klaphake and Scheumann, 2006; Wyatt and Baird, 2007; Grumbine et al., 2012) Particularly in Africa, political, capacity, and finance problems are so severe that progress on developing this key renewable energy resource is likely to remain slow unless there is substantial external support for such ventures (World Commission on Dams, 2000; Edenhofer et al., 2011) .

14.3.2.3 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 the next advances in mitigation and development policies, taking into consideration the growth of a regional approach to mitigation by the development of carbon markets and trading regimes in Europe and parts of the USA. An integrated approach of climate change policies was considered and large-scale mitigation opportunities at the national and regional level were identified, indicating that the scaling-up process 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). (Ayers and Huq, 2009) consider that in more vulnerable developing countries, such as LDCs, where mitigative capacity is low and adaptation needs are high, the linkage between adaptation and mitigation at the project level provides an avenue for integrating sustainable development priorities with climate policy, while simultaneously encouraging the engagement of local policymakers in the mitigation agenda.

Creating synergies between adaptation and mitigation can increase the cost-effectiveness of climate change actions. Many of these synergies can be harnessed and the potential conflicts minimized within the context of broader development initiatives. Opportunities of synergies vary by sector (Klein et al., 2007). 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 in sufficient depth for different regions.

Integrated approaches to mitigation and adaptation can provide very promising options, which 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). Forest related mitigation activities can considerably reduce emissions from sources and increase CO_2 removals by sinks at low costs, and can be designed to create synergies with adaptation and sustainable development (IPCC, 2007). Stable storage of carbon depends on stable and resilient forests (Convention on Biological Diversity, 2011). 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 adaptation of communities and the broader society, providing local ecosystem services that reduce vulnerability to climate change ('adaptation for people'). (Vignola et al., 2009; Locatelli et al., 2011)

The information in Box 14.1 and Box 14.2 is based on existing regional cooperation processes in which integrated approaches to mitigation and adaptation are necessary. The boxes indicate the existing difficulties for this integration and possible ways to overcome them.

Box 14.2 REDD+ in Congo Basin

The forests of Congo Basin extend across six countries: Cameroon, Central Africa Republic, Democratic Republic of Congo, Equatorial Guinea, Gabon, and Republic of Congo in the central region of Africa. These countries have a population of 122 800 000 inhabitants. Congo Basin carbon stocks are large. They are estimated in 56741 million of tons represents 8.7 per cent of forest carbon stocks of the world. This large amount of carbon creates opportunities to REDD+, as potential mitigation option (FAO and ITTO, 2011). The main question is to find ways to reduce emissions from deforestation and forest degradation with the aid of coherent mechanisms that also improve the life means of 60 million people that directly depend on forests.

The countries of the region have 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). The former engage member states of the Basin and seek to coordinate national efforts on forest policy with the stated goal of ensuring sustainable management of forest. It has called for the building of local capacity and the establishment of a policy framework before launching REDD+ financing mechanisms (Dkamela et al., 2009). The CBFP is an informal structure made up of about sixty partners from governments, including COMIFAC members countries and several developed countries, international institutions, NGOs, research groups and private sector with the objective of enhancing the effectiveness of the technical and financial contributions for the conservation and sustainable management of forest ecosystems, and poverty eradication in Central African countries (CBFP, 2006). There are 12 REDD+ projects ongoing in the Congo Basin countries that are financially and technically supported by CBFP partners.

Nkem et al. (2010) argued that REDD+ and other market mechanisms should be considered with caution and that they do not necessarily guarantee to enhance adaptation. Somorin et al.(2011) identified and assessed the discourses of relevant stakeholders in charge of the design and implementation of REDD+ activities in the Congo Basin, including the definition of priorities. These discourses differ substantially. Some give priority only to mitigation, others prioritize independent mitigation and adaptation policies, and others support integrated policies. The authors conclude that the Congo Basin policy community needs to combine adaptation and mitigation in a manner in which the multiple interests of the different stakeholders are represented. Mitigation policy should seek to address other issues and concerns and should not be based solely on reducing carbon emissions. Many of these issues and concerns specifically related to the Congo Basin forests have been suggested to be taken into consideration in designing and implementing mitigation policies such as REDD+ (Nkem et al., 2010; Brown et al., 2010; Ghazoul et al., 2010; Sayer et al., 2012).

Somorin et al. (2011) suggest considering the design of an overarching environmental road map or policy strategy from which policy approaches for implementation of REDD+, adaptation, biodiversity conservation and poverty reductions strategies are drawn.

The Great Green Wall of the Sahara and the Sahel Initiative (GGWSSI) is another regional example of collaboration among countries in the land use sector that is intended to promote sustainable development through adaptation and mitigation activities. The integration of both mitigation and adaptation in forestry activities might be useful for the implementation of this important regional megaproject.

Box 14.3 The Great Green Wall of the Sahara and the Sahel Initiative (GGWSSI)

Fifteen km wide and stretching 8,000 km from the Horn of Africa in the east to the coast of Senegal in the west, the Great Green Wall will pass through 11 of the poorest countries in the world: Burkina Faso, Chad, Djibouti, Eritrea, Ethiopia, Mali, Mauritania, Niger, Nigeria, Senegal, and Sudan, 10 of them being LDCs. The initiative is expected to lead to the sustainable management of land, water sources, such as the shrinking Lake Chad and vegetation on up to 2 million hectares of croplands, rangelands, and dryland forest ecosystems per country, protection of threatened dryland biodiversity, and the sequestering of 0.5 to 3.1 million tons of carbon per year. It will bring economic development to local communities, helping to stem the tide of youth emigration and providing them with energy resources, fruit, vegetables and other foods. Perhaps most importantly, it will also foster political stability through cooperation at all scales from the international level to the community.

The GGWSSI, launched by the African Union, is a priority action of the Africa–EU Partnership on Climate (European Union, 2011). It aims to catalyse “sustainable development and poverty reduction in the desert margins north and south of the Sahara” (African Union, 2009) to work in the zone which receives 100-400mm rainfall per year. It specifically focuses on the Saharan and Sahelian dryland ecosystems. 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 14.3.1 of this report, also contribute to mitigate climate change through the reduction of GHG emissions and carbon sequestration (Liniger et al., 2011).

14.3.3 Technology-Focused Agreements and Cooperation Within and Across Regions

A primary focus of regional 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. 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 for a variety of reasons. For example, geographical regions often exhibit similar challenges in mitigating climate change, and in some cases these similarities serve as a unifying force for regional technology agreements or for regional 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 such agreements, including those led by the United States and the EU, typically 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 the South to the North, from the North to the North, or from the South to the South. Other forms of regional agreements on technology cooperation, including bilateral technology cooperation agreements, may serve political purposes such as to improve overall 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.

14.3.3.1 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, which focus on a range of topics. These include 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). 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).

While not explicitly focused on energy, the Regional Innovation and Technology Transfer Strategies and Infrastructures (RITTS) provide an interesting example of a regionally coordinated technology innovation and transfer agreement. 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) has organized several regional initiatives focused on energy technology cooperation relevant 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). In addition, 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 (Kneeland et al., 2005; UNESCAP, 2008; Poocharoen and Sovacool, 2012). However it has mainly an advisory role and no clear mandate to implement energy projects (Poocharoen and Sovacool, 2012).

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., 2012), 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; c). Energy efficiency and renewable energy cooperation activities take place in the context of an active regional cooperation on energy. Among others, they encompass oil security, transnational natural gas pipelines and electricity interconnections (ASEAN, 2004, 2010; Sovacool, 2009), and play a comparatively marginal role. Action is supported by high-level political commitment through the

ASEAN Ministers on Energy Meeting (AMEM) and the Senior Officials on Energy Meeting (SOME). As a result, some policies have translated into action on the ground (Kneeland et al., 2005; Sovacool, 2009; IEA, 2010a). For example, during the APAEC 2004-2009, the regional 10% target to increase the installed renewable energy based capacities for electricity generation was met (ASEAN, 2010).

Asia-Pacific Economic Cooperation (APEC) has an Energy Working Group (EWG), which was launched in 1990 and seeks 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 EWG is assisted by four Expert Groups – Clean Fossil Energy, Efficiency & Conservation, Energy Data & Analysis, New & Renewable Energy Technologies – and two Task Forces – on Biofuels and on Energy Trade and Investment (ETITF) (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 signed by member states 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) in Accra, Ghana (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 (APCTT, 2011).

While all of the regional agreements discussed above have variation in their achievements, all of them could be improved with better governance and implementation (Sovacool, 2010; Poocharoen and Sovacool, 2012).

14.3.3.2 Inter-regional technology-focused agreements

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 various climate mitigation technologies, as well as a technology-oriented approach to climate change policy. The APP was perceived 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), and has been described as "a deeply intensive market liberal approach to international climate policy, which contests binding emission reduction targets and the development of a global carbon market" (McGee and Taplin, 2009). 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 on 5 April 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).

Another technology agreement that brings together clean energy technology experience from different regions is the Clean Energy Ministerial (CEM). The CEM brings together 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 announced by the United States at the Copenhagen Climate Negotiations in December 2009 and held in Washington in July 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 September 2008 to October 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, 2011b).

Other inter-regional technology cooperation initiatives and agreements focus on specific technology areas. Three such agreements were established from 2003 to 2004 by the United States government: the Carbon Sequestration Leadership Forum (CSLF), which coordinates carbon capture and storage technology research and development; the International Partnership for the Hydrogen Economy (IPHE), since renamed the International Partnership for Hydrogen and Fuel Cells in the Economy, which coordinates international efforts to develop a hydrogen economy; and the Methane to Markets Partnership (M2M), since renamed the Global Methane Initiative (GMI), which promotes the collection of methane from landfills, coal mines, natural gas and oil systems in order to provide a clean energy source (Tamura, 2006). CSLF involves 16 countries from around the world and aims to set a framework for international collaboration on sequestration technologies (Abraham, 2004; CSLF, 2012). IPHE aims to accelerate the transition to a hydrogen economy by providing a mechanism for partners to organize, coordinate and implement effective, efficient, and focused international research, development, demonstration and commercial utilization activities related to hydrogen and fuel cell technologies. In this effort, it involves 18 partner countries from around the world (IPHE, 2011). As of 2012, the GMI includes 38 governments plus the European Commission, the Asian Development Bank and the Inter-American Development Bank working together to facilitate methane reduction projects in agriculture, coal mines, landfills and oil and gas systems (US Environmental Protection Agency, 2012). Focused on demonstrating the feasibility of producing commercial energy from fusion, ITER is an agreement among 7 countries (China, EU, India, Japan, Korea, Russia, and the USA) working to construct a demonstration fusion power plant in France (Shimomura et al., 1999; Aymar et al., 2001; ITER, 2012).

14.3.3.3 Bilateral technology-focused agreements

Bilateral forums provide important opportunities for the concrete demonstration of commitment through the establishment of joint projects and initiatives with tangible deliverables. They can focus on issues that are less politicized than climate change such as clean energy, and can build bridges between government agencies and researchers outside of the diplomatic services of both countries (Lewis, 2010). Almost every country in the world is engaged in some form of bilateral energy or climate technology cooperation. This chapter does not provide a complete listing, but instead attempts to highlight some of the largest initiatives.

For example, both the United States and European Commission (EC) are engaged in many energy-focused bilateral initiatives that include cooperation on clean energy technology. The EC-Brazil Regular Energy Policy Dialogue includes a focus on strategies for the development of secure and sustainable energy (European Commission, 2012a), while the EC-India Energy Panel consists of four working groups focused on the development of clean coal technologies, increasing energy efficiency and savings, promoting environment friendly energies, as well as assisting India in energy market reforms (European Commission, 2012b). The EC also has a series of sectoral dialogues with China, focusing on six priority areas which include renewable energy, smart grids, energy efficiency in the building sector, clean coal, nuclear energy and energy law (European Commission, 2012c). It also has an Energy Dialogue Forum with South Africa with a focus on cooperation on coal, clean coal and CO_2 capture and storage (European Commission, 2012d).

The United States has seven bilateral clean energy initiatives with China, including the US-China Clean Energy Research Center, the Electric Vehicles Initiative, The Energy Efficiency Action Plan, the Renewable Energy Partnership, The 21st Century Coal Initiative, the Shale Gas Resource Initiative, and the Energy Cooperation Program (U.S Department of Energy, 2011). Such bilateral initiatives between the United States and China are critically important because the US and China are the largest national GHG emitters, and such talks can help to promote US-China understanding and facilitate a multilateral climate agreement that involves both countries (Lewis, 2010). The US Department of Energy's Office of Fossil Energy alone has bilateral energy agreements with 17 countries, while the US Department of State administers 15 individual bilateral and regional climate partnerships, and the US Environmental Protection Agency has a number of international energy and climate partnerships (Hassell et al., 2009).

14.3.3.4 South-south technology cooperation agreements

There are increasingly more examples of technology cooperation agreements among and between developing countries. For example, the Caribbean Community Climate Change Centre coordinates the Caribbean region's response to climate change and provides climate change-related policy advice and guidelines to the Caribbean Community. For this purpose, it serves as a cleaning house and archive for regional climate change data and documentation in the Caribbean (CARICOM) Member States (Caribbean Community Climate Change Center, 2012). China has been a leader in promoting South-South cooperation in multiple areas. For example, it has served as a key donor to the UNDP Voluntary Trust Fund for the Promotion of South-South Cooperation (United Nations Development Programme: China, 2005). 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. This was initiated in April 2012 and is funded by China's Ministry of Science and Technology (UNESCO Beijing, 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). In addition, the India, Brazil, South Africa (IBSA) Trust Fund implements South-South cooperation for the benefit of LDCs. IBSA aims to identify 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, though projects have included solar energy programs for rural electrification and other projects with climate change benefits (UNDP IBSA Fund, 2012).

14.3.4 Regional Mechanisms for Investments and Finance

14.3.4.1 Regional and sub-regional development banks and related mechanisms

In a non-carbon constrained world, the capital required to meet projected energy demand through 2030 would amount to an average of $1.1 trillion per year. Half of this amount will be for developing countries, roughly evenly distributed between the large emerging economies and the remaining developing countries (IEA, 2009; UNDP, 2011). Additional investment of close to $10.5 trillion over the next 20 years would be needed globally over this same period (2010-2030) to ensure a 50% chance of maintaining GHG concentration at less than 450 ppm CO_2 (IEA, 2009). The UNFCCC estimates that 80% of the capital needed to address climate change issues will come from the private sector, both from businesses and consumers (UNFCCC, 2007; UNDP, 2011).

The regional development banks play a key role in climate mitigation financing. They include the African Development Bank, Asian Development Bank, International American Development Bank, European Bank for Reconstruction and Development, and the European Investment Bank. 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, for example via regional and thematic windows in the context of the Copenhagen Green Climate Fund, such as a possible Africa Green Fund (United Nations, 2010). Among the regional development banks, the Asian Development Bank has a very active program of pipeline development for potentially transformative energy generation systems. Its Clean Energy Financing Partnership Facility and Clean Energy Fund are currently investing over $80 million, leveraging total investments of $1.1 billion (Brown and Jacobs, 2011). In addition, regional recipient funds managed by regional development banks such as the Congo Basin Forest Fund, which is managed by the African Development Bank (AfDB), and the Amazon Fund, which is managed by the Brazilian Development Bank (BNDES), play increasingly important roles in climate mitigation on regional issues(Buchner et al., 2011). A new USD 145 million AfDB fund, the Clim-Dev Africa Special Fund aims to support Africa's access to and management of flows from the forthcoming Green Climate Fund (Buchner et al., 2011).

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 (Table 14.5). 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).

Table 14.5: Regional Composition of Actual MBD Climate Change Financing

	ACTUAL 2006	ACTUAL 2007	ACTUAL 2008	ACTUAL 2009	TOTAL 2006-2009	Shares 2006-2009
Geographic						
Africa	0.8	1.4	1.5	1.3	5.0	12%
Asia and Pacific	1.2	1.5	4.1	3.7	10.6	26%
EMENA and Central Asia	2.6	3.5	3.5	5.3	14.8	37%
Latin America and Caribbean	0.9	0.7	1.5	6.8	9.8	24%
Total	**5.5**	**7.0**	**10.5**	**17.1**	**40.1**	**100%**

Source: Joint MDB Climate Finance Report (NB: Subject to revision)

Source: (United Nations, 2010)

14.3.4.2 South-south climate finance

Several studies have estimated that South-South development assistance flows range from USD 9-12 billion in 2006 and increase to USD 15 billion by 2010 (ECOSOC, 2008), but few have provided estimates of the proportion of aid directed specifically to climate finance (Buchner et al., 2011). One study estimates that Chinese foreign aid and support to projects in Africa, Latin America, and South-East Asia grew from less than USD 1 billion in 2002 to USD 25 billion in 2007 (Lum et al., 2009). The emerging non-OECD donors Brazil and India (Buchner et al., 2011) also play a significant role in providing South-South aid, with Brazilian contributions amounting to USD 437 million in 2007 and Indian contributions reaching approximately USD 610 billion in 2008-2009 (OECD, 2010; Buchner et al., 2011).

14.4 Taking Stock and Options for the Future

The discussion above has suggested that a regional approach to mitigation is indeed fruitful as it helps to identify key differences in the mitigation challenge by region and focuses on the options regional mechanisms might offer to address the mitigation challenge. Some of the key issues emerging from the chapter are:

1. The mitigation challenge is dramatically different by region.. In advanced industrial countries with very high per capita emissions, high institutional and technological capacity, and moderate growth effective mitigation will require them to drastically reduce per capita emissions, by re-orienting their energy and transport systems as well as their consumption and living patterns. Given the high institutional and technological capacity, the capacity to undertake such action is available, but the costs will be high given the sunk costs of the present economic structure. A second group consists of emerging economies with rapidly rising per capita emissions, high economic growth, and increasing but more fragile institutional and technological capacities. If global emissions are to be stabilized at low levels, a significant contribution of these countries is going to be critical, particularly since the current development paths will lead to rapidly rising emissions in a business-as-usual scenario. Opportunities for re-orienting the economies towards less carbon-intensive growth exist, but become increasingly costly as carbon-intensive technologies, settlement and consumption patterns are locked in. A third group of countries consists of poorer developing countries with presently very low (but rapidly rising) per capita emissions, and generally weak institutional and technological capacities. For these countries the opportunities for low-carbon development are sizable and the financial costs relatively low. However, weak institutional, technological and financial capacities will make it very difficult for these countries to embark on a low-emissions growth strategy unless such a strategy receives strong international institutional, technological and financial support. This suggests that no region will find it particularly easy to address the mitigation challenge and that there are two ways to investigate this further. First, it is important to investigate how countries within a region have been able to differ in addressing these challenges. Understanding the heterogeneity could be an important step in identifying appropriate policy options. Second, it is important to investigate to what extent inter-regional transfers of technology and finance can help overcome the challenges discussed above.

2. An assessment of available literature suggests that regional cooperation agreements have not, on the whole, played an important role in addressing the mitigation challenge to date. With the strong exception of the European Emissions Trading Scheme and directives on energy efficiency and renewable energy, initiatives in other regions have been much less ambitious and successful. To some extent this is not surprising as the level of regional integration, with the associated transfer of sovereignty to a regional body, is much less pronounced in all the other examined regional mechanisms.

3. At the same time, there is considerable scope for the use of regional mechanisms to promote mitigation activities. This can, on the one hand, involve making existing regional initiatives more mitigation-sensitive by considering the impact of trade agreements, regional development policies, regional energy policies, and regional infrastructure and migration policies on mitigation options. On the other hand, regional bodies can take on a much stronger role in directly coordinating, implementing, and monitoring national or supranational mitigation policies, including in the field of energy policies, carbon trading and carbon pricing. This can also be supported by better engaging regional bodies in international agreements that deal with mitigation, such as technological transfer and finance for mitigation. Successes in such ventures will likely depend on strengthening the capacity and decision making power of regional mechanisms to take on such an enhanced role.

14.5 Gaps in Knowledge and Data

There are large gaps in knowledge of relevance to the issues covered in this chapter. In particular, there is insufficient information (in peer-reviewed literature) on evaluating cooperation schemes in mitigation; the literature on synergies and trade-offs between mitigation and adaptation is only slowly emerging and still inadequate; much further information is needed on capacity barriers for low carbon development at the regional level (incl. information on costs of capital at the regional level, credit constraints); and, lastly, there is hardly any literature assessing the mitigation potential of climate-relevant regional cooperation agreements (such as trade, energy, or infrastructure agreements).

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