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This chapter has been allocated 40 template pages, currently it counts 86 pages (excluding this page and the bibliography), so it is 46 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. (Supra-national) regions (using a socioeconomic definition of regions that is consistent with, but more detailed than, the 5 so-called RCP regions used in most integrated assessment models) matter for greenhouse gas emissions and achievement of mitigation objectives for two rather distinct reasons:
    a. First, there is wide agreement that regions manifest vastly different patterns in the level, growth and composition of greenhouse gas emissions, underscoring significant differences in socio-economic contexts, energy endowments, consumption patterns, development pathways, and other underlying drivers that ultimately influence greenhouse gas emissions and therefore mitigation options and pathways available (Sections 14.1., 14.2., 14.3, high agreement, robust evidence). We call this the 'regional heterogeneity' issue.
    b. Second, most of the literature finds that regional cooperation, including the creation of regional institutions, has been a powerful force in global economics and politics– as manifest in numerous agreements related to trade, technology co-operation, trans-boundary agreements relating to water, energy, transport, and so on (robust evidence, medium agreement). It is critical to examine to what extent these forms of cooperation have already had an impact on mitigation to what extent they could play a role in achieving mitigation objectives (Section 14.4). We call this the 'regional cooperation issue'

**Regional Heterogeneity**

2. It is widely recognized that mitigation challenges differ dramatically by region. For example, low-income countries in Africa, whose contribution to consumption-based GHG emissions is currently very low, are facing the challenge of trying to promote economic development, including broadening access to modern energy and transport as well as promoting industrialization. Their mitigation challenges will be largely about different development paths with different mitigation potentials. Due to their starting situation (of low-carbon intensity) as well as their geographical endowments, they have the opportunity to leap-frog to low-carbon development paths. Similarly, in emerging countries in South and East Asia, who are further along the way of carbon-intensive development, the ability to adopt various mitigation options is greater but their gains from leapfrogging are relatively smaller. In industrialized countries, meanwhile, the opportunities to leapfrog are small and the challenge will be to drastically re-orient existing development paths towards lower carbon intensity. Thus opportunities for mitigation differ greatly by region, with poorer regions generally offering greater opportunities of leapfrogging to low-carbon development paths (high agreement, medium evidence).
3. Conversely, most of the literature suggests that opportunities for low-carbon development (including choosing renewable energy options, low-carbon urbanization, low-emission land use strategies) are typically very costly in terms of capital, skill, technology, and institutional quality (medium agreement, medium evidence). Poorer developing regions are generally very poorly endowed with capital, skills, technology, and institutional quality, so that their ability to seize these opportunities is limited. This mismatch between opportunities and capacities various across sectors but they imply that in a business as usual scenario, the capacity to leapfrog to low-carbon development strategies is not there in many developing regions (medium agreement, medium evidence).
4. As a result, successful mitigation strategies will have to tackle these capacity issues to implement low-carbon development strategies in poorer developing countries. These will

include technology development and transfer, finance, capacity-building and measures to support institutional quality. To date, the literature suggests that there is only limited evidence that this is happening to the extent required, as well as with the required effectiveness (medium agreement, medium evidence).

5. An extensive literature has emerged on the integration of climate change policies into sustainable development policies, including the identification of possible synergies and trade-off between mitigation and adaptation at conceptual and sectoral levels. However, there is not enough literature at present to assess these possible synergies and trade-offs and ways to maximize the former and avoid the latter in sufficient depth for different regions. Moreover, some examples in the scarce available literature indicate that there are difficulties to achieve their possible benefits. This also indicates the need of specific national, regional and international policies and actions to achieve the benefits resulting from possible mitigation and adaptation synergies (medium agreement, limited evidence).

**Regional Cooperation**

6. Many regional cooperation structures have started to develop initiatives to address mitigation challenges. Some have moved very far in setting clear and binding mitigation goals and targets, most notably the European Union. The EU has, with the EU ETS, a mechanism in place to achieve these mitigation objectives.

7. At the same time, other (non-climate related) modes of regional co-operation could also have significant implications for mitigation – even if mitigation objectives are not a manifest component of current policies/agreements (medium agreement, medium evidence).

8. On the basis of the current assessment, most of the literature suggests that climate-specific regional co-operation agreements have not, on the whole, 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 transfer of sovereignty to supra-national regional bodies. Even in places where regional integration is very deep, such as the EU, the EU ETS has so far not been as successful as anticipated in actually achieving the intended mitigation objective for reasons that are discussed in detail below (high agreement, robust evidence). Clearly, theoretical models and the experiences so far suggest that there is substantial potential to increase the role of climate-specific regional cooperation agreements (high agreement, medium evidence). It is also important to consider carbon leakage of such regional initiatives and ways to address them, a subject that is discussed quite controversially in the literature (medium agreement, medium evidence).

9. Other forms of regional cooperation, such as trade agreements, technology transfer, cooperation on infrastructure and energy, are to date, having negligible impacts on mitigation. The exception again is the EU where directives on energy policy (including renewable energy and biofuels) have had an impact on energy policy and associated energy-related emissions although here as well there is more potential than has been realized (medium agreement, medium evidence).

10. At the same time there is some *potential* of such mechanisms for contributing more to mitigation goals going forward. In particular, they can also serve as a platform for developing, implementing, and financing climate-specific regional initiatives for mitigation, possibly also as part of global arrangements to deal with 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 co-operation to achieve greenhouse gas (GHG) mitigation. It will examine the regional trends and dimensions of the mitigation challenge. It will also examine what role regional initiatives, both with a focus on climate change or in other domains such as trade and development, can play in addressing these mitigation challenges.

The regional dimension of mitigation was not explicitly addressed in the Fourth Assessment Report (AR4) that had a sectoral and thematic focus. The discussion of policies, instruments and co-operative agreements (AR4 Working Group III, chapter 13) was focused primarily at the global and national level, with some discussion of the local level as well.  However, the 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, level of economic development, patterns of urbanization and industrialization, access to finance and technology, and more broadly capacity to develop and implement various mitigation options. There are also existing modes of regional co-operation, 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 co-operation such as collaboration in energy markets and regional approaches to development-cooperation that could potentially provide an important platform for delivering and implementing mitigation policies. These dimensions will be assessed within the context of 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 the different regions?
- How do policy options interact with (sustainable) development (trade-offs versus co-benefits at the regional level?)
- 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 inter-linkages 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?
- What are the financial implications, opportunities and barriers of promoting mitigation policies in the different regions? To what extent can regional initiatives play a role in financing mitigation activities?

## 14.1.2 Overview of the Chapter

The chapter is organized as follows: After discussing some preliminary issues regarding the definition and importance of regions, sustainable development at the regional level and the regional differences in mitigation capacities, section 2 will examine **current development patterns and goals** and their emission implications at the regional level. In that context, this section will also discuss the issues of **energy and development, urbanization and development, and consumption and production patterns in the context of development**. Section 3 will then examine **opportunities and barriers for low carbon development** by examining policies and mechanisms for such development in different regions and at the regional level. This discussion will also analyse the issues of technology transfer, **investment and finance, and the role of public and private sectors and public-private partnerships**. Section 4 will then evaluate existing regional arrangements and their impact on mitigation, including climate-specific as well as climate-relevant regional initiatives. In that context, examples of **links between mitigation, adaptation, and development** will also be discussed. Also here, the experiences of technological transfer and leapfrogging will be evaluated. Lastly, section 4 will then discuss **opportunities and barriers of regional cooperation** to promote mitigation and spell out policy options for the future for different regions and at the regional level.

The chapter will draw on the chapters on transformation pathways (6), the sectoral chapters (7-12) and the chapter on investment and finance (chapter 16) by analysing 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 received not enough attention or the issues covered are too recent to have been properly analysed in the peer-reviewed literature. We will therefore sometimes draw on grey literature and sometimes we simply have to state the research gaps.

### 14.1.3 What is Meant by Regions?

For the purposes of this chapter, only supra-national (i.e. in between the national and global level) regions are considered. Sub-national regions are addressed in chapter 15. As the focus of the chapter will be on the interactions between development and mitigation, developing country regions will be discussed in somewhat greater detail, as the range of challenges and opportunities are greater and less studied in the context of the overall report; we will also include a section that emphasizes the particular challenges of least developed countries (where we will use the official UN classification of LDCs). However, the interaction between development and mitigation is also a challenge for industrialized countries so that this group of countries is also examined. 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), Japan, Aus, NZ, (JPAUNZ), 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 regions used in scenarios and IAMs (e.g. RCP regions), commonly used World Bank socio-geographic regional classifications, and geographic regions used by WGII. In some cases, however, other regional classifications have to be used if dictated by the literature that is being reviewed here.

### 14.1.4 Why Regions Matter?

Thinking about mitigation issues 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, level of economic development, patterns of urbanization and industrialization, access to finance and technology, and more broadly capacity to develop and implement various mitigation options.

For example, low-income countries in Africa, whose contribution to GHG emissions is currently very low, are facing the challenge of trying to promote economic development, including broadening access to modern energy and transport as well as promoting industrialization. Their mitigation challenges will be largely about choosing different development paths with different mitigation potentials; due to their tight resource situation and further risks associated with the need to adapt to climate change, their ability to choose low carbon development paths, should they prove to be more costly, is severely constrained as are their opportunities to wait for more mitigation-friendly technologies (Collier and Venables, 2012). On the other hand, given sufficient access to finance, technologies and the appropriate institutional environment, they 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. Meanwhile, in emerging economies, who are further along the way of carbon-intensive development, the ability to adopt various mitigation options is greater but their gains from leapfrogging are relatively smaller. In industrialized countries, meanwhile, the opportunities to leapfrog are small and the challenge will be to drastically re-orient existing development paths and technologies towards lower carbon intensity.

Consumption patterns, viewed by the ecological footprint of consumption, which measures the amount of land required to produce the goods and services consumed in a region (Figure 14.1), show clearly the different challenges for different regions to change the path of development. Whereas regions such as North America and Middle East and North Africa have countries with very large ecological footprints, the latter also having the highest intra-regional variation, followed by Western Europe and the Economies in Transition regions. Conversely, the footprint is smallest in Sub-Saharan Africa and the differential within the region is rather small as well.

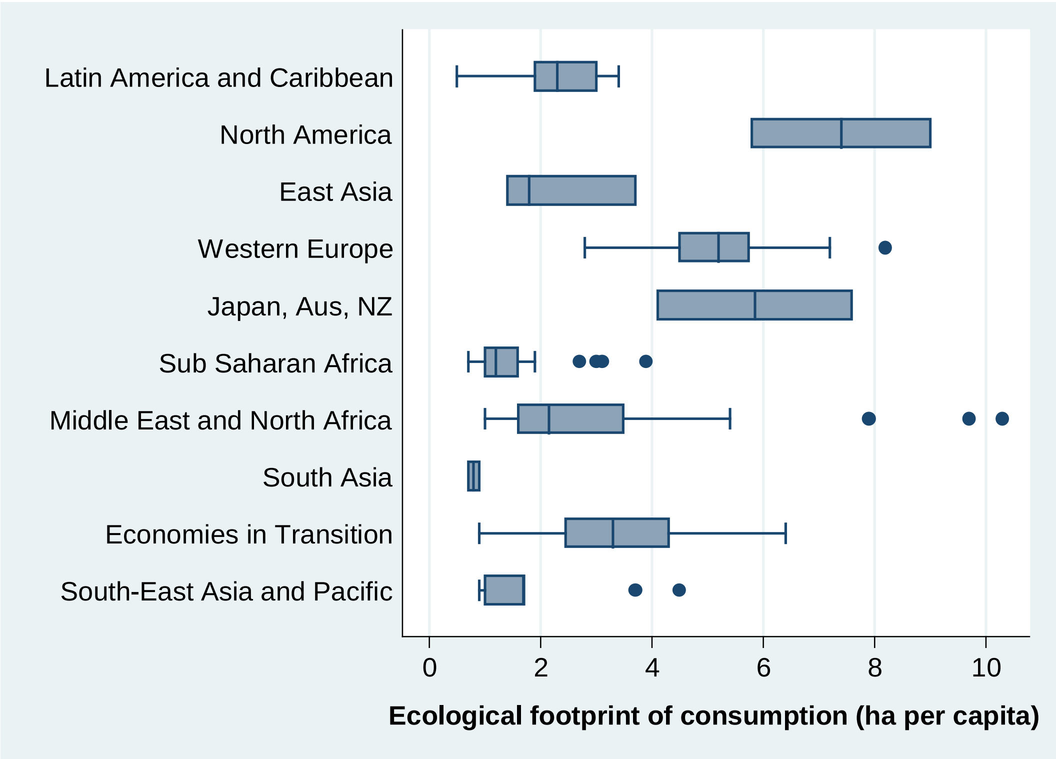



**Figure 14.1**. Ecological footprint of consumption by regions.
Source: Own elaboration based on (UNDP, 2010).

There is a second reason why regions matter. For many decades, regional integration has been a powerful force in the global economy and politics. From loose free trade areas in many developing areas to deep integration involving monetary union in parts of the EU, these regional integration initiatives have built up platforms of cooperation between countries that could become the central institutional forces to undertake regionally coordinated mitigation activities. Some regional integration initiatives, most notably the EU, have already used deep cooperation to promote a carbon trading scheme; others have focused largely on trade integration which might similarly have repercussions for the mitigation challenge; many regional initiatives have also been supported by regional development and aid initiatives. It will be critical to analyse to what extent these regional activities have been able to effectively promote mitigation activities and what options exist to build on these platforms of regional cooperation to implement further mitigation actions.

Thus 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.

### 14.1.5 Sustainable Development and Mitigation Capacity at the Regional Level

Sustainable development is about the aspirations of regions to attain a high level of well-being without compromising the opportunities of future generations. Climate change concerns relate to the level of development, as there might be trade-offs between development aspiration 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 their contribution to climate change. It will also pose greater challenges to adapt to climate change and lead societies to higher vulnerability (McCarthy et al., 2001).

As shown in Figure 14.2, human development shows great disparities among regions and within regions jeopardizing the implementation capacity of countries for implementing mitigation policies. Generally, levels of education, life expectancy, and the Human Development Index, are particularly low in Sub-Saharan Africa, with the greatest intra-regional variation, posing particular challenges to mitigation and adaptation capacity. Conversely, unemployment is very high there, making employment-intensive economic growth a high priority (Fankhaeser et al., 2008).

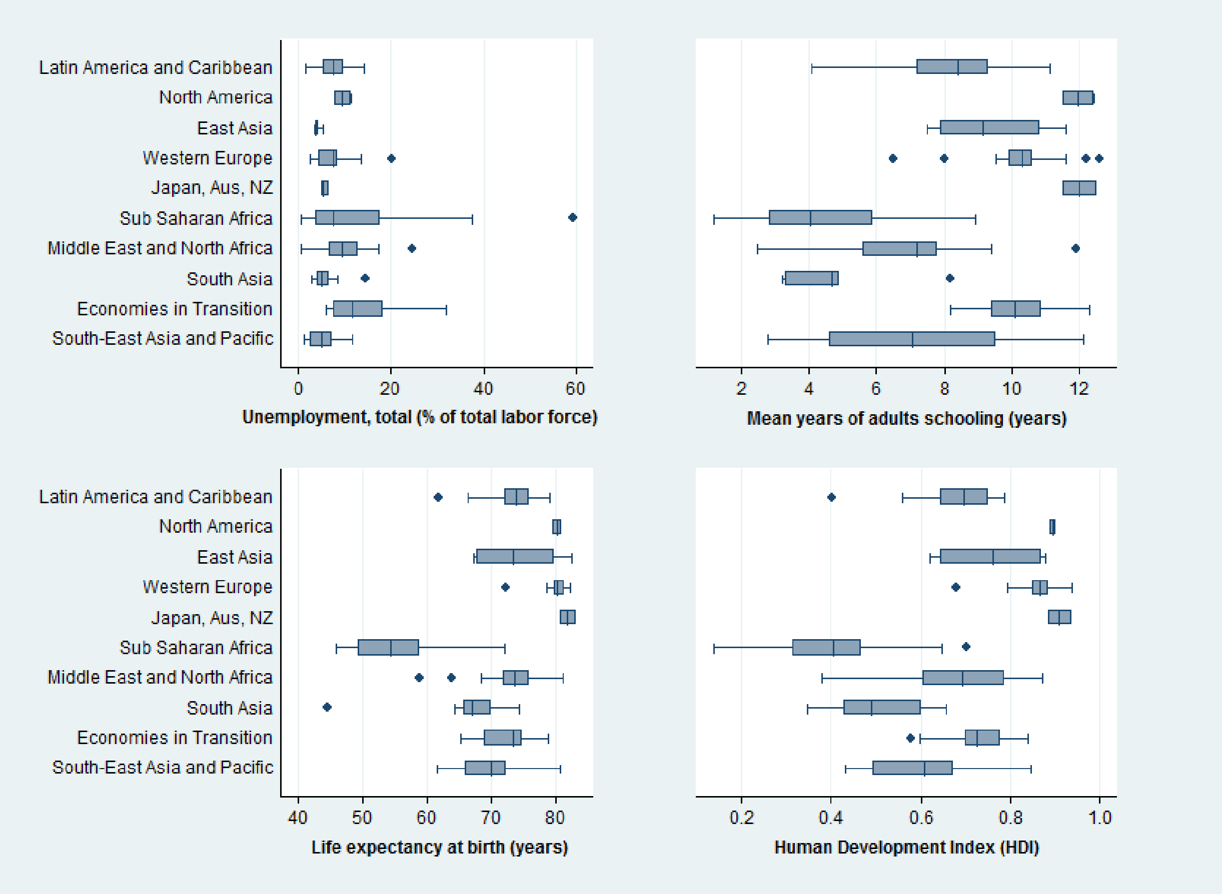



**Figure 14.2**. Regional Human Development Comparison
Source: (UNDP, 2010).

The regions with the poorest average development indicators also tend to have the largest disparities in human development (Grimm et al., 2008); (Harttgen and Klasen, 2011). For example, women are seriously disadvantaged vis-a-vis men in educational opportunities in Sub Saharan Africa and South Asia, although there are also countries with great disparities in the Middle East and North Africa (Figure 14.3).

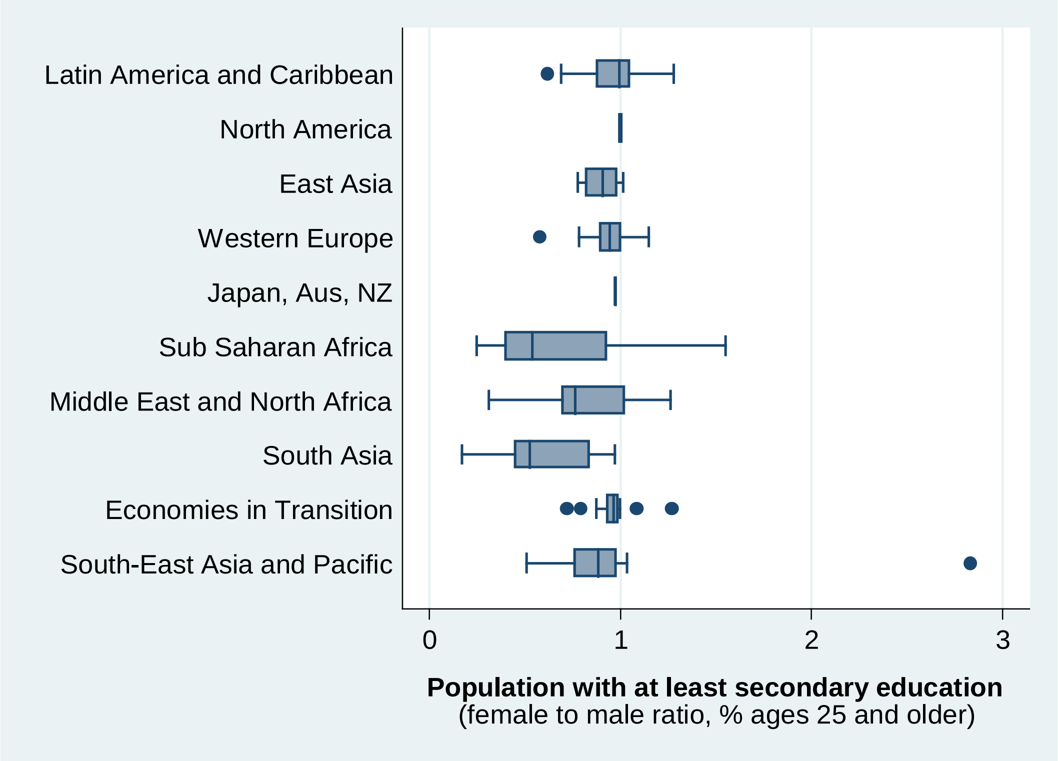



**Figure 14.3**. Population with at least secondary education. Female to male ratio, % ages 25 and older Source: (Barro and Lee, 2010).

Income-based measures of well-being tell a similar story, as shown in Figure 14.4 where absolute income poverty is particularly high in Sub-Saharan Africa, followed by South Asia. When it comes to income inequality (Figure 14.4), Latin America and the Caribbean seems to have particularly high levels of inequality. Such inequality will raise difficult distributional questions within countries regarding costs and benefits of mitigation and adaptation challenges.

Lastly, when thinking about inter-generational inequality, a key aspect of sustainable development, adjusted net savings (savings minus depreciation of physical and natural assets, plus investments in education and minus damage associated with CO2 emissions) is one way to measure whether societies are transferring enough resources to coming generations. As shown in Figure 14.4 there is great variation in these savings rates. In several regions including Sub Sahara Africa, the Middle East and North Africa, and Latin America and the Caribbean, there are a number of countries where adjusted net savings are negative, i.e. countries are savings less than depreciation of assets. Matters would look worse if one considered that future generations are larger due to substantial population growth 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.

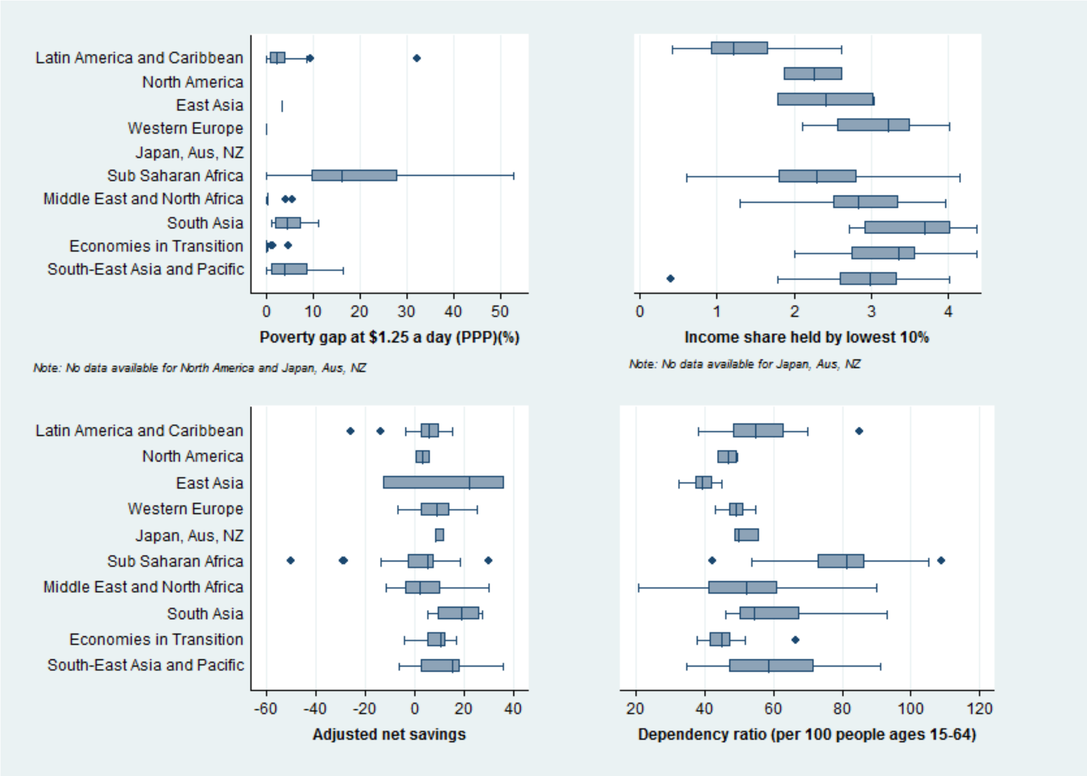



**Figure 14.4.** Regional Economic Development Comparison
Source: (World Bank, 2011).

To examine regional challenges using a different regional aggregation, Figure 14.5 shows differentials in two critical variables of sustainability: human development and adjusted net savings for least developed countries (LDC), landlocked developing countries (LLDC), and small island developing countries (SIDC). Clearly these groups of countries are particularly disadvantaged in terms of human development, relative to other countries not falling in any of these categories. They also have a larger share of countries where adjusted net savings are negative, i.e. they are facing a declining asset base.

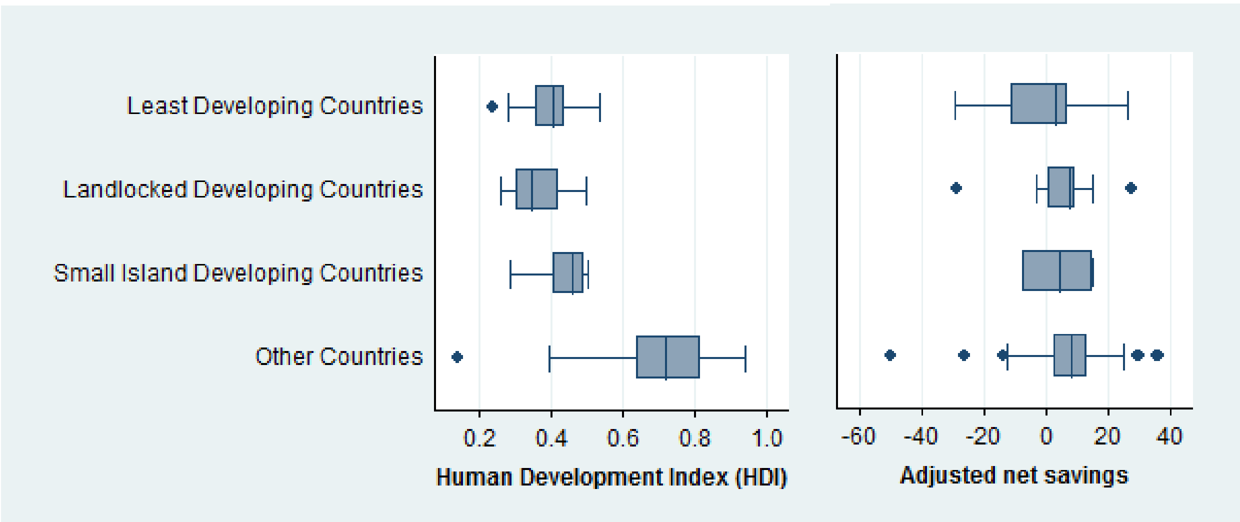



**Figure 14.5.** Sustainability opportunities for least developed countries, landlocked developing countries and small island developing countries.
Source: HDR 2010

### *14.1.5.1 The Ability to Absorb New Technologies*

Figure 14.6 presents key indicators of technology development or innovative capacity on a regional basis, including the number of researchers involved in R&D per million people, the number of scientific and technical journal articles published high-technology exports as percentage of total manufactured exports, both in percentage and in monetary terms.

Clearly, the high capacity of innovative and technology development is located basically in four regions: North America; East Asia; Western Europe, and Japan, Australia and New Zealand. Even in those regions, there exists a great gap within countries for all these measures.

High-technology exports refer to products with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery. Under this line, the situation describe above is also portrayed; however, high tech exports from Western Europe; Japan, Australia and New Zealand, and East Asia only represents 11.6%, 4.3% and 2.2%, respectively, of those from North America, in spite of the great gap that these regions show within them. When these exports are put as the percentage of manufactured exports, the panorama changes somehow. East Asia followed by Western Europe; North America, and Japan, Australia and New Zealand, are the regions with highest percentages of high tech exports in relation with manufactured exports. For example, using the median value of high tech exports, one third of East Asia manufactured exports is explained by high technology exports, while for South Asia region it represented only 0,8%. Obviously, these disparities undermine the capacity of regions to truly embrace a development path of low carbon intensity.

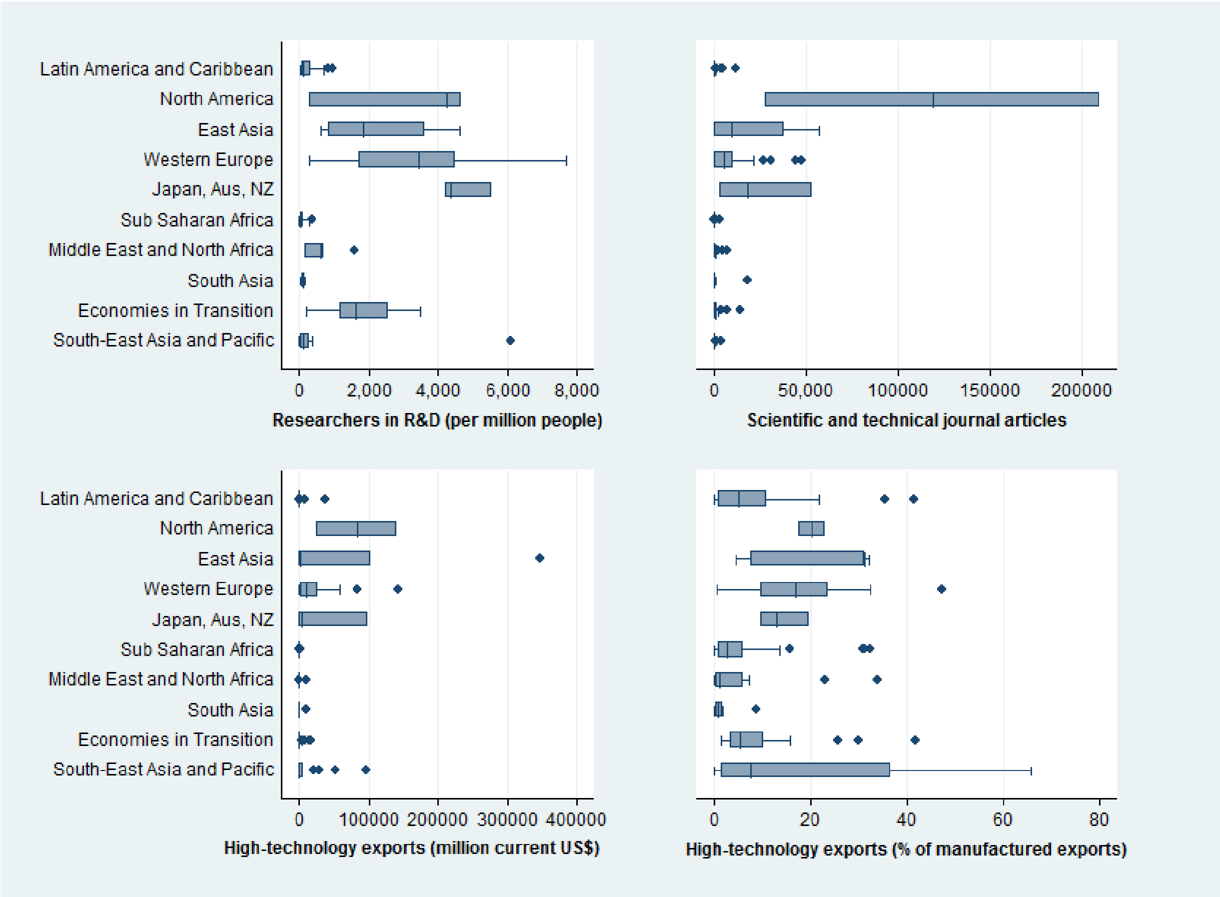



**Figure 14.6**. Regional measures of Science and Technology Development (Innovative) Capacity Source: High-technology exports: (UN Comtrade, 2011); Journal articles: (National Science Board, 2011; National Science Foundation, 2011); Researchers in R&D: (UNESCO, 2011), Institute for Statistics); all for most recent year in the period 2000-2010.

#### *14.1.5.2 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 as well as differences in governance. Figure 14.7 presents the lending interest rate to firms by region as well as the corruption perception index. The poorer regions are facing higher interest rates and are struggling more with corruption, both of reduce the ability to effectively invest in mitigation.

Conversely, there are different natural opportunities to promote mitigation activities. As discussed by Collier and Venables (Collier and Venables, 2012), it is particularly Africa which has substantial advantages in the promotion of solar and hydropower. But these investments are costly in human and financial capital as well as depend on effective states and policies. Thus these advantages may go unrealized unless these challenges are addressed, also with international support.

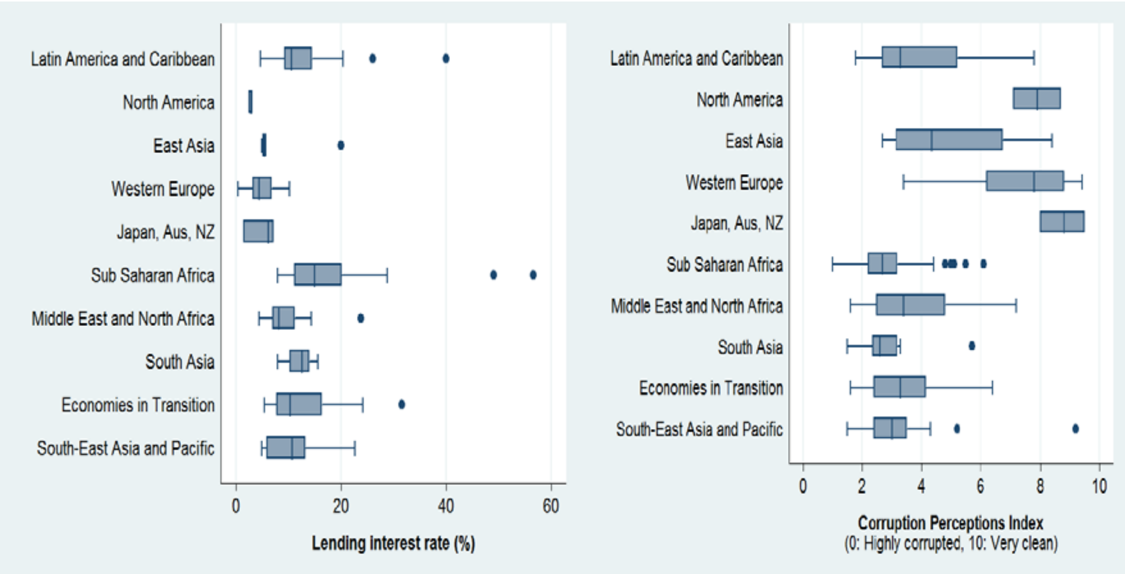



**Figure 14.7**. Lending interest rate and corruption perception index by region (Zimbabwe excluded). Source: (World Bank, 2011), (Transparency International, 2012).

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 levels 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 those differences into account, regional cooperation on climate change can serve the goal to foster approaches to mitigation which are more distribution-aware and can aid the purpose of addressing climate change effects (Asheim et al., 2006). Disparities between and within regions diminish the opportunities countries have to undertake effective mitigation policies (Victor, 2006) and, therefore, put at risk the sustainability of development itself.

### 14.1.6 Links Between Mitigation, Adaptation and Development

Creating synergies between adaptation and mitigation can increase the cost-effectiveness of climate change actions (R. J. Klein et al. 2007). Many of these synergies can be harnessed (and the potential conflicts minimised) within the context of broader development initiatives. In particular, opportunities of synergies exist in some sectors (e.g., agriculture, forestry, buildings and urban infrastructure). There may however be significant differences across regions in terms of the scope of such opportunities. However, there is not enough literature at present to assess these possible synergies and trade-offs and ways to maximize the former and avoid the latter in sufficient depth for different regions.

The relevant literature related to sectors is covered mainly in chapters 9, 11 and 12 of this report. The inputs at the conceptual level include methods for assessing this integration and the assessment of the importance of the scales for such an integration and their interrelationship (Laukkonen et al. 2009), (Halsnaes and Verhagen, 2007),(Sovacool and Brown, 2009), (Wilbanks, 2007), ,(Wilbanks et al., 2010),(Winkler et al., 2007) and (Wilson and McDaniels, 2007).

Several authors (Ayers and Huq, 2009),(Bizikova et al., 2008),(Bhandari et al., 2007), (Daniell et al., 2011), (Goklany, 2007),(Halsnaes et al., 2008), (Kok et al., 2008), (Swart and Raes, 2007) and (Wilbanks and Sathaye, 2007) stressed that to achieve a meaningful integration of mitigation and adaptation, even in the sectors where this integration is more feasible, it is needed to: a) integrate climate policies into the development planning process taking into account the socio-economic conditions and main national and regional developmental goals, such as poverty reduction, rural development, food and water security, energy supply ; b) coordinate and integrate decision making among different ministries and other stakeholders; c) engage multiple stakeholders at different scales, in particular at the local level with through a participatory approach ; d) enhance capacities and responses, including mitigative and adaptive ones, in particular through the improvement of socio-economic conditions of the population, and; e) continue gathering information, learning and researching to identify the more efficient portfolio of mitigation and adaptation strategies and measures at different scales, including the consideration of synergies, trade-offs, cost and benefits and socio-economic consequences.

Referring to potential regional actions to integrate adaptation and mitigation, (Burton et al., 2007) pointed out the need to find ways 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 part of the USA. An integrated approach of climate change policies was considered and large-scale mitigation opportunities at national and regional level were identified, indicating that the scaling-up process could be realized through international initiatives (Kok and De Coninck, 2007). (Ayers and Huq, 2009) considered that in more vulnerable developing countries, such as LDC, where mitigative capacity is low and adaptation needs are high, the linkage of adaptation to mitigation at the project level provides an avenue for integrating core sustainable development priorities with climate policy, while simultaneously encouraging the engagement of local policymakers in the mitigation agenda. Some regional examples of synergies and trade-offs between adaptation and mitigation are provided in section 14.4.2.3.

## 14.2 Development Trends and their Emission Implications at the Regional Level

### 14.2.1 Overview of Trends in Economic Development and GHG Emissions

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, EIT was the world's highest emitter of GHG emissions at 18.9% of global total of 37.7Gt $CO_2$, followed by NAM (17.9%) and WEU (12.6%) and 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.

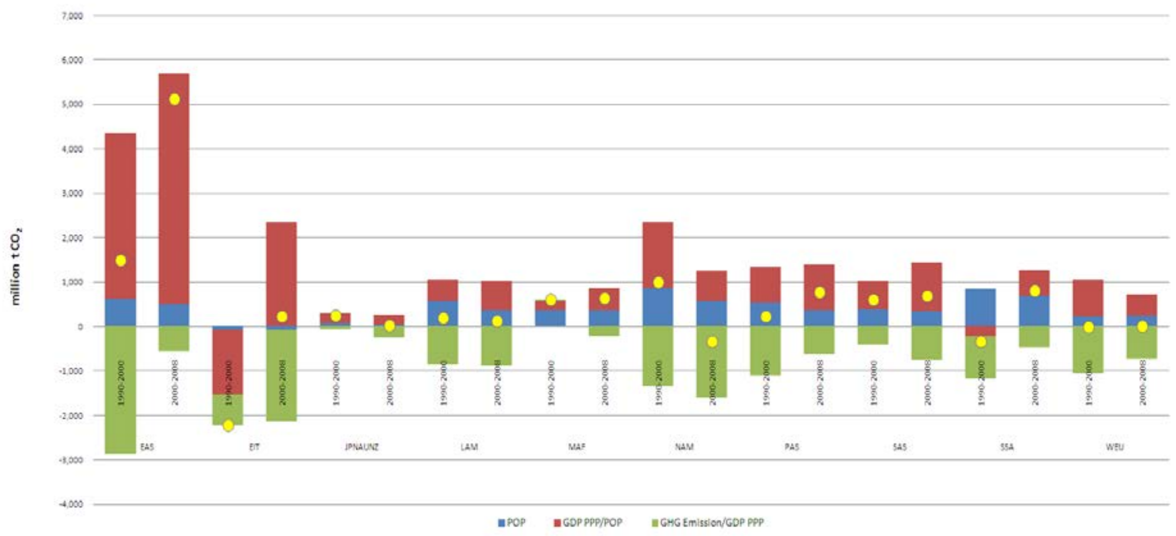
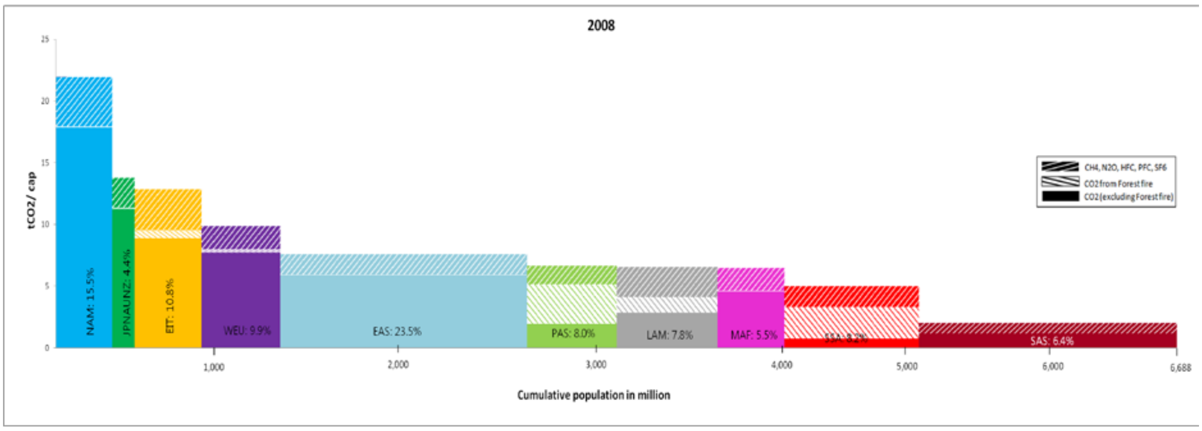



**Figure 14.8.** Decomposition of drivers for GHG emissions in different world regions
Source: GHG emission data from (Emission Database for Global Atmospheric Research (EDGAR) v4.2, 2011) and GDP ppp from (International Energy Agency, 2011).

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 14.8 shows the per capita GDP growth is the overwhelming driving force in most regions except for EIT and SSA in 1990-2000 period.

In 2008, NAM, JPNAUNZ, 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) 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 14.8 (upper graph) is that some regions such as SSA and PAS have lowest levels of per capita emissions of CO2 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 (lower graph in Figure 14.9). The four regions with highest per capita emissions, NAM, JPNAUNZ, EIT and WEU, have the lowest GHG emission intensities (emission per GDP), except EIT. Some regions with lowest per capita emissions, such as SSA and PAS, have highest 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.



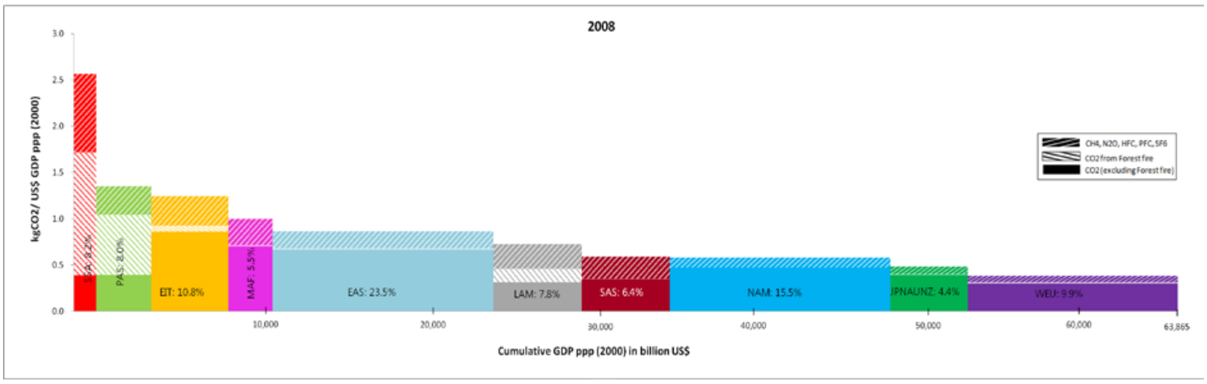




**Figure 14.9**. Distribution of regional GHG emissions in relation to population and GDP.
Note: The percentages in the bars indicate a regions share in global GHG emissions.
Data Source: GHG emission data from (Emission Database for Global Atmospheric Research (EDGAR) v4.2, 2011) and GDP ppp from (International Energy Agency, 2011).

### 14.2.2 Energy and Development

Rapid growth in final energy consumption is occurring in many developing countries. GHG emissions in developing country regions such as EAS, MAF and PAS in 2008 are more than double the level of 1990, while the GHG emission in EIT decreased by around 30%. Figure 14.10 shows that the composition of energy consumption also varies region by region. Oil is the dominant type of final energy consumption in many regions such as NAM, JPNAUNZ, WEU, LAM, MAF, while Coal has the highest share in EAS. The share of electricity in final energy consumption has tended to grow in all the 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 JPNAUNZ, followed by NAM and WEU, which are among the highest-income regions.

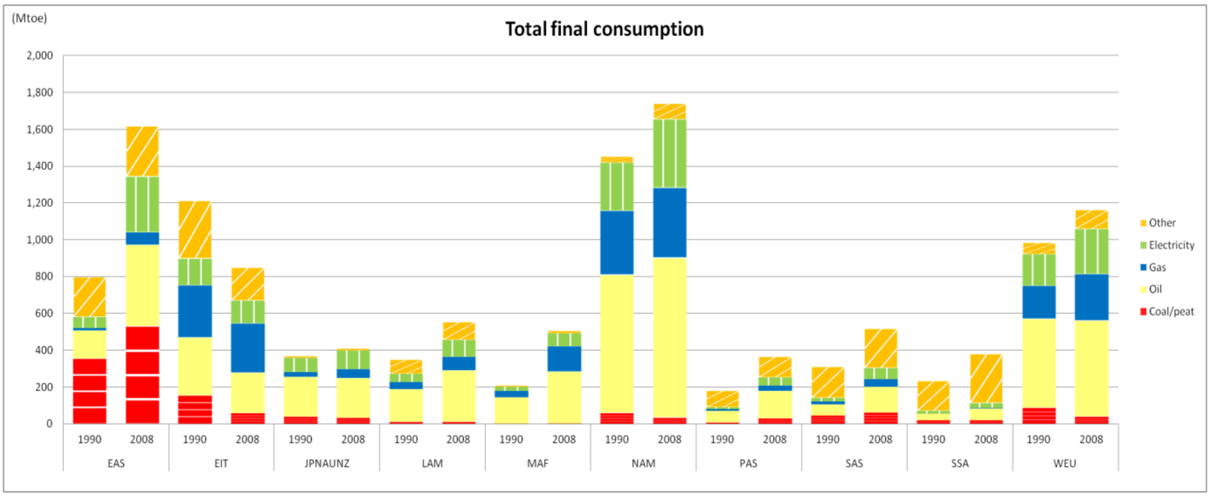



**Figure 14.10.** Final Energy Consumptions by regions
Source: (International Energy Agency, 2011)

When looking at trends in CO2 emissions by source (see Figure 14.11), 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 in EAS by 3,767 Mt-CO2, which is equivalent to roughly a half of global net increase of CO2 emission 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.

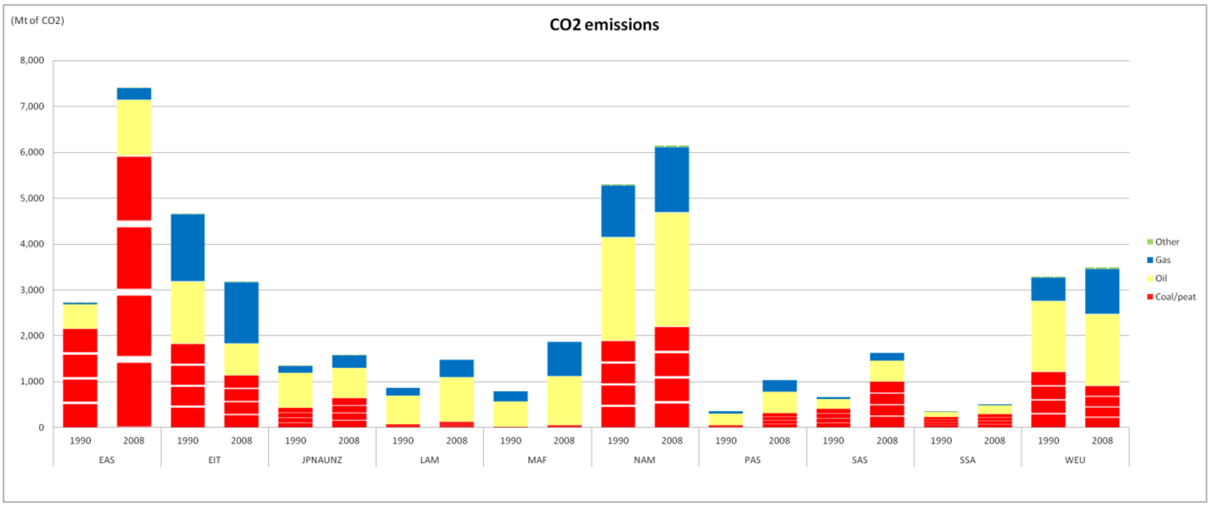



**Figure 14.11**. $CO_2$ emissions by sources and regions
Source: (International Energy Agency, 2011)

Figure 14.12 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. Only Europe and North America appear to have grown with stable per capita emissions, with the former having much higher levels of per-capita emissions throughout. It is also difficult to find an evidence for environmental Kuznets curves (EKCs) in all the regional and global trends.[1] (Huang et al., 2008) observed that the economic development and GHG emissions in EIT exhibit a hockey-stick curve trend and that statistical data for most of Annex II countries do not

[1] The environmental Kuznets curve (EKC) postulates an inverse-U relationship between pollution (e. g., GHG emission) and per-capita income.

possess evidence that supports the EKC hypothesis for GHG emissions, which is confirmed in Figure 14.12.

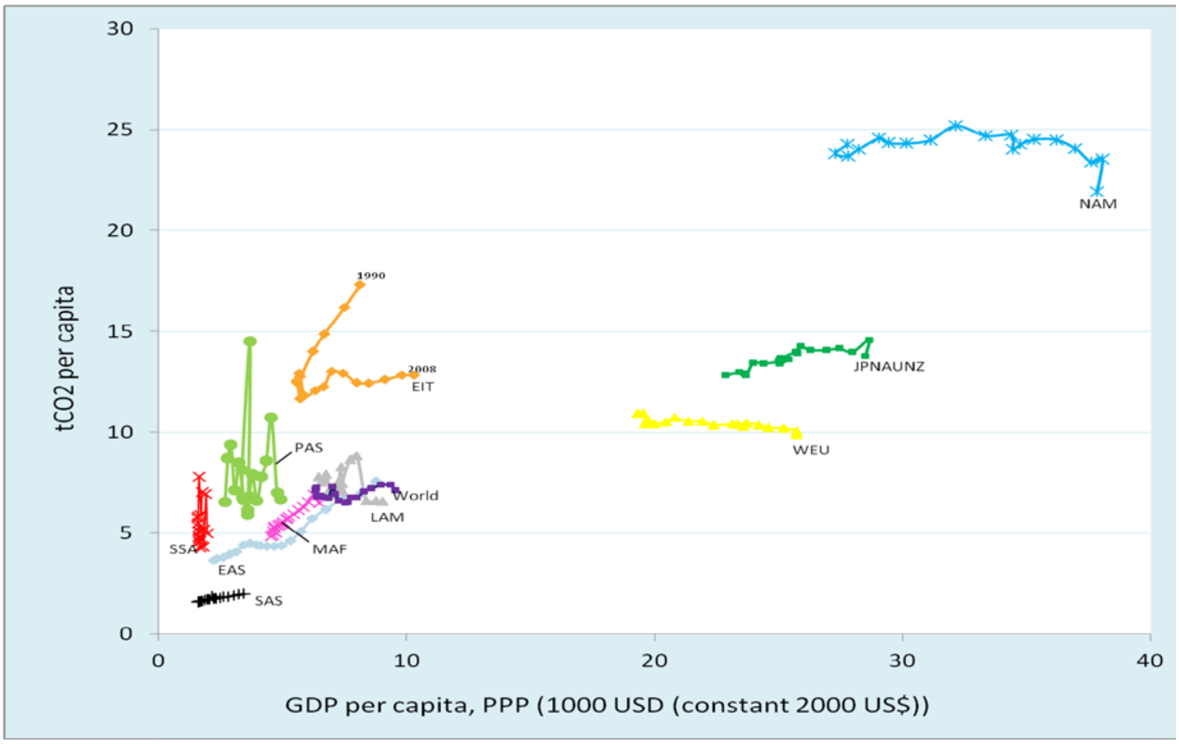



**Figure 14.12**. Relationship between emissions per capita and GDP per capita (1990-2008)
Data Source: GHG emission data from (International Energy Agency, 2011) and GDP ppp from International Energy Agency (2011)

Energy is central to achieve interrelated economic, social, and environmental aims of sustainable development. Unless energy can be reliably produced, delivered and made accessible to poor households at affordable cost, it will stay beyond the reach of many in developing countries (International Energy Agency, 2011). Lack of access to modern energy services is a serious hindrance to economic and social development and must be overcome if the UN Millennium Development Goals (MDGs) are to be achieved. About 1.4 billion people — over 20% of the global population — lack access to electricity in 2009 (International Energy Agency, 2010b). Following Table 14.1 and Table 14.2 provides number of people without access to electricity (by region). The greatest challenge is in Sub-Saharan Africa, where only 31% of the population has access to electricity, the lowest level in the world (International Energy Agency, 2010b).

**Table 14.1:** Number of people lacking access to electricity in 2009

| Regions | Number of people lacking access to electricity in 2009 (million) |
|---|---|
| **Africa** | 587 |
| *Sub-Saharan Africa* | *585* |
| **Developing Asia** | 799 |
| *China* | *8* |
| *India* | *404* |
| *Other Asia* | *387* |
| **Latin America** | 31 |
| **Developing countries** (including Middle East countries) | 1 438 |
| **World** (including OECD and transition economies) | 1 441 |

Source: (International Energy Agency, 2010b)

**Table 14.2:** Number of people (urban and rural areas) lacking access to electricity in 2009 and 2020

| | 2009 | | | 2020 |
|---|---|---|---|---|
| | Rural | Urban | Total | Total |
| Africa | 466 | 121 | 587 | 644 |
| Sub-Saharan Africa | 465 | 120 | 585 | 640 |
| Developing Asia | 716 | 82 | 799 | 650 |
| China | 8 | 0 | 8 | 2 |
| India | 380 | 23 | 404 | 342 |
| Other Asia | 328 | 59 | 387 | 307 |
| Latin America | 27 | 4 | 31 | 16 |
| Developing countries[a] | 1229 | 210 | 1438 | 1350 |
| World[b] | 1232 | 210 | 1441 | 1352 |

Source: (Kaygusuz, 2012)

Rural areas in developing countries are suffering more than urban areas in terms of energy access as 41% of rural population are without electricity access compared to 10% of urban population in developing countries (UNDP, 2009). The situation is much more severe in rural areas of least developing countries (87 %) and sub-Saharan Africa (89 %) is lack of electricity access compared with 41% in developing countries (UNDP, 2009).

Access to energy (see Figure 14.13) is inextricably linked to improved welfare and human development since energy services have a direct impact on development or on productivity, health, education, and communication (Johnson and Lambe, 2009). At the local level, access to energy facilitates economic development by improving productivity and enabling income generation.

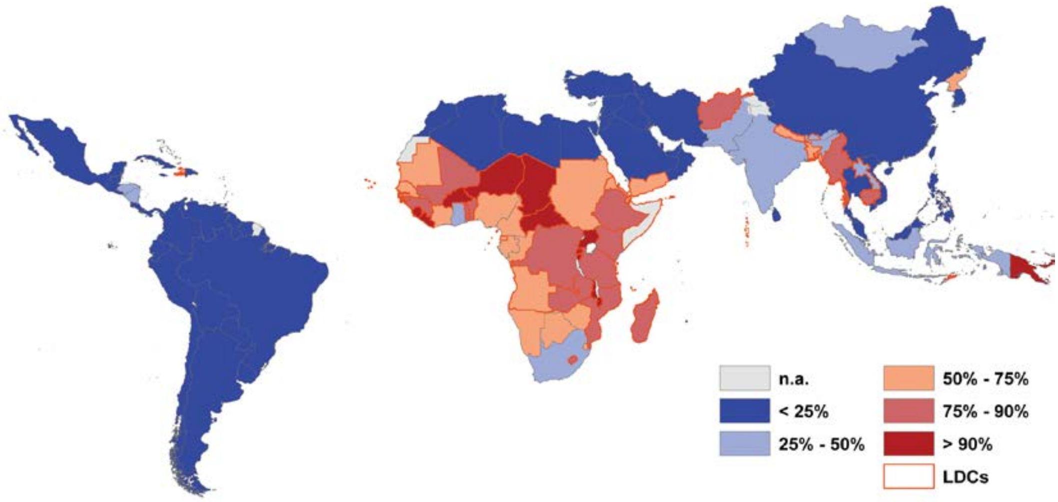



**Figure 14.13**. Share of people without electricity access for developing countries in 2009.
Notes: Based on UNDP's classification of developing countries and the UN's classification of LDCs. Some of the small countries and island states are not visible in the map.
Source: (UNDP, 2009).

### 14.2.3 Urbanization and Development

Urbanization is a process of transferring population from the rural areas to the urban ones, and labour force from agricultural pursuits to industrial and service occupations. Accompanying by the changes in industrial structure and economic development, urbanization increases fuel consumption, particularly fossil fuels, per worker and per unit of output (Jones, 1989), and introduces important challenges for climate change mitigations in global regions (Montgomery, 2003, 2008; Cohen, 2006; United Nations, 2009).

During the past decades, urbanization has been one of the most profound socioeconomic and demographic trends in the world. By 2008, more than half of the world population had already resided in the urban areas (United Nations, 2009). However, the urbanization processes vary remarkably across regions, in the urbanization levels, speeds, and its relationship with economic growth (Figure 14.14). In general, urbanization levels of all regions increased with per capita GDP during the past decades. The West Europe, North America, Australia and New Zealand, and Economics in Transition had already been largely urbanized by the middle of the last century, and their urban growth rate was relatively low. The urbanization level of Japan was still low in the 1950s but caught up quickly during the period 1950-1990. Within the developing regions, the speed of urbanization differed substantially across countries and fluctuated dramatically over time (Cohen, 2006; Montgomery, 2008). By 2010, Latin America and Caribbean had been as urbanized as Northern and Western Europe, while the majority of Asian and African population was still rural dwellers. Inside Asia, the region had some highly urbanized countries such as Korea in East Asia, oil-rich Gulf nations in the Middle East, as well as large rural countries like Cambodia in Southeast Asia and Pacific and Nepal in South Asia. The Sub-Saharan Africa region experienced rapid urbanization growth in the 1960s to 1980s, even though their industrialization and the economic growth were very slow, and per capita GDP remained unchanged (Easterly, 1999; Fay and Opal, 2000). On the other hand, some other countries (e.g. China and former socialist countries in Eastern Europe) had a very slow urban growth during the same period, which was significantly lagged behind its industrialization (Zhang and Zhao, 2003; Chang and Brada, 2006).

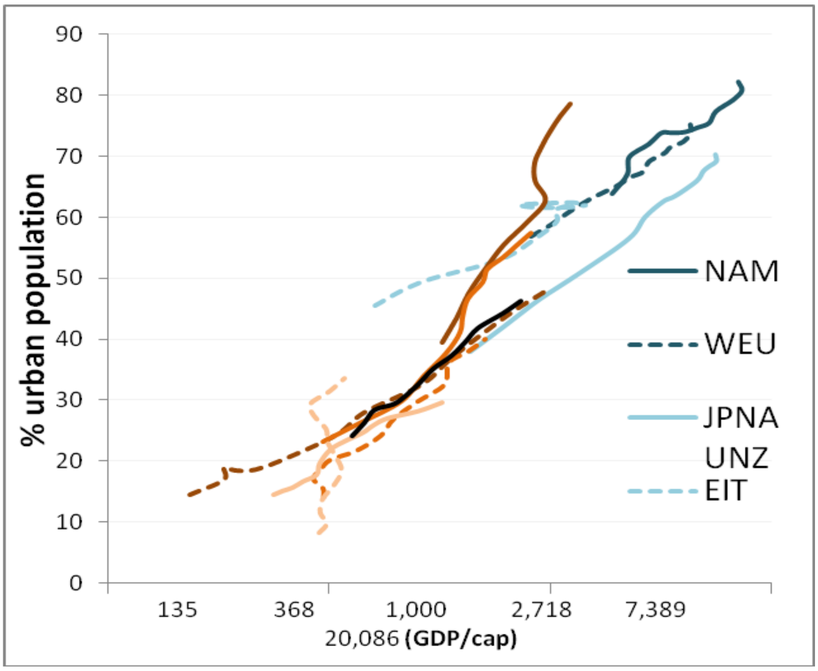



**Figure 14.14.** Changes in urbanization level and per capita GDP by regions (1950-2005)
Data sources: (1) urbanizaton levels from UN World Urbanization Prospects 2009 Revision; (2) GDP from Penn World Table.Regions: NAM – North America; WEU-Western Europe; JPNAUNZ- Japan, Australia, New Zealand; EIT – Economics in Transition; LAM – Latin America and Caribbean; EAS – East Asia; MAF-Middle East and North Africa; PAS – Southeast Asia and Pacific; SAS- South Asia; SSA-Sub-Saharan Africa.

While the urban system is relatively mature than in Europe, North America, and developed Asia and Pacific, urbanization in the developing region spans a big range of stages, and includes all types of urban forms. Although the rapid urbanization in many developing countries over the past half century have been accompanied by excessively high levels of population concentration in the large cities (Henderson, 2002), urban sprawl has already been occurring in the Latin America, as well as in some Asian countries (Burchell et al., 1998). Meanwhile, the majority of urban population growth is observed in the small or medium size urban areas (Grubler, forthcoming; Martine et al., 2008); the rural poor have consistently been urbanized faster than the non-poor, which suggests a prominent phenomenon of urbanization of poverty (Haddad et al., 1999; Ravallion, 2002). These variations in urbanization have generated significantly different social, economic and environmental impacts among global regions.

As urbanization is largely associated with industrialization and economic growth, energy consumption and carbon emission per person in more urbanized regions is generally higher than in less urbanized ones (Figure 14.15). However, urbanization is only one of the important driving forces of increasing CO2 emissions; regions with the same urbanization levels may differ significantly in emissions. For instance, although the LAM region has the similar urbanization level as the NAM and WEU regions, its per capita CO2 emissions is substantially lower than the latter, largely driven by different income levels. Moreover, while the urbanization level of Sub-Saharan Africa almost doubled in the past four decades, the per capita carbon emissions in this region remained unchanged. Studies reveal an inverted-U shape between urbanization and CO2 emissions among developing countries of different income levels. The elasticity of urbanization for carbon emissions is larger than one 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).

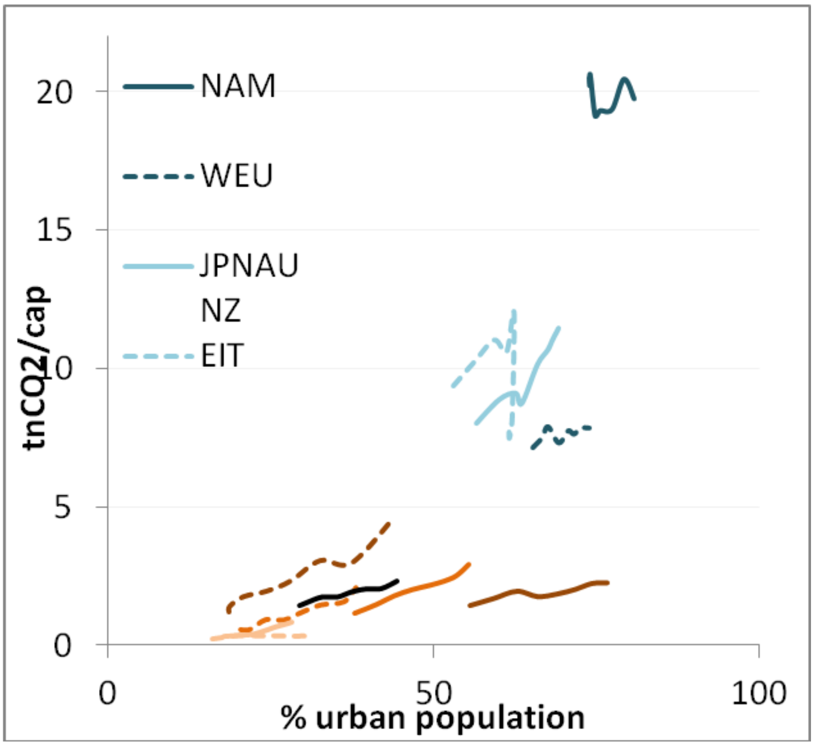



**Figure 14.15**. Relationship between urbanization levels and per capita CO2 emissions by regions, 1970-2005

Data sources: (1) urbanization data same as Figure 14.14; (2) emission data from (Emission Database for Global Atmospheric Research (EDGAR) v4.2, 2011), $CO_2$ excluding carbon from short-cycle biomass burning and forest fires.

The impact of urbanization on energy consumption and emissions differs not only by the stages of urbanization and economic development levels of the regions, but also by the forms and patterns of their urban systems. In responses to increased affluence and growing dependence on automobile, urban sprawl occurs in many parts of the world, particularly in the US (Burchell et al., 1998). Urban density and spatial organization are crucial elements that influence energy consumption, particularly in transportation and residential energy use.

Studies comparing energy consumption of cities in different regions reveal that per resident energy use is generally higher in developed regions than in developing regions (Figure 14.16). More importantly, per capita emissions of cities in developing regions are usually higher than that of national average, while the relationship is reversed in developed regions (Grubler, forthcoming; Kennedy et al., 2009). It is mainly because urban residents of the developing regions have relatively higher income levels than their rural counterparts, and cities in developing regions are also the manufacturing centers in the economy, which requires high-energy input per unit of GDP output. This is particularly true in the cities of the developing Asia. However, many cities in Sub-Saharan Africa and Latin America and Caribbean have lower than national average per capita energy use, because their rapid urbanizations were not accompanied by significant industrialization and economic growth, which resulted in the so called 'urbanization of poverty" (Easterly, 1999; Haddad et al., 1999; Fay and Opal, 2000; Ravallion, 2002).

Within the developed regions, cities in North America consume significantly more energy per capita than their counterparts in West Europe, developed Asia and Pacific, and the region of Economies in Transition. A comparison of 10 major cities in the US with 12 European cities shows that the US cities consume 3.5 times more energy in transportation than their European counterparts (Steemers, 2003). This is mainly because the latter are five times as dense as the former; and the suburban households in the US drive 31% more than the residents in the central cities (Kahn, 2000).

Suburbanization may also contribute to increasing residential fuel consumption and land use (Kalnay and Cai, 2003). Although a more compact development in the low-latitude regions may induce greater demands for space cooling due to the strong effect of urban heat island (Santamouris et al., 2001; Pitts, 2010), urban sprawl increases energy use for housing everywhere that generates a much stronger effect than the possible energy saving from space cooling (Ewing and Rong, 2008). Considering the effects of urban form and transportation system, moving households from a city with the characteristics of Atlanta to a city with the characteristics of Boston reduces annual vehicle miles travelled by 25% (Bento et al., 2005).

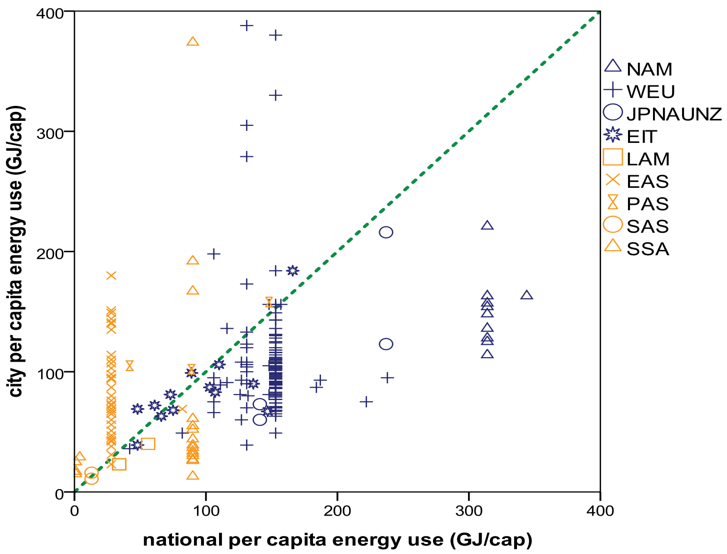



**Figure 14.16.** Per capita energy use of cities compared with the national average by regions, 2000
Note: The per capita energy use of cities represented by dot above the green line is higher than the national average; otherwise, is lower than the national average. The city energy use data is calculated based on 'production accounting' approach, which focuses on the direct final energy use in the cities. As most of cities in the developed regions have higher share of less energy-intensive services activities compared to the national average, the goods and services consumed by the city dwellers are disproportionately produced outside the city boundaries. If one uses a 'consumption accounting' approach, which accounts for both direct and embodied energy use in producing the goods and services consumed by the urban households, the per capita energy consumption of cities in the more developed regions would be comparatively higher (Grubler, forthcoming).
Data sources: (1) city energy data is from (Grubler, forthcoming); (2) national energy data is from IEA energy balances (International Energy Agency, 2010a).

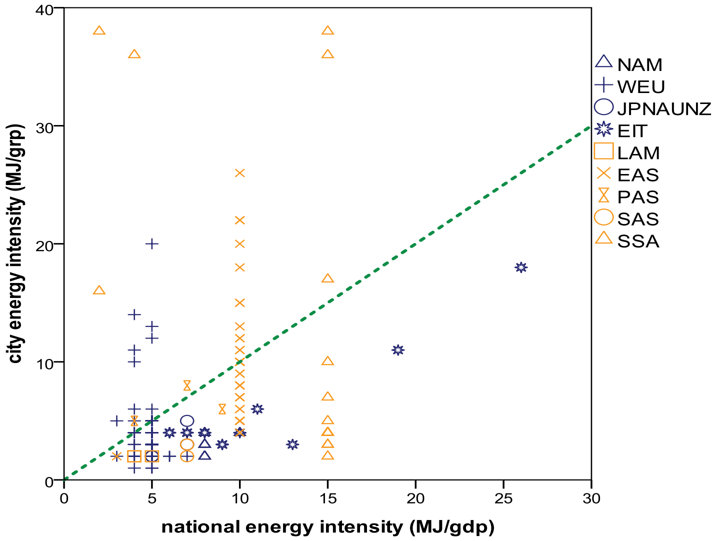



**Figure 14.17.** Energy intensity of cities compared with the national average by region, 2000
Note: The energy intensity of cities represented by dot above the green line is higher than the national average; otherwise, is lower than the national average.
Data sources: (1) city energy data is from (Grubler, forthcoming); (2) national energy data is from IEA energy balances (International Energy Agency, 2010a).

Nevertheless, the majority (two out of three) of American cities, like their European and Asian and Pacific counterparts, have lower than national average per capita energy use, although their income levels are higher than national average, because of the lower energy intensity (energy use per GDP) (Figure 14.17). The relatively lower energy intensity in the cities is also true for the developing regions. More than 60% of the cities in the developing regions have lower than national average energy intensity. Moreover, energy intensity in the developing regions and their cities are significantly higher than in the developed regions, although their per capita energy consumption is generally lower.

This has important implications for global and regional challenges and opportunities of climate change mitigation.

Although urbanization and its associated income growth and industrialization generally increases energy consumption and greenhouse gas emissions, evidences from households of developing countries in different urban development forms indicates that energy consumption per unit of income is significantly lower than the national average; and, within cities, energy intensity is also lower in planned areas than unplanned areas (Permana et al., 2008). Strategic urban planning and introduction of resource efficient and environmentally friendly technology can greatly enhance energy efficiency. Therefore, increasing carbon emissions due to urbanization in the developing regions are not inevitable. Moreover, urbanization in most developing countries also contributes to energy poverty alleviation and improvement of standard of living in the less developed countries (Pachauri, 2007). The household energy transition from traditional solid fuel to modern clean sources along urbanization process significantly enhances energy efficiency and reduces adverse health consequences from traditional fuel combustion (Jiang and O'Neill, 2004; Pachauri and Jiang, 2008), which contributes to improving human wellbeing and meeting the millennium development goals.

### 14.2.4 Consumption and Production Patterns in the Context of Development

Under the United Nations Framework Convention on Climate Change (UNFCCC) countries are required to submit National Emission Inventories (NEI) to benchmark domestic reductions in greenhouse gas (GHG) emissions (Glen P. Peters 2008). There are three emission accounting methods in the literature: territorial, production and consumption-based accounting approaches (see Chapter 5). The territorial approach adopted by the UNFCCC has been criticised for failing to fully attribute international transportation emissions and for overlooking the increasing importance of emissions transfer, via internationally traded goods and services, from developing to developed countries (Glen P. Peters, Jan C. Minx, et al. 2011; G. P. Peters et al. 2012). To address these issues, studies have suggested the complementary use of consumption-based inventories (production emissions less exports plus imports) in national emissions accounting.

If we compare the production and consumption emission accounting methods, the former identifies the place where emissions occur and the latter investigates the driving forces of emissions discharged. Sharing the responsibility between production- and consumption-based national emission inventories have also been raised and discussed (R. Andrew & Forgie 2008; Glen P. Peters 2008; Serrano & Dietzenbacher 2010; Gallego & Manfred Lenzen 2005; Manfred Lenzen et al. 2007; Rodrigues & Domingos 2008).

Global $CO_2$ emissions (CDIAC data, which includes fossil-fuel, cement and gas-flaring sources) grew from 22Gt $CO_2$ in 1990 (the Kyoto Protocol base year) to 30Gt $CO_2$ in 2008, an increase of 39% with an annual growth rate of 2% (Glen P. Peters, Jan C. Minx, et al. 2011). Global per capita emissions increased by 9% from 4.15t in 1990 to 4.54t in 2008. However the contribution to global emissions from different regions varies considerably. While remaining as the world's major emissions contributors, developed regions' (North America and West Europe) share of global emissions has declined from 60% to 40% over the period of 1990 to 2008; the gap being filled by the emerging developing countries in East and South Asia (e.g., China and India). East Asia has seen its production emission increase almost three-fold from 2.7 to 7.7Gt during 1990 – 2008, pushing China into the position of top emitter followed by the United States (Dabo Guan et al. 2008; Dabo Guan et al. 2009; Gregg et al. 2008). Similarly, emissions from South Asia and South East Asia have increased about 2.5 times from 0.8 to 1.8Gt and 0.5 to 1.3Gt, respectively, during the same period. India became the world's third largest emitter in 2008. The production emissions of least developed countries (e.g. in Sub-Saharan Africa) have not changed significantly over the same period. In terms of per capita production emissions, residents of North America are attributed 19 tonnes per year: a figure that has not changed significantly since 1990. The most significant changes occurred in East Asia and South Asia where per capita production emissions have grown 2.4 (from 2.1 to 5.2t) and 1.9 times (0.7 to 1.3t) during 1990 – 2008 respectively.

Researchers have argued that the consumption-based accounting method can provides a better understanding of the common but differentiated responsibility between countries in different economic development stages (Steven J. Davis & Caldeira 2010; G. Peters & E. Hertwich 2008; J. C. Minx et al. 2009; Thomas Wiedmann 2009; Weber & H. S. Matthews 2007; Weber & H. S. Matthews 2008). Consequently, a great research effort has been focused on estimating: (a) country level $CO_2$ emissions from both production and consumption perspectives; and (b) the magnitude and importance of international trade in transferring emissions between regions (Steven J. Davis & Caldeira 2010; Steven J. Davis et al. 2011; Glen P. Peters, Jan C. Minx, et al. 2011; Giovanni Baiocchi & Jan C. Minx 2010; E. G. Hertwich & Glen P. Peters 2009; Glen P. Peters & E. G. Hertwich 2008; Nakano et al. 2009; Wiebe et al. 2012). Methodologies and definitions vary between studies, leading to different estimates of consumption-based emissions and measures of emissions embodied in trade (see Kanemoto et al. 2011; G. P. Peters et al. 2012). However, Peters et al. (2012) synthesis of global studies revealed that results are broadly consistent after controlling for different production-based emissions estimates as inputs and different definitions of allocating emissions to international trade. As such, representative findings from (Peters et al., 2011) are discussed below for two core methods: (a) the emissions embodied in bilateral trade (EEBT) method; and (b) the multi-region input-output (MRIO) method[2]. The EEBT method considers domestic supply chains only and answers

[2] Reliance on the GTAP database portfolio (from which complete international sets of trade-linked national input-output tables can be derived following the steps outlined in (Peters et al., 2011) Glen P. Peters, R.

questions such as "how much of China's 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 the USA"?

During the period 1990 – 2008, major increases in the consumption emissions of large developing countries in East Asia, South Asia and Latin America have been reported. 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 between 1990 - 2008.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. Between 1990 and 2008, the value of world trade almost tripled, showing an average growth rate of 6% a year. The transfer of emissions via traded products between developing countries grew at 21.5% annually during 1990 – 2008. During the same period, the developed countries regions have been gradually increasing their consumption emissions. For example, North America has increased their consumption emissions by 1.3% per year. In terms of per capita consumption $CO_2$ emissions, residents in North America have triggered a relatively constant 20 tonnes per person per year over the last two decades, while other developed regions and have averaged 11 – 13t per person: thus consumption emissions of developed regions are found to be 3 – 5 times higher than the global average of 4.5t per person.

Typically, per capita carbon footprints' in developed countries 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) have similar carbon footprints to those in developed regions (Hubacek et al., 2007; Feng et al., 2010). Along with the rapid economic developments and lifestyle changes in Asia, the average carbon footprints have increased 72%, 74% and 120% in South East Asia, South Asia and East Asia respectively. The growth is projected to be further accelerating (Guan et al., 2008). Per capita carbon footprint in least developed country regions have seen only relative small changes, indicative of minimal improvements in their lifestyle. It is worth to mention that the per capita carbon footprint in Sub-Sahara Africa has slightly decreased from 0.63 to 0.57t, which is largely driven by population growth.

Hertwich and Peters (2009) quantified GHG emissions associated with the final consumption of goods and services for 73 nations and 14 aggregate world regions. National average per capita footprints vary from 1t$CO_2$e/y in African countries to ~30t/y in Luxembourg and the United States. On the global level, 72% of GHG emissions are related to household consumption, 10% to government consumption, and 18% to investments. Food accounts for 20% of GHG emissions, operation and maintenance of residences is 19%, and mobility is 17%. Food and services are more important in developing countries, while mobility and manufactured goods rise fast with income and dominate in rich countries.

Figure 14.18 illustrates the net CO2 emission transfer between the 10 world regions in 2004 using the MRIO method. The global $CO_2$ emission in 2004 is 27.3Gt, which consists of 22.8Gt from the global production system and 4.5Gt from global residential sources. If we focus on the production related emissions, the left-hand-side of Figure 14.18 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 14.18 illustrates the magnitudes and origins of production emissions embodied in regional final

Andrew, et al. (2011)means that detailed analysis can only be performed using the EEBT and MRIO methods for the years 1997, 2001, and 2004 due to data availability. However, an annual time-series (1990-2008) approximation of EEBT is derived using components of the Gross Domestic Product (GDP). Several projects are now underway to construct consistent time-series of MRIO tables, but they have not yet reached completion.

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 is the largest net emission exporter (1,099 Mt) in 2004, with total exported production emissions (1,501Mt) accounting for 27.8% of total production emission (5,399 Mt), while imported consumption emissions (402Mt) account for less than 10% of total consumption emissions (4,323Mt). Developed countries are the major destinations of export products in East Asia. For example, North America and Western Europe account for 33% and 27% of East Asia's total exported production emissions, respectively. Over 60% of embodied emissions in Chinese exports, mainly formed by electronics, metal products, textiles, and chemical products, are transferred to developed countries (Weber et al., 2008). In contrast, North America is the largest net emission importer (747Mt) in 2004, with total exported production emissions (456Mt) accounting for 9.2% of total production emission, while imported consumption emissions (1,203Mt) account for 21.2% of total consumption emissions.

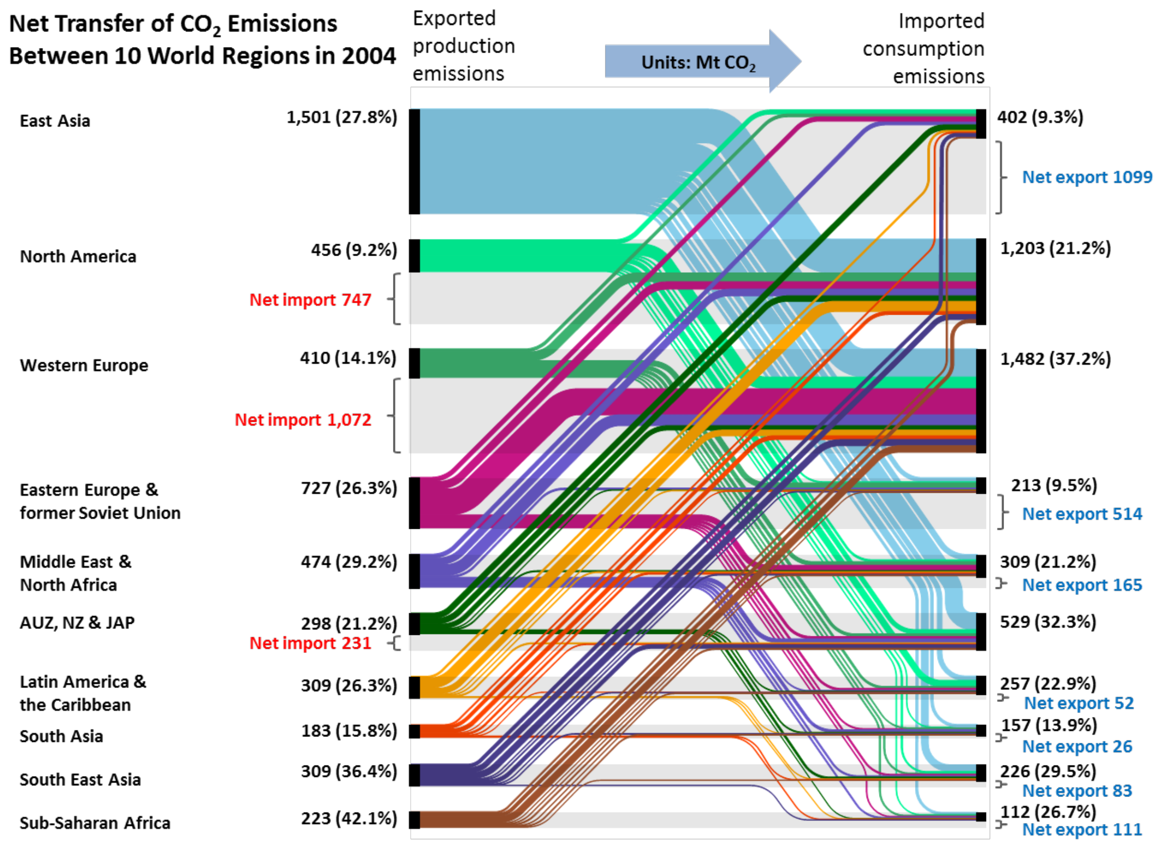



**Figure 14.18.** Net Transfer of CO2 Emissions between World Regions in 2004 using MRIO method. Flow widths represent magnitude of emissions (in Mt CO2) released by left-hand-side regions that have become embodied (along global supply chains) in the good and services consumed by right-hand-side regions. 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 production emissions (regions are ordered top to bottom by rank of total production emissions), while percentage figures on right-hand-side indicate total imported emissions as percentage of total consumption emissions (excluding household emissions). Analysis performed using multi-regional input-output model derived from GTAP database. Global production emissions estimated at 22.8Gt CO2 (global household emissions estimated to be 4.5Gt CO2, giving global CO2 emissions of 27.3Gt CO2 for 2004).

Figure 14.19 demonstrates (using the EEBT method, see Chapter 5 for methodology explanation) 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 (1366Mt $CO_2$), followed by exports from Middle East & North Africa and South Asia with 20% (510 Mt$CO_2$) and 12% (290Mt $CO_2$) of global growth, respectively. The main driver of the growth in those developing country regions is the significant increase of imports from the developed countries in North America and Western Europe, which are ranked as the top two countries reporting growth in bilateral imported emissions. 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 268Mt in some bilateral trade connections, primarily from Eastern Europe & former Soviet Union (257Mt). Counter to all other regions, Eastern Europe & former Soviet Union countries has experienced net reduction in exported emissions due to political instabilities, deindustrialisation policies and related changes in export patterns, while their imported emissions increased by 213Mt, facilitated by exports from East Asia (102Mt) and Western Europe (58Mt).

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 260Mt, 242Mt and 212Mt, 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. Both exported and imported emissions in Sub-Saharan Africa during 1990 – 2008 have steadily increased. About 60% of increase exported emissions in Sub-Saharan Africa are driven by Western Europe and North America imports while 15% by East Asia. Primary energy and other raw natural resources account for large portion of their exports growth. In terms of imported emission growth in Sub-Saharan Africa, 40% are due to the increase of imports from China, followed by 23% from Middle East & North Africa and 17% from South Asia.

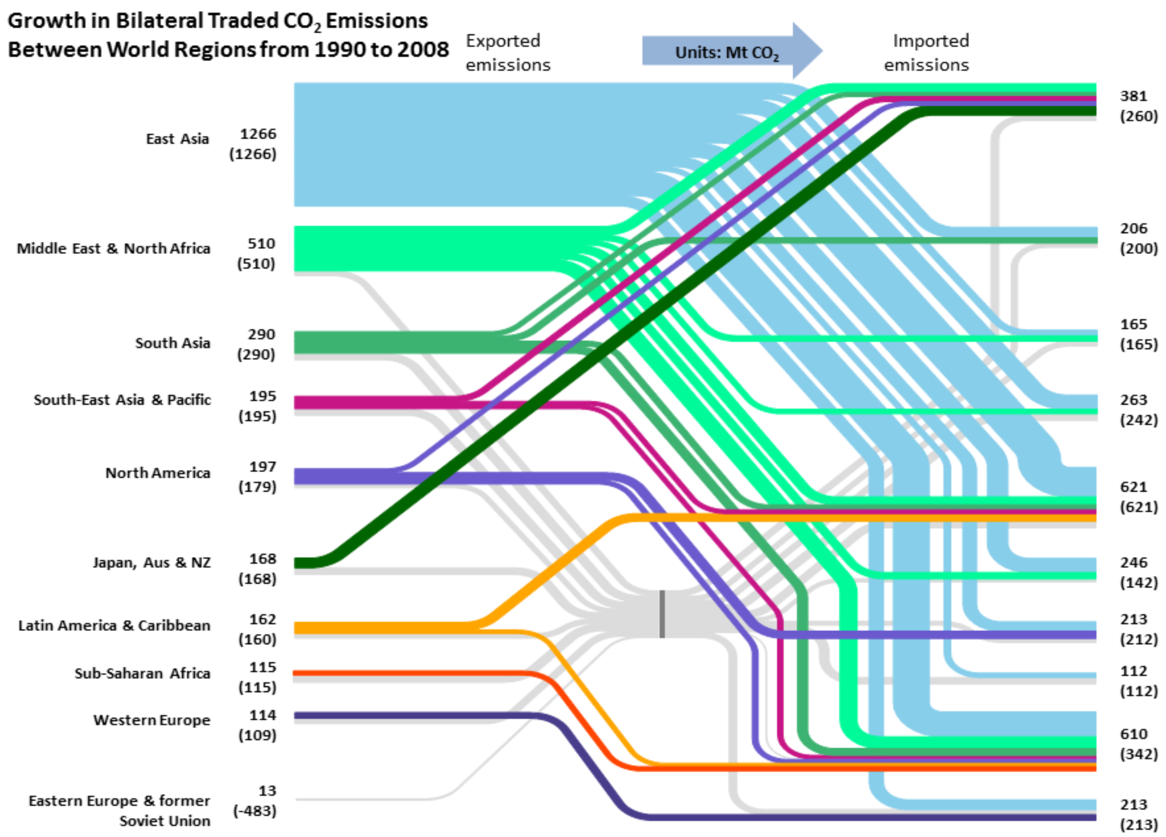



**Figure 14.19.** Growth in bilateral traded $CO_2$ emissions between world regions from 1990 to 2008 (using EEBT method): Flow width represents growth in bilateral traded emissions (in Mt $CO_2$) between 1990 and 2008, exported from left-hand-side region and imported by right-hand-side region. Flows representing growth greater than 30Mt $CO_2$ are shown individually. Less significant flows have been combined and dropped to the background. Figures for the sum of all export/import connections of each region exhibiting positive growth are 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 2.5Gt $CO_2$ (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 (-267Mt $CO_2$), to East Asia (-121Mt $CO_2$), and to Japan, Aus & NZ (-80Mt $CO_2$).

Taking the above analysis a step further, Figure 14.20 breaks down the (MRIO-based) regional emissions transfers by industry sector groups for the largest importer of emissions, Western Europe, and the largest exporter of emissions, East Asia. The top left and right diagrams show absolute measures of exported and imported emissions by sector group for each region respectively. The following sector groups are indicated on each diagram: utl - utilities (electricity, gas & water); trn - transportation (road, rail, air & water); met - metal production & products; pcp - petroleum, chemicals & plastics; min - mineral products (inc. cement); and, exm - extraction & mining. For example, East Asia exports 229Mt $CO_2$ of *met* production emissions (inc., 77Mt to North America, 61Mt to Western Europe and 33Mt to Jap, Aus & NZ), while only importing 55Mt (inc., 24Mt from Jap, Aus & NZ, 10Mt from Eastern Europe & FSU and 6 Mt from Western Europe). The trend is reversed for Western Europe, which imports 160 Mt of *met* production emissions (inc., 61Mt from East Asia, 48Mt from Eastern Europe & FSU and 15Mt from Jap, Aus & NZ), while exporting only 56Mt (inc., 15Mt to North America, 11Mt to Eastern Europe & FSU and 9Mt to Middle East & North Africa).

The bottom left and right diagrams present exported and imported emissions as a share of total production emissions and total consumption emissions respectively, allowing the identification of sector groups that are particularly associated with traded emissions but that may have relatively low absolute measures of exported and imported emissions. For example, 60% of the total production emissions from East Asia's textiles, clothes & leather (tcl) sector group are exported to other regions (primarily Western Europe, North America and Jap, Aus & NZ). The degree of aggregation in sector groups can mask the importance of certain sectors: for example, other manufacturing (man) includes electronic equipment, which for East Asia 68% of production emissions are exported. Similarly, 68% of Western Europe's consumption emissions from the extraction & mining sector group are imported; this includes coal, oil, gas and other mining sectors where the figures are 55%, 63%, 79% and 70% respectively.

The advantage of having this type of chart is to illustrate the emission transfers at economic sectoral level, which provides the quantitative evidence for what aspects of low carbon policy at sectoral level in different regions should be addressed in order to minimize carbon emissions throughout the global supply chain.

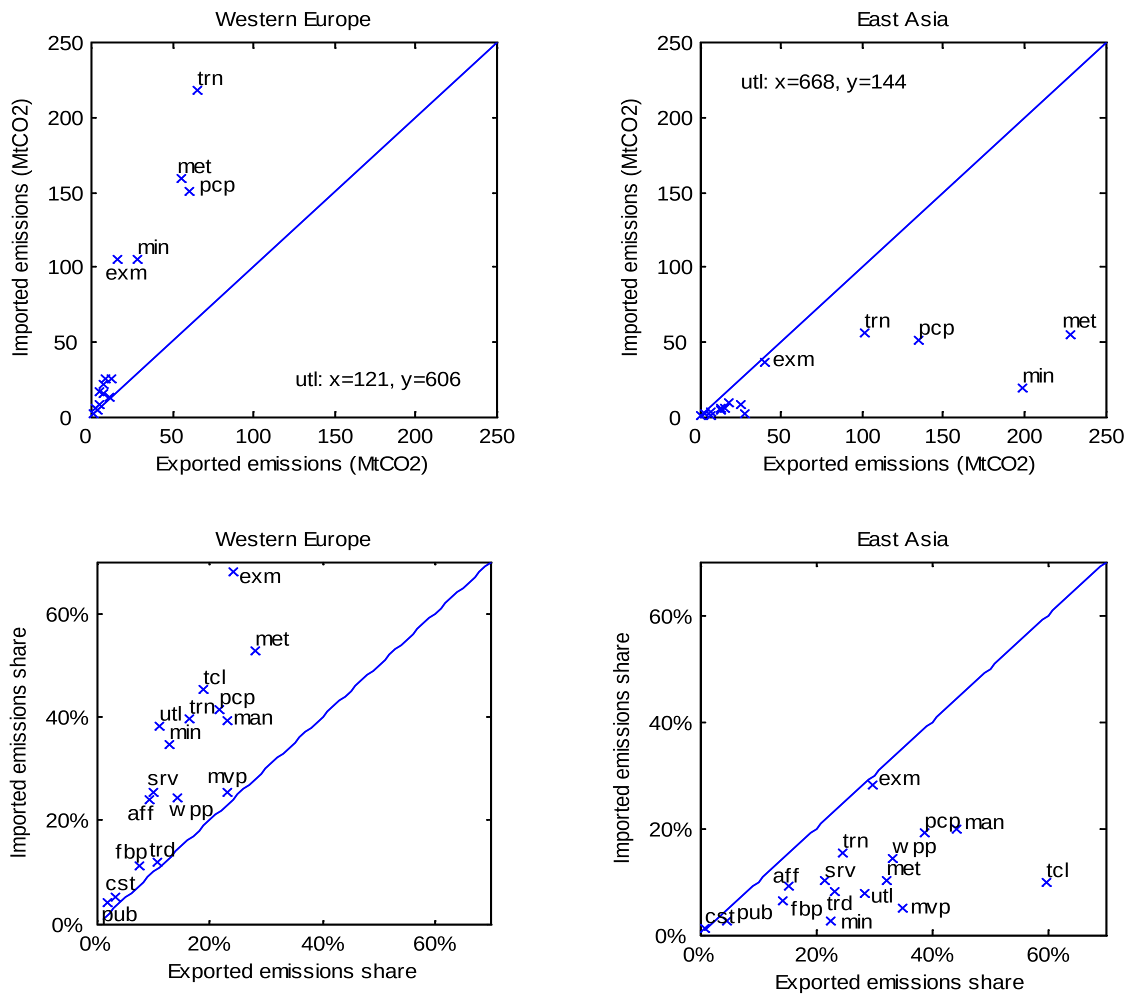



**Figure 14.20**. Emission Transfers between World Regions by Economic Sectors

**Note: Top left: x-axis represents Western Europe production emissions, by sector group, that become embodied (through global supply chains) in the final goods and services consumed by other regions (i.e. exported production emissions); y-axis represents non-Western Europe production emissions, by** sector group, that become embodied in the final goods and services consumed by Western Europe (i.e. imported production emissions). Similarly, top right represents East Asia's exported and imported emissions by sector group. Bottom left: x-axis represents Western Europe's exported production emissions as a share of Western Europe's total (exported + domestic) production emissions; y-axis represents Western Europe's imported production emissions as a share of Western Europe's total consumption emissions (imported + domestic production emissions). Similarly, bottom right represents East Asia's exported and imported emissions shares by sector group. Diagonal lines are shown to indicate the location of a net balance of exports to imports. Sector key: aff - agriculture, fishing & forestry; exm - extraction & mining; fbp - food & beverage products; tcl - textiles, clothes & leather; wpp - wood, paper & publishing; pcp - petroleum, chemicals & plastics; min - mineral products; met - metal production & products; mvp - motor vehicles & transport equipment; man - other manufacturing; utl - utilities; cst - construction & dwellings; trd - trade; trn - transportation; srv - services; pub - public services.

### 14.2.5 Agriculture and Land Use Change by Region

In terms of development pathways in agriculture and land use, over the historical period from 1850 to 2005 the global extent of cropping increased threefold, from around 5 to 15 million km$^2$ (Ramankutty and Foley, 1999; Hurtt et al., 2011; Foley et al., 2011; Lawrence et al., 2012). Over the same period grazing land extent increased from around 16 to 29 million km$^2$. When the cropping and grazing lands are combined they result in current day agriculture covering over a third of the Earth's ice-free land surface. Regionally, the largest historical increases in cropping have occurred in North America, Latin America, and Sub Saharan Africa (Figure 14.21). Regionally grazing land increases have been largest in Latin America, Sub Saharan Africa and Australia.

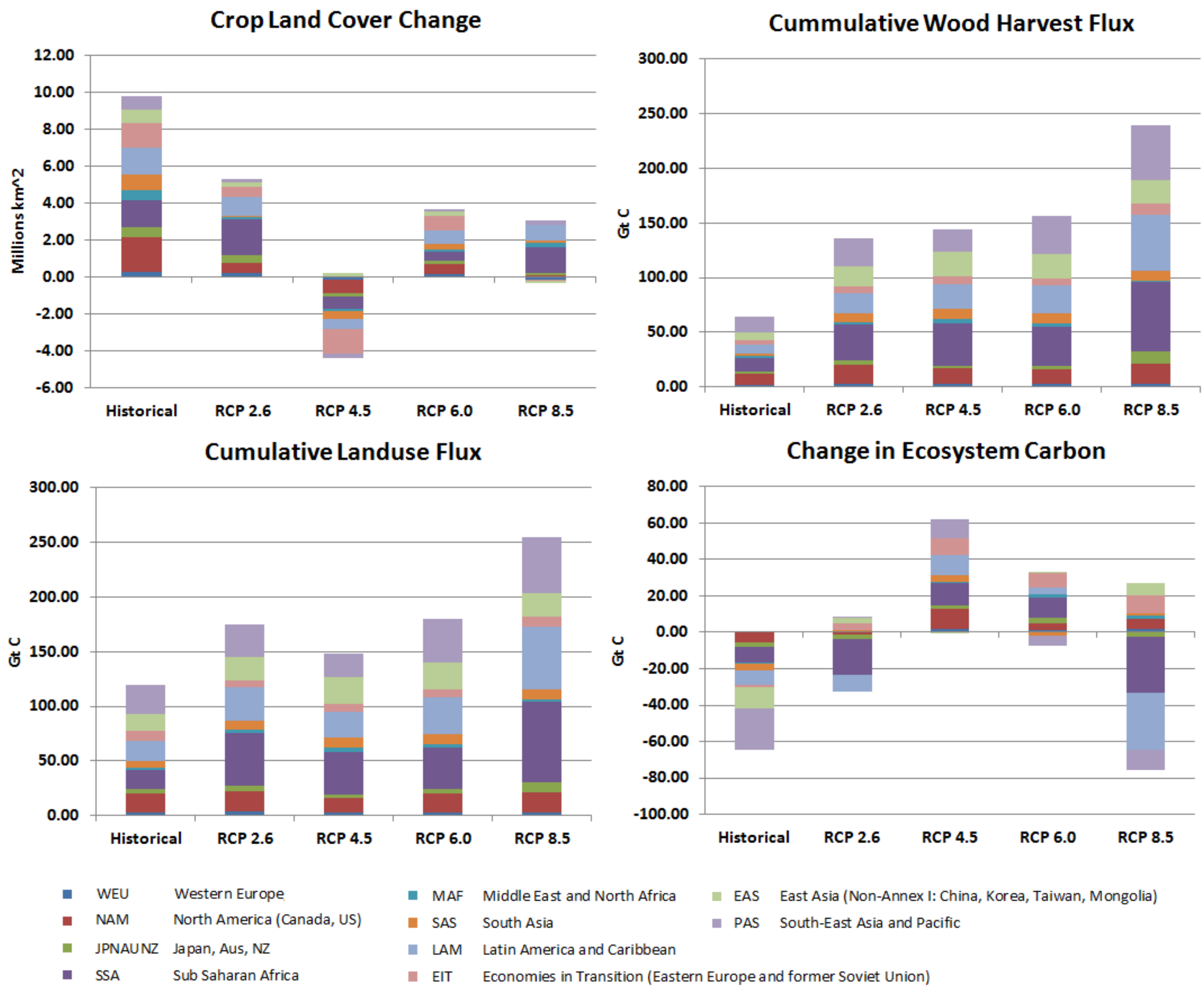



**Figure 14.21.** Regional Land Use Change
Note: RCP are the representative concentration pathways (Meinshausen et al., 2011).

Historical cumulative global wood harvest is estimated to be around 65Gt C (excluding slash) between 1850 and 2005 (Hurtt et al., 2006, 2011; Lawrence et al., 2012). Regionally the largest historical wood harvest amounts were in South East Asia, Sub Saharan Africa and North America (Figure 14.21). As a result of the historical increases in agricultural land and wood harvest, the cumulative global land use flux to the atmosphere between 1850 and 2005 is estimated to have been between 115Gt C (Pongratz et al., 2009; Lawrence et al., 2012) to over 150Gt C (Houghton, 2003; Canadell et al., 2007). Regionally, the largest historical land use fluxes were in South East Asia, Latin America, Sub Saharan Africa, and North America (Figure 14.21).

The global estimate of historical changes in ecosystem carbon associated with land use and land cover change have large uncertainties due to uncertainties in biomass densities and carbon uptake from afforestation, reforestation, fertilization due to increased atmospheric $CO_2$, and changes in nutrient availability from increased nitrogen deposition and fertilizer application (Houghton, 2003; Hurtt, et al., 2011; Pan, et al., 2011; Pongratz, et al., 2009). Despite these uncertainties (Lawrence, et al., 2012) and (Pongratz, et al., 2009) both simulated a historical loss of around 65 Gt C in ecosystem carbon from 1850 to 2005 in fully transient ecosystem modelling. Regionally, these historical ecosystem carbon losses were largest in South East Asia, East Asia, Sub Saharan Africa, and Latin America (Figure 14.21).

As for future land use and land cover change, the Coupled Model Intercomparison Project 5 (CMIP5) prescribes land cover change and wood harvest trajectories from 2006 to 2100 from the four Integrated Assessment Models (IAMs) that produced the radiative trajectories of the four Representative Concentration Pathways (RCPs) of the project (Hurtt, et al., 2011; Lawrence, et al., 2012; Taylor, et al., 2009). The land cover change and wood harvest of the four RCPs differ greatly, with the lowest radiative pathway of RCP 2.6 having the largest increase in cropping land, the second lowest radiative pathway of RCP 4.5 having large scale crop abandonment, and the highest radiative pathway of RCP 8.5 having the third smallest increase in cropping. Regionally, the RCP 2.6 and RCP 8.5 increases in cropland are largest in Sub Saharan Africa and Latin America, while decreases in cropland in RCP 4.5 are larger in Eastern Europe and the former Soviet Union, North America, and Sub Saharan Africa (Figure 14.21).

Changes in grazing land also differ greatly between radiative pathways, with RCP 8.5 the only pathway to increase grazing land, and with RCP 6.0 having the largest decrease. Regionally, the RCP 8.5 increases in grazing land were largest in Sub Saharan Africa, Australia, and Latin America, and the RCP 6.0 decreases were largest in Sub Saharan Africa, Latin America and Australia. The cumulative global wood harvest of RCPs 2.6, 4.5 and 6.0 were all similar ranging from 135 to 155Gt C, with RCP 8.5 having substantially higher wood harvest at 240Gt C. Regionally RCPs 2.6, 4.5 and 6.0 all had the largest wood harvest amounts in Sub Saharan Africa, with South East Asia, Latin America and East Asia making large contributions. The largest increases in wood harvest in RCP 8.5 over the other RCPs occurred in Sub Saharan Africa, Latin America and East Asia.

The different combinations of land cover change and wood harvest were evident in the cumulative global land use fluxes and the changes in global ecosystem carbon in the RCPs. RCP 8.5 had the largest cumulative land use flux of 255Gt C resulting in a loss of ecosystem carbon of 49Gt C. Regionally, the RCP 8.5 land use fluxes were largest in Sub Saharan Africa, Latin America, and South East Asia, with ecosystem carbon losses in these regions offsetting smaller gains in the other regions. RCP 4.5 by contrast had the smallest cumulative land use flux of 148Gt C which combined with reforestation to result in a gain of ecosystem carbon of 61Gt C. Regionally RCP 4.5 land use fluxes were largest in Sub Saharan Africa, East Asia and Latin America, while increases in ecosystem carbon were largest in Sub Saharan Africa, North America and Latin America.

## 14.3 Low Carbon Development at the Regional Level: Opportunities and Barriers

### 14.3.1 Low Carbon Development at the Regional level: Conceptual Challenges and Opportunities

As already discussed in 14.1.5 and in (Collier and Venables, 2012), there are great differences in opportunities and challenges for low-carbon development at the regional level. Poor and emerging countries have legitimate aspirations to increase their levels of human welfare which typically is associated with higher energy use and emissions although there are, in principle, different pathways are available. In particular, great opportunities exist for poorer economies to benefit from a latecomer advantage that would provide access to more advanced low-carbon technologies; many poor countries also have particularly attractive opportunities to invest in low-carbon technologies such as solar power, hydropower, biomass as well as more dense urban settlements. Quite a few have policy options that would imply negative costs at conventional costs of capital. Conversely, it is precisely these countries that face particular challenges in terms of access to capital and technologies, human capital, and effective governance to implement such policies. Bearing these opportunities and constraints in mind, we now discuss sectoral issues for mitigation at the regional level.

### 14.3.2 Low Carbon Development at the Regional level: Sectoral Issues

#### *14.3.2.1 Energy*

The choice of energy technologies that are currently in use and the choices that will be made in coming years depend on the local costs of alternative technologies. Local prices (i.e. those within the region or country being studied) generally indicate the opportunity cost of different inputs that are used, so are the appropriate guide to decision taking. These local costs vary across regions and countries and affect the viability of different technologies. In some regions diverting resources from other productive uses into climate mitigation has a high opportunity cost, in others regions this cost is lower.

##### Local Circumstances and Local Costs

Local costs are country-specific and may vary widely. They depend on two main features of a country or region.

First, local costs depend on the *natural advantage* of the region. Some regions are abundantly endowed with hydro or solar potential, others less so. Some regions are abundantly endowed with hydrocarbons. An abundant endowment will tend to reduce the local price of these resources, although only to the extent that they are not freely traded internationally. This may because of high transport costs (important in some regions of the world) or because of high variability of the price of the resource, which reduces the return to exports, and thereby reduces 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 14.1.5). 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 regularly framework.

These country and region specific factors shape local costs. Local costs in turn shape energy choices, since different techniques have different input requirements.

### Technological Requirements: Energy Production and Use

A number of features of energy production interact with local costs and thereby determine the extent to which different technologies are appropriately used in different regions.

### Energy Production: Capital and Feedstock

The capital intensity and overall costs of alternative generation technologies are given in Table 14.3. While the table does not report all relevant costs (in particular those of a power grid), the facts are clear. All generation is capital intensive, with gas and coal the least capital intensive and nuclear and solar the most. With a discount rate of 5%, and including imputed carbon cost at $30 per tonne $CO_2$, onshore wind and solar are the two most expensive technologies. At 10%, the gap between the two renewables and coal, the cheapest technology, widens still further. Thus the capital intensity of renewable technologies tends to make them inappropriate for capital scarce developing economies, unless external access to capital for these investments can be assured; from a mitigation perspective, such external capital could be particularly useful in capital-scarce developing regions with large natural advantages for particular technologies.

**Table 14.3**: Costs of electricity generation

| | Nuclear | Gas (CCGT) | Coal (US/USC) | Onshore wind | Solar PV |
|---|---|---|---|---|---|
| Capacity MW | 1400 | 480 | 750 | 45 | 1 |
| Capital cost ($/kW)* | 4102 | 1069 | 2133 | 2349 | 6006 |
| O&M ($/MWh) | 14.7 | 4.5 | 6.0 | 21.9 | 30.0 |
| Fuel ($/MWh) | 9.3 | 61.1 | 18.2 | 0 | 0 |
| $CO_2$ ($/MWh) | 0 | 10.5 | 24.0 | 0 | 0 |
| Expected lifetime | 60 | 30 | 40 | 25 | 25 |
| LCOE ($/MWh): 5% | 58.5 | 85.8 | 65.2 | 96.7 | 410.8 |
| LCOE ($/MWh): 10% | 98.7 | 92.1 | 80.0 | 137.2 | 616.6 |

LCOE = Levelised cost of energy; *overnight cost.
Source: (International Energy Agency, 2010a)

Different generation techniques use different feedstocks, the price of which depends on their local availability and tradability. This is illustrated by the costs of coal based electricity generation in different parts of the world. (Heptonstall, 2007) finds that the highest cost countries are those without coal (Japan, Sweden, Italy, in the range $60-$80 per MWh), the world average is around $50, while coal abundant Australia and South Africa have respective costs of $36 and $27 per MWh.

### Large Scale Investments: Demands on Regulatory Capacity

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 power 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. Regulation of private sector operators requires that the regulator is competent and trustworthy and will maintain prices that allow a return on capital. 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 section14.4).

**Small-Scale Investments:**

Smaller scale power technologies include solar (PV), on-shore wind and small-scale hydro. As noted above these technologies have very high capital costs, although they might economise on grid costs (at least for outlying areas) and associated regulatory demands. In capital scarce regions capital costs may be a particular barrier, preventing these techniques from being adopted by small enterprises, which may have borrowing constraints or face very high interest rates.

**Energy Use:**

Some reports suggest that developing countries have particularly large opportunities for 'negative cost' mitigation, often to do with cooking techniques, old and poorly maintained vehicle stock, and the use of small scale diesel generators. However, these costs are sensitive to the discount rates used and are much reduced at the high discount rates prevalent in developing regions (National Science Board, 2010). Capital scarcity therefore creates a significant barrier to implementing 'negative cost' mitigation; again access to external finance might reduce this barrier.

**Latecomer Effects:**

Many developing regions are latecomers to large-scale energy production. There are two implications. First, while developed regions of the world have sunk capital in irreversible investments in power supply, transport networks and urban structures, many developing countries have yet 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, the second implication is that there are current energy shortages, a high shadow price on power, and an urgent need to expand capacity. Discount rates (rates of social time preference) are high. Further delay in anticipation of future technical progress is therefore particularly expensive in developing regions.

Regional differences in energy/carbon intensity of production and what this means for low-carbon development paths (refer to industry chapter to see what key messages are emerging for different regions for transformation pathways)

#### *14.3.2.2 Urbanization*

Urbanization has significantly contributed to increasing energy consumption and carbon dioxide emission during the past decades (Cleveland and Ayres, 2004). The studies of 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 total energy consumption per unit of GDP by 0.25% (Parikh and Shukla, 1995) to 0.47% (Jones, 1989, [CSL STYLE ERROR: reference with no printed form.]), and the impact differed remarkably across regions. Urbanization contributed to not only more total energy consumption, but also a larger increase in modern fossil fuel use, which translated into a higher elasticity of urbanization for overall carbon dioxide emission. Because traditional biomass as a renewable source largely used in rural societies is generally neutral to long-term carbon emissions. As a result, a 1% rise in urbanization increased carbon dioxide emissions by 0.6% to 0.75% (Cole and Neumayer, 2004), while the urbanization-emissions relationship shows an inverted-U shape among countries by urbanization stages and income levels (Martínez-Zarzoso and Maruotti, 2011). Assuming the derived historical effect of urbanization on energy use and carbon emission remain unchanged, the doubling of current urbanization level by 2050 in many low urbanized developing countries such as India implies 10-20% more energy consumption and 20-25% more carbon dioxide emission (Jones, 1989).

While this type of static analysis could serve as a basic accounting strategy for predicting the regional carbon emissions under 'business as usual' scenario, it may misinterpret the impacts of future urbanization on emissions across regions. First, the simple extrapolation of average historical impacts is affected by how the statistic analyses that derive these average impacts were carried out. It varies significantly from whether the analysis is conducted for all regions or for regions distinguished by development levels, and whether the analysis is based on time series data or cross-sectional data. The simple extrapolation does not reflect the different patterns of interactions between urbanization and other demographic, economic, and technological factors, across regions and over time. Even if it could capture the full dynamics, the interactions between urbanization and other factors in the future may very likely differ from the ones in the past. Second, there exist large uncertainties in the levels and forms of urbanization across regions, particularly in the less urbanized developing regions. Different trends in urbanization imply different urbanization paradigms and interactions with socioeconomic, demographic and technologic factors, and consequently different challenges for climate changes mitigations. To project future regional impacts of urbanization on carbon emissions, a more accurate and realistic estimation needs to fully consider the dynamic interactions between urbanization and economic growth and technological changes (Krey et al., forthcoming).

A dynamic analysis, adopting the integrated assessment model iPETS, reveals that if the world follows different socioeconomic, demographic and technologic pathways, the same urbanization trend may generate very different emissions consequences (O'Neill et al., 2010)(Figure 14.22). The research compares the net contributions of urbanization to the 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 (UNPD 2005, extrapolated up to 2100 by (Grübler et al., 2007)), the global total carbon emissions in 2100 increases 3.7GtC/year due to the impacts of urbanization growth. However, in a B2 world, which emphasize on local solutions to economic, social and environmental sustainability, with continuous population growth and intermediate economic development, and faster improvement in environmental-friendly technology, the same urbanization trend generates a much smaller impacts (1.5GtC/year in 2100) on global total carbon emissions. After considering the differences in total emissions under different scenarios, the relative changes in emissions due to urbanization under B2 scenarios (12%) is also significantly lower than under A2 scenario (15%). Comparing the impacts in different regions, the 1.5GtC/year more global total emissions due to urbanization under B2 scenario is mostly from East Asia, South Asia, and other less urbanized developing regions. The contribution from the already very urbanized North America, Europe, developed Asia and Pacific, and Latin America and Caribbean is very limited. Moreover, the relative changes in regional emissions due to urbanization are also very significant in the East Asia (27%), South Asia (24%), and Sub-Saharan Africa, Middle East and Southeast Asia and Pacific (15%), considerably higher than in other regions (<10%).

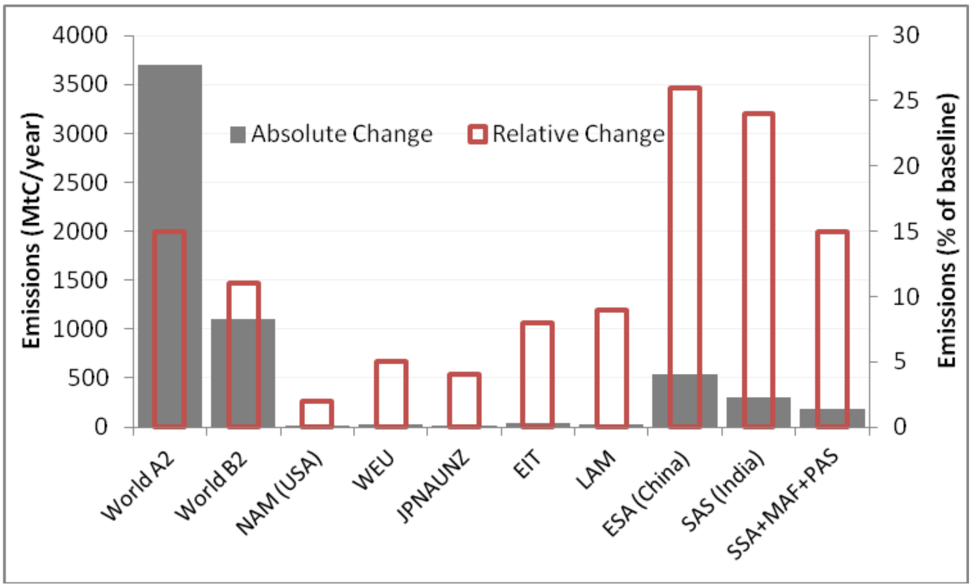



**Figure 14.22.** Impact of urbanization on carbon dioxide emissions in 2100 for the world under SRES A2 and B2 scenarios and by regions under SRES B2 scenario
Note: This figure is based on (O'Neill et al., 2010). Urbanization scenario follows UN Urbanization Prospects (United Nations, 2005), extrapolated up to 2100 by (Grübler et al., 2007). Effect of urbanization on emissions for the world and by region is in both absolute and relative terms.

The regional impacts of urbanization on carbon emissions not only differ under different socioeconomic and demographic circumstances, but also vary due to different patterns of urban growth. The widely used UN urbanization projections, which is adopted in the above-mentioned studies, is criticized for not adequately considering the uncertainties in urbanization, as it assumes urban growth in all regions will quickly converge and follow the 'global norm' derived based on mostly the experiences of more industrialized countries (Bocquier, 2005; Montgomery, 2008; Alkema et al., 2011). A new urbanization projection that accounts for the variations of urbanization in different countries at different urbanization stages suggests that the global urbanization levels may span the range from 60% to above 90% by the end of century under the slow and fast urbanization scenarios (Jiang and O'Neill, forthcoming). The range of uncertainty in future urbanization differs remarkably across regions. While the variation is quite small among the more developed regions, the less developed regions such as India and China have large uncertainties in their future urbanization trends (Figure 14.23)

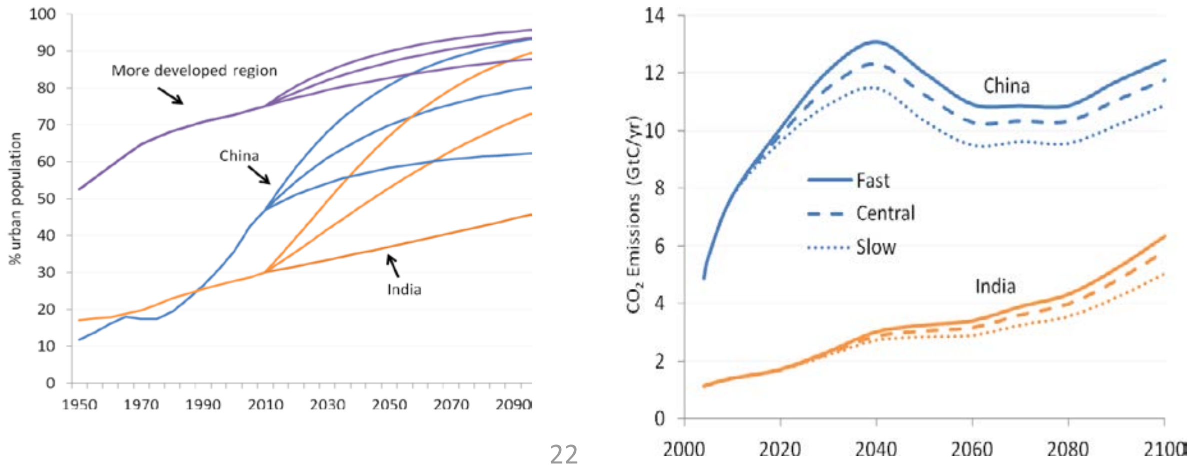



**Figure 14.23**. Carbon dioxide emissions under alternative urbanization scenarios

Note: The alternative urbanization scenario is based on (Jiang and O'Neill, forthcoming); the emission assessment is based on (O'Neill et al., 2012).

Accounting for the uncertainty in urban growth, an assessment of the implication of the plausible range of urbanization pathways for emissions shows that changes in urbanization have a somewhat less than proportional effect on aggregate emissions and energy use. In China, for example, under the central scenario (similar to UN projection) it will reach 70% urban population by 2050, and the total carbon emissions will reach 11GtC/year. The slow (or fast) urbanization scenario produces an urbanization level that is 13 (or 11) percentage points lower (or higher) than the level in the central urbanization scenario. This difference in urbanization leads to emissions that are 9% lower (or 7% higher). In India, the urbanization level in 2050 will be 16 percentage points lower under the slow urbanization scenario than under the central scenario, or 15 percentage points higher under the fast scenario than under the central scenario. These more significant differences in urbanization levels than in China, however, leads to a smaller difference in emissions of 7% between the slow and central urbanization scenarios, or 6% between the fast and central scenarios (O'Neill et al., 2012). The effects of different urbanization pathways is due primarily to an economic growth effect driven by the increased labour supply associated with faster urbanization. Moreover, the difference in urbanization also indicates different speeds of transition away from traditional solid fuel uses and toward modern fuels such as electricity and natural gas (Krey et al., forthcoming). The slower urbanization pathway results in higher shares of solid fuels in the final energy mix due to the higher solid fuel use in rural areas in the base year, lower per-capita income in rural areas as well as less developed infrastructure for modern fuels (Jiang and O'Neill, 2004; Pachauri and Jiang, 2008). While these differences appear small in terms of energy use, the associated health impacts due to indoor air pollution (Bailis et al., 2005; Venkataraman et al., 2010) and social impacts (e.g., labour force participation of women (United Nations, 2009) are generally much bigger.

Therefore, the urbanization impacts on future energy use and carbon emissions can differ considerably, depending on the choices of urbanization pathways and on the ways that the world is organized. As almost all future global population growth is anticipated to occur in the urban areas of the developing regions, and cities of developing countries continue to serve as the main engine of global economic growth, the possible reductions in emissions due to the changes in urbanization patterns will almost exclusively come from the less urbanized the developing regions. A world with effective regional cooperation will help the developing regions face the challenge due to urbanization on climate change mitigation.

#### *14.3.2.3 Consumption*

Climate change analysis and policies pays increasing attention to importance of consumption (Nakicenovic and Swart, 2000; Michaelis, 2003), because anthropogenic warming is directly linked to changing lifestyles. 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 14.24) (O'Neill et al., 2010). 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, security and other purposes. Moreover, the regional differences in expenditure shares are affected not only by their income levels, but also by the geographic and climatic conditions, local available resources, and governmental policies. For instance, American households spend much large share of income on transportation but much less on direct energy use than their Japanese counterparts, because of different transportation system and energy prices. The larger share of spending on energy intensive goods and services, multiplied by much higher income level, translates into substantially higher per capita energy consumption and carbon emissions in the more developed regions than in the developing ones.

With economic growth and improving income, however, households in the less developed Asian, Sub-Saharan African, and Latin American regions are very likely to change their expenditure shares. If they follow the consumption patterns of the households in the developed regions, the changing life style will substantially increase per capita and global total carbon emissions (Stern, 2006).

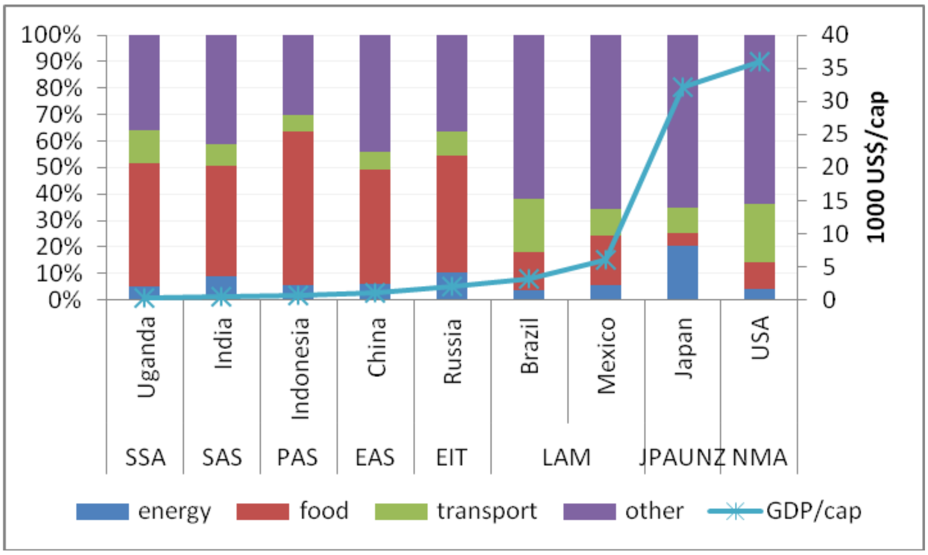



**Figure 14.24**. Expenditure share of households and per capita income, 2001
Note: Household expenditure share is based on (Zigova et al., 2009; O'Neill et al., 2010). Per capita GDP is from World Bank Development Indicators (World Bank, 2011).

The impact of changing consumption patterns on emissions is not only reflected by the increasing share of energy intensive goods and services, but also by the changes in less energy intensive food consumptions. The energy inputs in food life cycles vary from 2 to 220 MJ per kg due to a multitude of factors related to animal or vegetable origin, degree of processing, choice of processing and preparation technology and transportation distance (Carlsson-Kanyama et al., 2003). A recent study shows that the effect of food consumption on GHGs emissions can span the range of 0.4 to 30kg $CO_2$ equivalents/kg edible products (Carlsson-Kanyama and González, 2009). The Carbon emissions is 1.1kg $CO_2$ equivalents from producing per kg foods rich in carbohydrates such as potatoes and wheat, and 2.5kg $CO_2$ equivalent from per kg vegetable and fruits, which are all much smaller than from per kg animal products. Even among animal products, carbon emissions from producing per kg beef, cheese and pork can be 30 times higher than from producing per kg legumes, poultry and eggs.

The characteristics of food consumptions differ remarkably across regions (Figure 14.25). Per capita annual intake of animal products in the OECD region is about 3 times higher than in the non-OECD regions (BRIC - Brazil, Russia, India, and China, and the Other region) (Stehfest et al., 2009), while per capita consumption of grain and other crops is higher in the BRIC and the other regions. Under a 'business-as-usual' or 'median' development pathway, per capita consumptions of animal products in 2050 will increase in all regions, while consumption of grain and other crops generally remain unchanged. More importantly, increase of animal products consumption is most significant in the BRIC regions, owing to its anticipated rapid economic growth. Increasing food consumption and dietary structure generates 10% more annual GHGs emissions from land use changes: from 3GtC-eq. to 3.3GtC-eq. between 2000 and 2050. To further examine the impacts of changing diet on climate change, sensitively analyses were carried to compare the GHGs emissions from land use changes under different assumptions of food consumption patterns. First, under a complete substitution of meat from ruminants (beef, sheep and goat meat), the annual GHGs emissions from land use change will reduce from 3tC-eq. in 2000 to 1.7GtC-eq in 2050 (or a -43% change). Second, under a complete substitution of all meat, the annual GHGs emissions from land use change will drop down to 1.5GtC-eq. in 2050 (or a -50% change). Third, under a complete substitution of all animal products (meat dairy, and eggs), the annual GHGs emissions from land use change will decline to 1.1GtC-eq. in 2050 (or a -63% change). Therefore, the biggest impact on GHGs emissions comes from the ruminant meet consumptions. In addition to comparing the three types of 'extreme' scenarios, the authors also test the changes by adopting a healthy diet, which recommends sparing consumption of ruminant meat and pork, and advises zero to two servings of fish, poultry and egg per day. This translates into approximately 52%, 35% and 44% of daily global average consumption of beef, pork and poultry/eggs under BAU scenario in 2050. As a result, the annual GHGs emissions from land use changes under healthy diet scenario would fall by 30% by 2050.

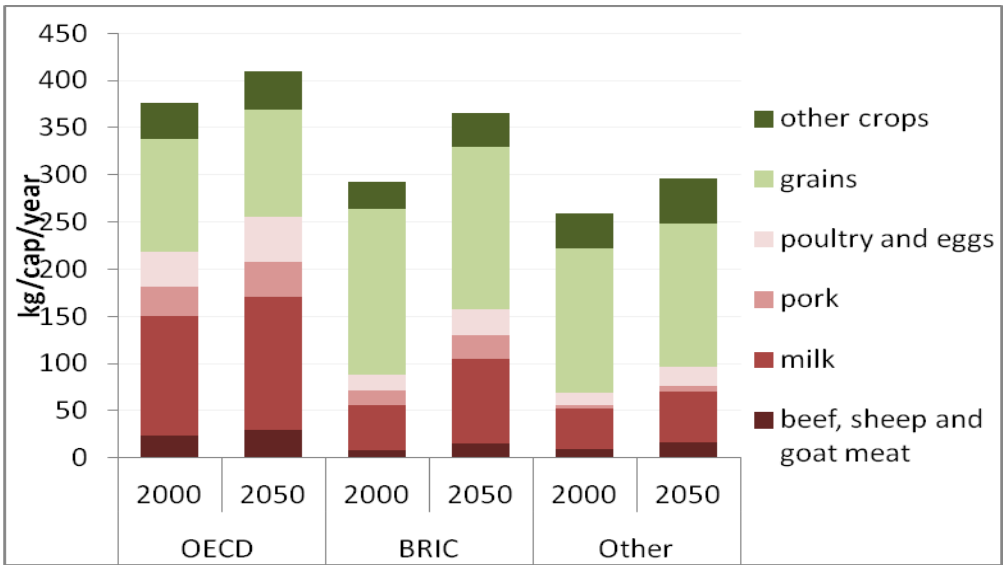



**Figure 14.25.** Per capita annual intake of food by regions
Note: (1) The figure is based on (Stehfest et al., 2009). (2) The 2050 number is based on reference scenarios portraying a possible future, with default assumptions on meat consumption and no climate policy.

### *14.3.2.4 Agriculture*

Through agriculture and forest production, water catchment, recreation, and settlement to meet human needs, land use has, since the 1850, contributed to about a third of world greenhouse gas (GHG) emissions (Golub et al., 2009); and is in turn affected by climate change. Agriculture is the major land use across the globe: 1.2-1.5 billion hectares are under crops, another 3.5 billion hectares being grazed; and 4 billion hectares of forest are used to differing degrees (Howden et al., 2007). As mentioned in Chapter 11 of this Report, by 1990 emissions from agricultural sources accounted for 60% of global non- CO2 emissions, and had increased 3% by 2005. Historical estimations of CH4 rose to 8%, N2O emissions increased 4%, and high-GWP emissions reached 146%, from 1990 to 2005 (US-EPA, 2011 in Chapter 11). In 2006, agriculture was estimated to yield about 14% of total global anthropogenic emissions of GHGs, and for 47% and 84% of total anthropogenic CH4 and N2O emissions, respectively; whereas emissions of CO2 mainly from land use change (mostly deforestation) were estimated to account for 15% of anthropogenic $CO_2$ emissions (Smith et al. 2007).

In this context, in 2005, a group of five regions consisting mostly of non-Annex I countries was responsible for 74% of total agricultural emissions (IPCC, 2007): developing countries of East Asia emitted 25% of world's total in that year; followed by those in Latin America and the Caribbean (17%), South Asia (17%), and Sub-Saharan Africa (13%). In seven out of 10 regions analysed by(Smith et al., 2007), N2O from soils was the main source of GHGs in the agricultural sector in 2005, mainly associated with the use of N fertilizers and manure application to soils. In Latin America and the Caribbean, the Former Soviet Union and OECD Pacific, $CH_4$ from enteric fermentation was the dominant source.

As shown in Figure 14.26, regions with the largest share of global agricultural GHG emissions are to expect the largest rates of increase in emissions during the period 1990–2020. The Middle East and North Africa and Sub-Saharan Africa will experience the highest growth, with a combined 72% increase in emissions; in the latter case; this is so in spite of the decline in per-capita food production and because of a higher demand for livestock products. GHG emissions from animal sources are to grow in East Asia; mirroring increased total production of meat and milk in Asian developing countries (in 2004 by more than 12 times and 4 times, respectively, compared to 1961 levels). Also, 153% and 86% increases in emissions from enteric fermentation and manure management are forecast from 1990 to 2020, respectively. In South Asia, keeping up with the increasing demand for food resulting from rapid population growth will lead to more GHG; as will in Latin America and the Caribbean being agricultural products a main source of exports (Smith et al., 2007).

Concomitantly, changes in land use and management with forest conversion to cropland and grassland have resulted in higher GHG emissions from soils ($CO_2$ and $N_2O$), mainly as livestock, cropland areas, and the use of N fertilisers increase. In the Former Soviet Union and Eastern European countries, agricultural production was reduced by 20-40% as compared to 1990, but is expected to grow by 15-40% in this decade. OECD North America and OECD Pacific are the only developed regions showing a consistent increase in GHG emissions (16% and 19%, respectively, between 1990 and 2020) in the agricultural sector due to reduced N2O emissions from soils. In Oceania, nitrogen fertiliser use has increased exponentially over the past 45 years with a five-fold increase since 1990 in NZ, and two and a half-fold increase in Australia. In North America, on the other hand, N fertiliser use has remained stable, and the main driver for increasing emissions is manure management associated with cattle, poultry and swine production, and manure application to soils. In both regions, conservation policies have resulted in reduced CO2 emissions from land conversion. Land clearing in Australia has declined by 60% since 1990 with vegetation management policies restricting further clearing, while in North America, some marginal croplands are been returned to trees or grassland. Western Europe is the only region where, according to US-EPA (2006a), GHG emissions from agriculture are to decrease until 2020 (Smith et al., 2007): 16-17).

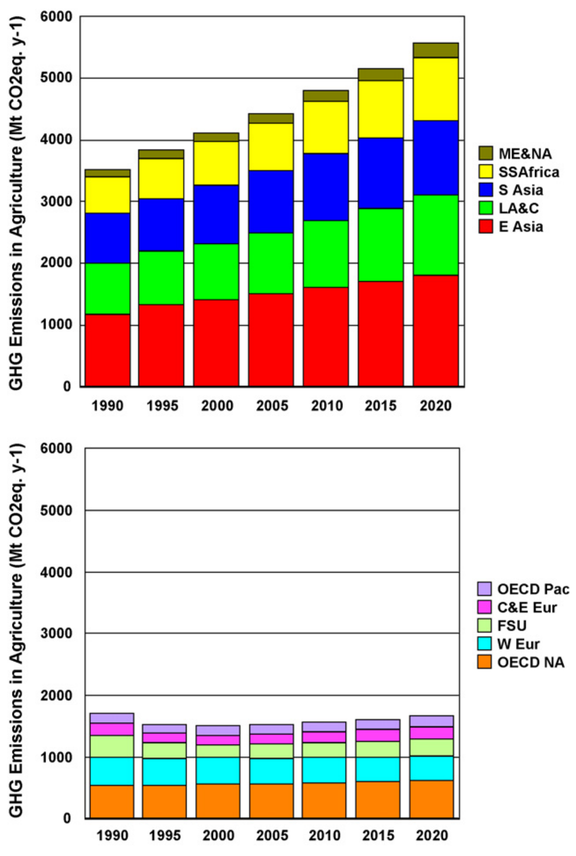


**Figure 14.26.** Evolution of GHG emissions in the agricultural sector by world region, 1990–2020
Note: ME&NA, Middle East and North Africa; SS Africa, Sub-Saharan Africa; S Asia, developing countries of South Asia; LA&C, Latin America and The Caribbean; E Asia, developing countries of East Asia; OECD Pac, OECD countries of the Pacific Region; C&E Eur, Central and Eastern Europe; FSU, Former Soviet Union; W Eur, Western Europe; OECD NA, OECD countries of North America.
Source: (Smith et al., 2007).

Under business as usual, emissions of non-$CO_2$ GHGs are projected to increase in every region by 2030, the fastest in East Asia (95%), OECD Pacific (62%), Middle East and North Africa (50%), OECD North America (49%), and South Asia (46%). N2O emissions from agricultural soil management in all regions will get higher, driven by increases in China, US, India, Brazil, Argentina, and Pakistan. Among OECD countries the US, Canada, Turkey, New Zealand, and Australia will lead the growth. The largest increases in CH4 emissions from enteric fermentation are expected in Sub-Saharan Africa (48%), Middle East and North Africa (46%), and South Asia (43%). Although in nearly all regions the dominant sources of non-$CO_2$ emissions are $N_2O$ emissions are agricultural soil management and CH4 emissions from enteric fermentation, crop patterns play an important role, such as rice cultivation in South Asia and East Asia regarding CH4 emissions; savannah burning in tropical areas in the case of Sub-Saharan Africa and Latin America and the Caribbean; or manure management in Western Europe.

Land use changes also affect emission trends. Rising demand for corn, the primary feedstock for ethanol processing under conventional technology, has increased competition for land resources in food and feed production. From 1980 to 2008, worldwide production of maize (for food) and wheat, two of the largest commodity crops, declined by 3.8% and 5.5%, respectively (Lobell et al., 2011). Yet land use changes do not necessarily mean reduced emissions. Biofuel production as a substitute for gasoline, for instance, could help reduce GHG emissions but carbon emissions stemming from the conversion of forest and grassland to new cropland to replace the grain diverted to biofuels could offset these gains. The potential emissions per hectare of land conversion exceed the annual greenhouse reductions per hectare of biofuels; particularly in the case of corn-based ethanol (Crutzen et al., 2007; Searchinger et al., 2008), which instead of producing 20% savings, can double greenhouse emissions over 30 years and increase greenhouse gases for 167 years (Searchinger et al., 2008). An effective system would have to guarantee that biofuels use a feedstock, such as a waste product or carbon-poor lands that will not trigger significant emissions from land use change; similarly, using good cropland to produce food helps to avert greenhouse gases from land use change (Searchinger et al., 2008).

Figure 14.27 shows land resources are expected to meet future food demands of a world population, which is expected to near 9 billion people by 2050. However, regional disparities are acknowledged and a reason for concern since in some regions rain-fed cultivation potential has already been exhausted; global warming may alter the condition and distribution of land suitable for cropping; consumption patterns exert pressures on land use; and competition is likely to arise for scarce resources such as water, to mention a few constraints. Research in 2000 estimated that 10.5 thousand million hectares of land, i.e., more than three-quarters of the global land surface (excluding Antarctica), suffer rather severe constraints for rain-fed crop cultivation. Some 13% is too cold, 27% is too dry, 12% is too steep, and about 65% are constrained by unfavorable soil conditions (IIASA, 2000).

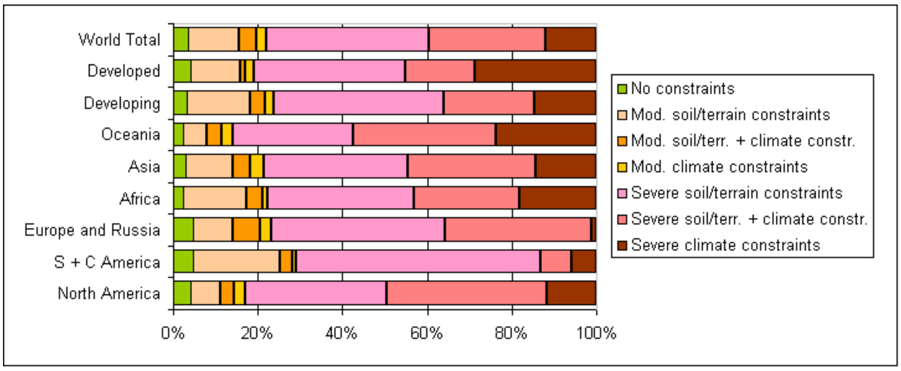



**Figure 14.27**. Distribution of climate and soil/terrain constraints by region Source: (IIASA, 2000).

In Table 14.4 according to IIASA, estimations of the extent of land with rain-fed cultivation potential for rain-fed crops ranged from 3 billion ha (land very suitable and suitable for major cereal crops, under high inputs and mechanization, outside current forest areas) to 3.3 billion ha (land very suitable, suitable or moderately suitable for at least one of the AEZ crop types, within or outside current forest areas). Also, assuming no restrictions for land-cover conversion, one-quarter of the global land surface (excluding Antarctica) was regarded as potentially suitable for crop cultivation, in developed countries 20% was deemed as land with rain-fed cultivation potential, whereas in developing countries it amounted to about 28% (twice the area estimated for cultivation in 1995-97). And yet, there are several regions where the rain-fed cultivation potential is nearly fully exhausted or has already been exceeded.

In Figure 14.28 significant potential was identified for conversion to arable use in Africa and South America, including from current forest areas. In other regions this potential is either exhausted (e.g., Asia) or unlikely to be exploited for agriculture under current and expected future conditions (i.e., Europe, North America and Oceania).

**Table 14.4**: Land with rain-fed cultivation potential for major food and fiber crops (million ha) Source: (IIASA, 2000).

| Region | Total Land | Land with cultivation potential | | Housing, Infra-structure | Not suitable |
|---|---|---|---|---|---|
| | | Total | Under forest | | |
| **North America** | 2138 | 384 | 135 | 9 | 1637 |
| **South and Central America** | 2049 | 858 | 346 | 16 | 1048 |
| **Europe and Russia** | 2259 | 511 | 97 | 21 | 1645 |
| **Africa** | 2990 | 939 | 132 | 26 | 1909 |
| **Asia** | 3113 | 516 | 47 | 83 | 2407 |
| **Oceania** | 850 | 116 | 17 | 1 | 694 |
| **Developing** | 8171 | 2313 | 527 | 124 | 5383 |
| **Developed** | 5228 | 1012 | 247 | 33 | 3956 |
| **World Total** | 13400 | 3325 | 774 | 156 | 9338 |

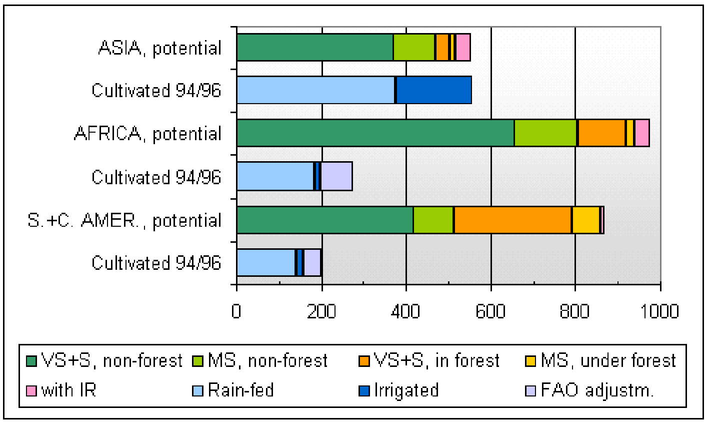



**Figure 14.28.** Comparison of land with crop cultivation potential and land used for cultivation in 1994-96 (million ha) in developing regions. Note: VS = very suitable, S = suitable, MS = moderately suitable, mS = marginally suitable, NS = not suitable. Source: (IIASA, 2000).

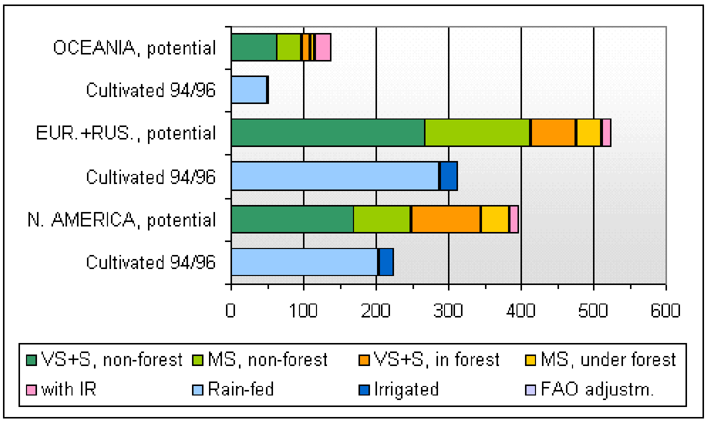



**Figure 14.29**. Comparison of land with crop cultivation potential and land used for cultivation in 1994-96 (million ha) in developed regions. Note: VS = very suitable, S = suitable, MS = moderately suitable, mS = marginally suitable, NS = not suitable. Source: (IIASA, 2000).

When restricting the considered crop types to the three major cereals, namely wheat, rice, and grain-maize, and allowing for nonagricultural land uses, an estimate of about 2.4 thousand million ha of land with rain-fed cultivation potential was obtained. Of these, 1.5 thousand million ha were found in developing countries and 0.9 thousand million ha in developed regions (Figure 14.29).

IIASA assessed about 237 million hectares of the area as forest ecosystems, which were very suitable or suitable for cultivation of wheat, rice or grain-maize at high level of inputs. On the other hand, the analysis shows that globally almost 85% of forest ecosystems are considered not suitable or at best marginally suitable for cereal cultivation. Yet, assuming availability of water resources, but limiting the analysis to soil conditions indicating presence of water, some 65 million hectares, i.e., only about 1.8% of arid and hyper-arid zones, were assessed as prime land for cereals under irrigation, which in turn equates to less than 3% of total prime land for cereals (see Table 14.5). The results suggest that irrigation is more important in providing stable water supply in areas of climatic variability rather than for bringing land in hyper-arid and arid regions into cultivation.

**Table 14.5**: Land with rain-fed cultivation potential for wheat, rice or grain-maize (million ha)

| Region | Total Land | Land with good cultivation potential | | Land with moderate cultivation potential | |
|---|---|---|---|---|---|
| | | Total | Under forest | Total | Under forest |
| North America | 2138 | 235 | 82 | 107 | 33 |
| South and Central America | 2049 | 283 | 128 | 191 | 72 |
| Europe and Russia | 2259 | 282 | 41 | 181 | 35 |
| Africa | 2990 | 404 | 25 | 188 | 18 |
| Asia | 3113 | 263 | 14 | 121 | 11 |
| Oceania | 850 | 44 | 7 | 29 | 4 |
| Developing | 8171 | 1076 | 166 | 498 | 100 |
| Developed | 5228 | 565 | 132 | 319 | 72 |
| World Total | 13400 | 1612 | 298 | 817 | 172 |

Source: (IIASA, 2000).

Full exploitation of all potential irrigable land would increase the suitable land for cereals globally by 6 to 9%. The global cereal production potential would increase by 30 to 40% (see Figure 14.30). The application of a set of temperature and rainfall sensitivity scenarios revealed a modest increase of cultivable rain-fed land for temperature increases up to 2°C on global scale. With a higher temperature increase alone, extents of cultivable rain-fed land start to decrease. When both temperature and rainfall amounts increase, the extents of cultivable rain-fed land increase steadily. For example, a temperature increase of 3°C paired with a rainfall increase of 10% would lead globally to about 4% more cultivable rain-fed land. In the developed countries this increase is even markedly higher; it exceeds 25%. Contrarily, developing countries can expect a decrease of 11% (IIASA, 2000).

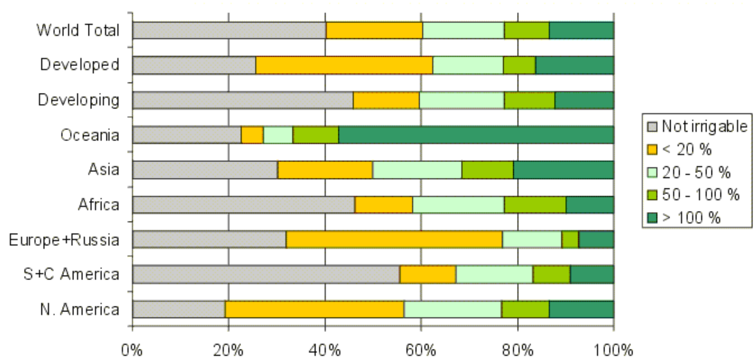



**Figure 14.30.** Distribution of land with cultivation potential by impact classes, showing increase in potential output with full exploitation of irrigation
Source: (IIASA, 2000).

The above-referred study shows potential conditions in a scenario of lack of restrictions. But other projections on changes in land productivity for the 2080s have been developed based on global scenarios of environmental and social changes (Iglesias et al., 2011). The results show the persistence, in the future, of current patterns of agricultural comparative advantage in different regions, and its intensification. These results are similar to other contributions (Reilly et al., 2001; Parry et al., 2004; Lobell et al., 2008), insofar as general development conditions affect the possibilities to adaptation and leap-frogging. The figures below show the aggregated changes in average land productivity under scenarios A1B and E1 (about 4ºC and 2ºC, respectively) of global temperature increase for the 2080s as compared with current land productivity:

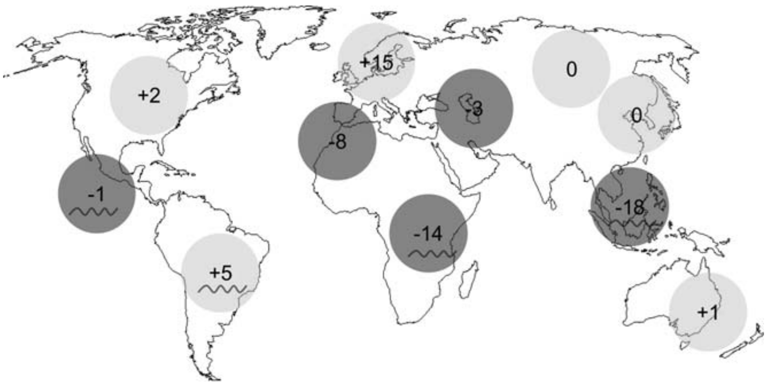



**Figure 14.31.** Aggregated changes in average land productivity under scenarios A1B for the 2080s compared with current land productivity
Note: Light grey indicates increase and dark grey indicates decrease in land productivity compared to current values. Wave symbol indicates significantly increased variability.
Source: (Iglesias et al., 2011).

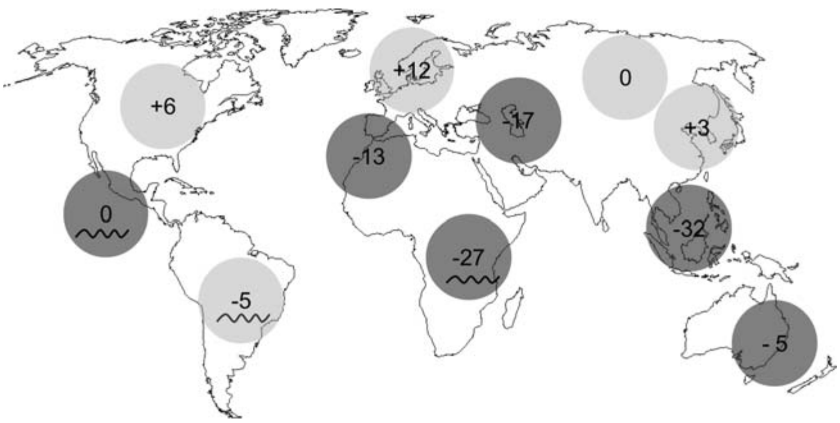



**Figure 14.32.** Aggregated changes in average land productivity under scenarios E1 for the 2080s compared with current land productivity
Note: Light grey indicates increase and dark grey indicates decrease in land productivity compared to current values. Wave symbol indicates significantly increased variability.
Source: (Iglesias et al., 2011).

In Figure 14.31 and Figure 14.32 the Iglesias et al. study linked land productivity to the increase in water irrigation demand in the 2080s to maintain food production levels similar to those in the present. In this regard, challenges likely to emerge, especially in regions, such as Africa and South East Asia, which are in need of technology and investment. (Iglesias et al., 2011) offer a scenario of risk level from climate change based on an index of adaptive capacity and projections of agricultural productivity, in which adaptive capacity is inversely related to climate change impacts. According to their results, successful adaptation policy will depend on region specific strategies to allow for flexibility in the face of impacts, and the creation of synergies with development policies that enhance adaptive lower levels of risk. They place in this case the Mediterranean region of Europe and Australia; but identify regions such as South East Asia, Latin America and Africa under threat (see Figure 14.33).

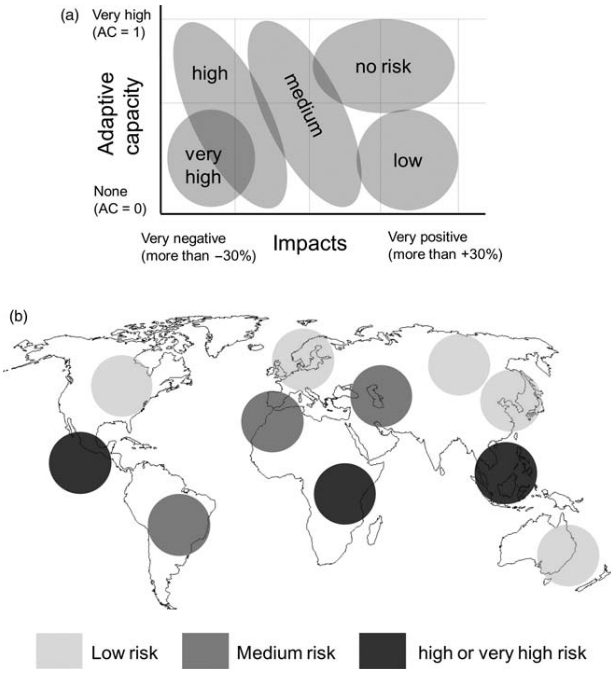



**Figure 14.33**. a) Definition of risk profiles as determined by projected changes in productivity and levels of adaptive capacity. (b) Mapping of profiles as determined by projected changes in productivity and levels of adaptive capacity.
Source: (Iglesias et al., 2011).

Regarding forestry and agriculture, opportunities for adaptation and mitigation need overcoming numerous barriers; this is a situation that has been aided through regional and international cooperation in the forms of climate and non-climate policies. These include UN conventions such as Biodiversity, Desertification and actions on Sustainable Development, macroeconomic policy such as EU Common Agricultural Policy (CAP)/CAP reform, international free trade agreements, trading blocks, trade barriers, region-specific programmes, energy policy and price adjustment, and other environmental policies including various environmental/agro-environmental schemes (Smith et al., 2008). 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). These aspects lead to the question of development patterns, and possibilities for leap-frogging in the case of developing countries. Differences in development levels and resources within developing countries play an important role in terms of adaptation and mitigation policies. Those countries and regions endowed with market-oriented resources need to achieve a balance, on the one hand, to take advantage of the opportunities of expanding markets and higher investment levels in their territories and, on the other, to address the issues of higher GHG emissions and income distribution derived from extensive and intensive production and consumption patterns. For developed countries, re-orienting existing growth paths towards lower carbon intensity is a major challenge in the context of domestic pressures and increased world market competition.

### 14.3.3 Leapfrogging, Technology Transfer and Low Carbon Development

The "leapfrogging" concept, or the skipping of some generations of technology or stages of development, has particular resonance in the area of climate change mitigation, suggesting 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 (Watson and Sauter, 2011). The actual evidence for whether in fact low carbon leapfrogging can or has already occurred, as well as specific models for low carbon development, both 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 the industrialized countries (Goldemberg, 1998; Perkins, 2003; Unruh and Carrillo-Hermosilla, 2006; Watson and Sauter, 2011). 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). 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).

#### *14.3.3.1 Examining Low-Carbon Leapfrogging Across and Within Regions*

##### Supra-National 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). Within Latin America, much attention has been focused leapfrogging in transportation fuels, and specifically the Brazilian ethanol program (Goldemberg, 1998; Dantas, 2011; Souza and Hasenclever, 2011).

Time and again, absorptive capacity, i.e., the ability to adopt, manage and develop new technologies, has 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. As a result it is useful to examine regional differences across such technological capabilities, using metrics such as number of researchers within a country, and total R&D invested. These metrics are investigated on a regional basis in Figure 14.34, along with the total carbon dioxide emissions footprint from energy use, to give a sense of the magnitude of the climate mitigation challenge as well as the potential ability of different regions to leapfrog across regions.

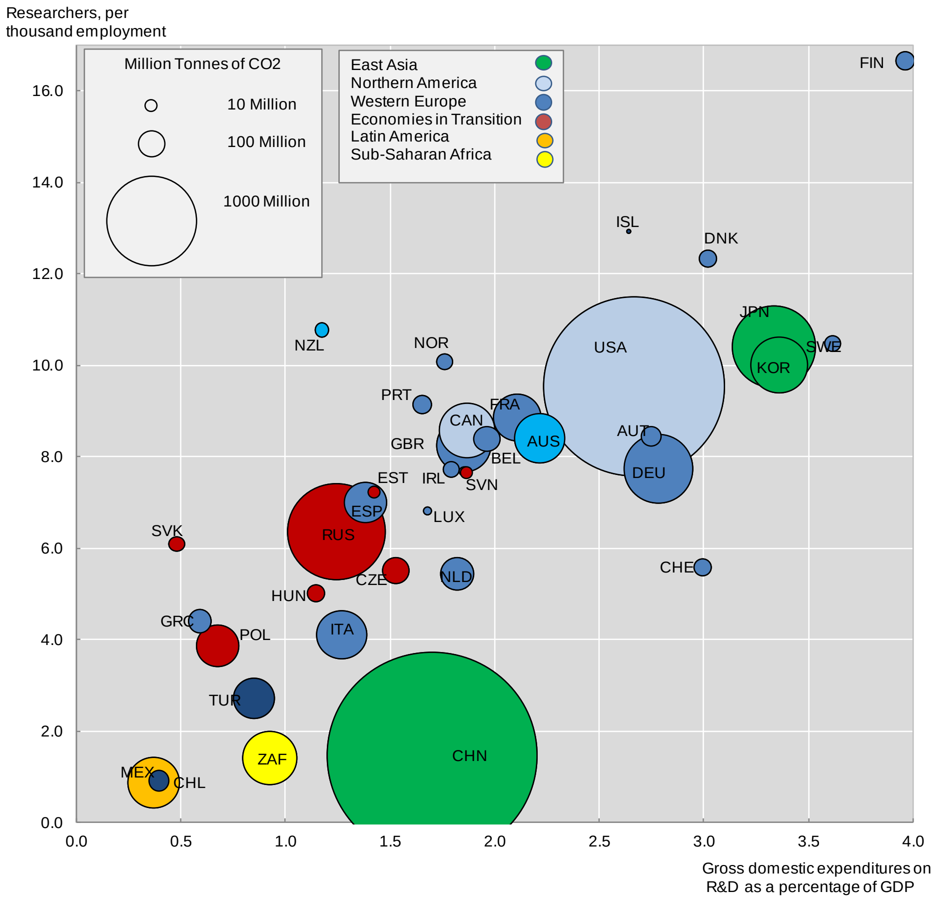



**Figure 14.34.** Emissions Contribution and Innovative Capacity: Regional Comparison
Source: Data on researchers and R&D expenditures as percentage of GDP from OECD, Main Science and Technology Indicators Database (OECD, 2011b), June 2011; $CO_2$ from fossil fuels from (International Energy Agency, 2011).

## Sub-National Regions

Technology development and transfer may be encouraged on a subnational regional basis if, for example, national innovation systems are insufficient (as in small countries). Regional development policy stemmed from early resource transfers within countries from wealthier regions to lagging regions in an attempt to compensate for regional disparities in economic development (OECD, 2011a). One important concept related to technological leapfrogging at the subnational, regional level is an industrial cluster (Porter, 1998). Clusters can be characterized as a dense network of economic actors who directly contribute to the dominant production process of a region, including manufacturing companies, supply and marketing companies, financial institutions, research institutes and technology transfer agencies, economic associations and unions, training institutions, the regional government and informal associations (Cook and Memedovic, 2003). For example, Silicon Valley in the state of California in the United States is a large technology development complex including ICT and biotechnology clusters, and the Ruhr region in Germany is an economic region with long-established coal, steel and engineering clusters (Cook and Memedovic, 2003).

Patents are one of the mechanisms firms use to appropriate the results of investments in intangibles with industrial applicability, and are considered a good proxy of innovation efforts, (OECD, 2011a) however data are frequently unavailable in developing nations making true regional comparisons difficult. Patenting in low carbon or “green” technologies is increasing around the world, and new regional leaders are emerging. While patent activity is still highly concentrated in the older technological leaders of the United States, Japan and Germany, the last decade has seen a change in the dominant actors, both at a national and regional level, even within the OECD countries. As illustrated in Figure 14.35, the most dynamic green technology patent regions within the OECD were Hokuriku, Japan, in which patent applications increased 28 times between 1995-1997 and 2005-2007; followed by the Capital Region of Korea, where the number of applications has increased eightfold over the last decade. These regions are followed by Baden-Württemberg in Germany and Michigan in the United States, both of which more than tripled the number of their patent applications over this timeframe. Non-OECD green technology patenting is clearly increasing as well. For example, according to the patent data from China's State Intellectual Property Office (SIPO), in 1985 there were only 13 patents related to wind power manufacturing in China, while the annual number of patent applications rose to 522 in 2002, and 1132 in 2008 (Ru et al., 2012).

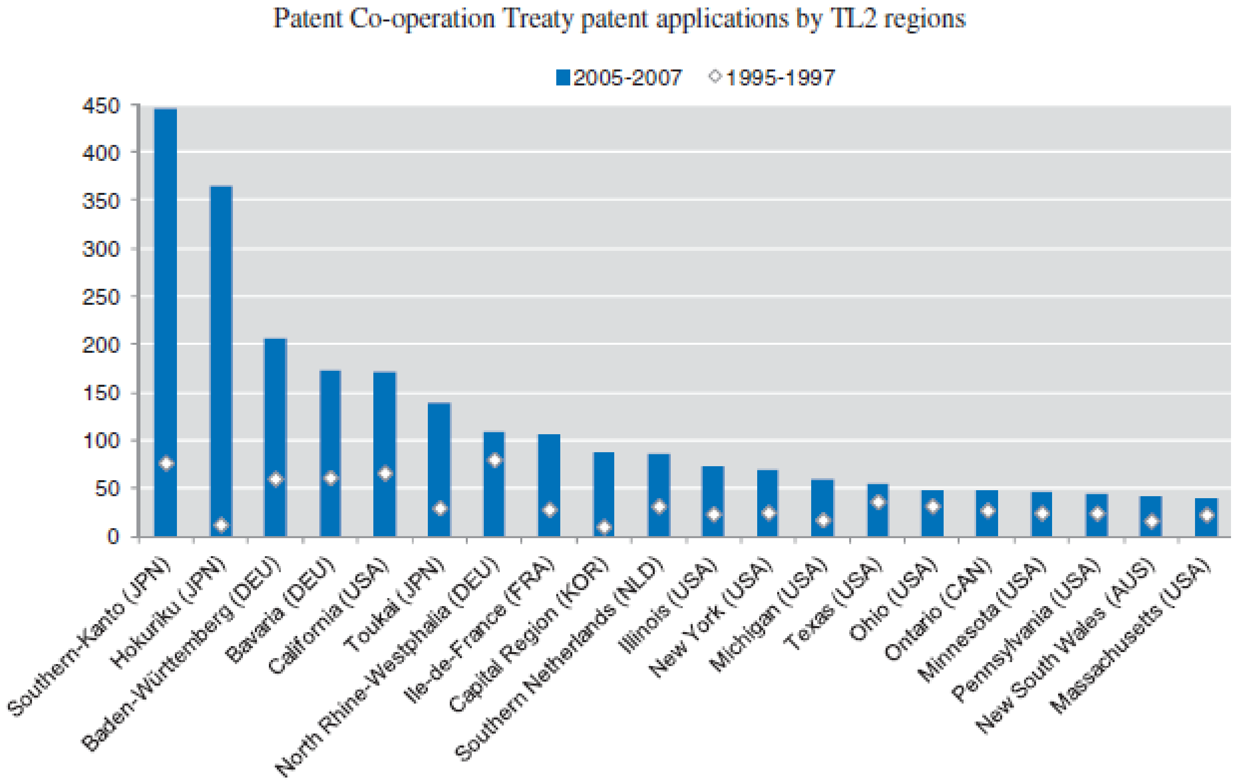



**Figure 14.35**. Top 20 OECD Subnational Regions in Green Technologies Patenting from 2005-2007 Source: (OECD, 2011a, p. 56)

### *14.3.3.2 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 regions, within different countries and in different regions within those countries; and the different 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 South-East Asia or Sub-Saharan Africa 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

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 sub-Saharan African countries (Doig and Adow, 2011). More common are low development roadmaps with a national focus, such as a recent study by the Sussex Energy Group and the Tyndall Centre which explored four possible low carbon development pathways for China (Wang and Watson, 2008).

Studies examining 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 sub-Saharan Africa that focus on biomass (Marrison and Larson, 1996; Hiemstra-van der Horst and Hovorka, 2009; Dasappa, 2011) and solar energy technologies (Wamukonya, 2007; Munzhedzi and Sebitosi, 2009; Zawilska and Brooks, 2011). However, other technologies have perhaps less clear regional advantages, including biofuels which have been widely studied not just for use in Brazil or in Latin America (Goldemberg, 1998; Dantas, 2011; Souza and Hasenclever, 2011) but also in southeast Asia (focusing on Malaysia) (Lim and Teong, 2010), and in the 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 have proposed 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 COP 17.

In a report prepared for 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 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 14.36.

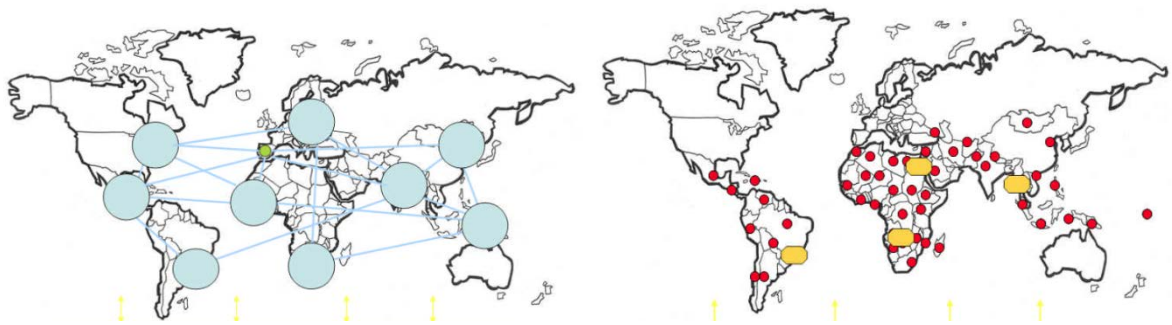


**Figure 14.36**. Options for Regionally-Coordinated Climate Technology Networks
Notes: Map on left illustrates a network of climate technology RD&D centers (blue circles) with a small secretariat (green circle); map on right illustrates a network of climate technology RD&D centers with national hubs (red dots) and regional centers (yellow shapes).
Source: (Cochran et al., 2010, pp. 35–36)

### 14.3.4 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 bilateral flows. Moreover, since the setup of the pilot phase for Activities Implemented Jointly in 1995 and the operationalization of the Clean Development Mechanism and Joint Implementation 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). So 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 levy climate finance within advanced developing countries, as these have a capital surplus.

#### 14.3.4.1 Financing Needs and Modalities to Achieve Low Carbon Development in Different Regions

The most elaborate study on regional financing needs is (UNFCCC, 2008), where under a scenario for stabilization of global greenhouse gas emissions at 2004 levels in 2030 financing requirements for mitigation and adaptation are estimated compared to the reference scenario as shown in Table 14.6.

**Table 14.6:** Investment need differential in 2030 (billion $)

| Region | Energy | Industry | Transport | Buildings | Waste | Adaptation[3] | Total |
|---|---|---|---|---|---|---|---|
| Africa | -6.5 | 0.9 | 3.9 | 2.8 | 0.1 | 3.3 | 4.5 |
| Asia[1] | -16.5 | 20.0 | 28.8 | 14.3 | 0.4 | 15.2 | 62.2 |
| Australasia | 1.5 | 0.5 | 1.2 | 0.8 | 0 | 1.1 | 5.1 |
| Europe[2] | -28.7 | 7.0 | 19.3 | 15.5 | 0.1 | 6.5 | 19.7 |
| Latin America | -15.2 | 1.2 | 6.6 | 1.1 | 0.1 | 2.5 | -3.7 |
| North America | 1.6 | 6.1 | 27.7 | 16.3 | 0.2 | 16.4 | 68.3 |

[1] Including Middle East
[2] Including Russia and countries in transition
[3] Water supply and coastal protection, compared to A1B scenario, using the assumptions about grant period und climate change shares (p. 107), as well as infrastructure (Munich Re data, 20%, see p. 123), 50% of OECD Pacific allocated to Asia.
Data sources: (UNFCCC, 2008), p. 46, 47, 57, 62, 68, 70, 106, 107, 119, 123). Forestry and agricultural mitigation estimates were not differentiated regionally and thus have been excluded.

#### 14.3.4.2 Overview of Different Streams of Public and Private Financing

Official development assistance (ODA) predates climate policy for many decades. Since 1998, the Creditor Reporting System (CRS) data include a marker for climate change mitigation, and since 2011 a marker for adaptation is being used. In the last years, aid flows from non-OECD donors (Gulf Cooperation Council members, China and Brazil) have increased but they are not well documented (Woods, Ngaire, 2008; OECD, 2010).

The Global Environment Facility set up in 1991 implements the financial mechanism of the UNFCCC and has been allocated 3.4 billion $ to climate change mitigation and adaptation (Climatefinanceoptions.org, 2012). Beyond the GEF, since the early 2000s a plethora of funds has been set up under the umbrella of the UNFCCC - either directly, through multilateral development banks or through ad-hoc groups of donor countries. These funds have received funding from the following sources (all numbers are from (Climatefinanceoptions.org, 2012)), unless otherwise stated):

- Directly under the UNFCCC, the Kyoto Protocol's Adaptation Fund is funded through a 2% levy on emissions credits issued to CDM projects, totalling 0.15 billion $ of revenues and has been operational since 2009, with the GEF serving as secretariat. The Least Developed Country Fund has donor-financed resources of 0.17 billion $, and the Special Climate Change Fund of 0.11 billion.

- The World Bank's Climate Investment Funds (CIFs) set up by 2009 are financed through industrialized country pledges. They comprise the Clean Technology Fund (CTF) with 4.5 billion $, the Pilot Program for Climate Resilience (1 billion $), the Forest Investment Program (0.6 billion $) and the Scaling Up Renewable Energy Program in Low Income Countries (SREP) with a volume of 0.3 billion $. Moreover, the World Bank hosts the Forest Carbon Partnership Facility with funds of 0.2 billion $, operational since 2008.

The flows of private funds to developing countries have been under-researched due to the wide range of options (see Figure 14.37).

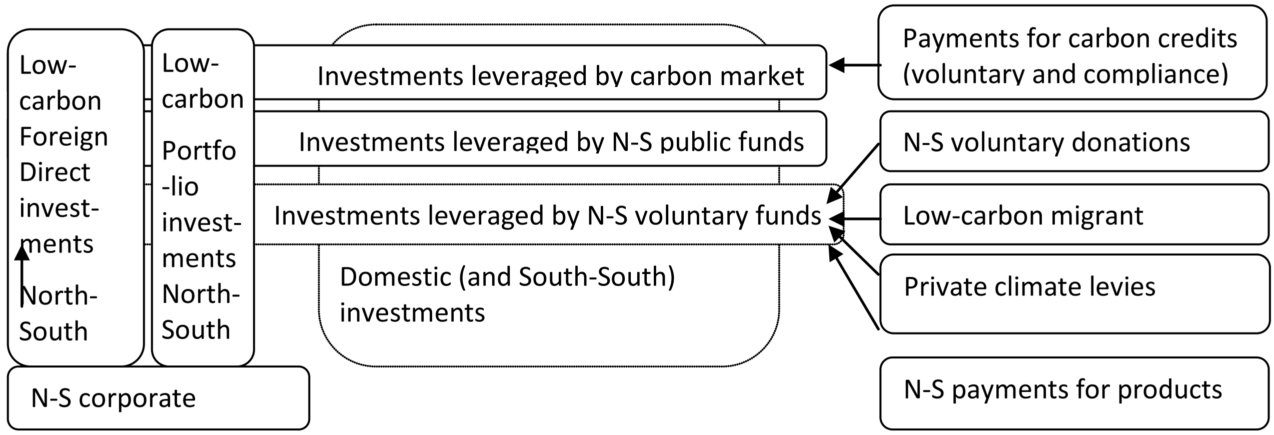



**Figure 14.37.** Options for private finance flow
N-S = North-South
Source: (Stadelmann et al., 2011a), p. 15

(Stadelmann et al., 2011b) 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 $ p.a., 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 $ p.a., as estimated by (UNCTAD, 2010) and investments leveraged by industrialized countries' public funds (20-90 billion $ p.a.), 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.

### *14.3.4.3 Participation in Climate-Specific Policy Instruments*

#### Regional Distribution of International Climate-Specific Policy Instruments

Regional participation in the different climate policy instruments varies strongly. It often is 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 regards 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 13.13, the following climate-specific programmes with a regional view could be identified:

The CDM has developed a distinct pattern of regional clustering of both 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 14.38). This pattern has been relatively stable since 2006

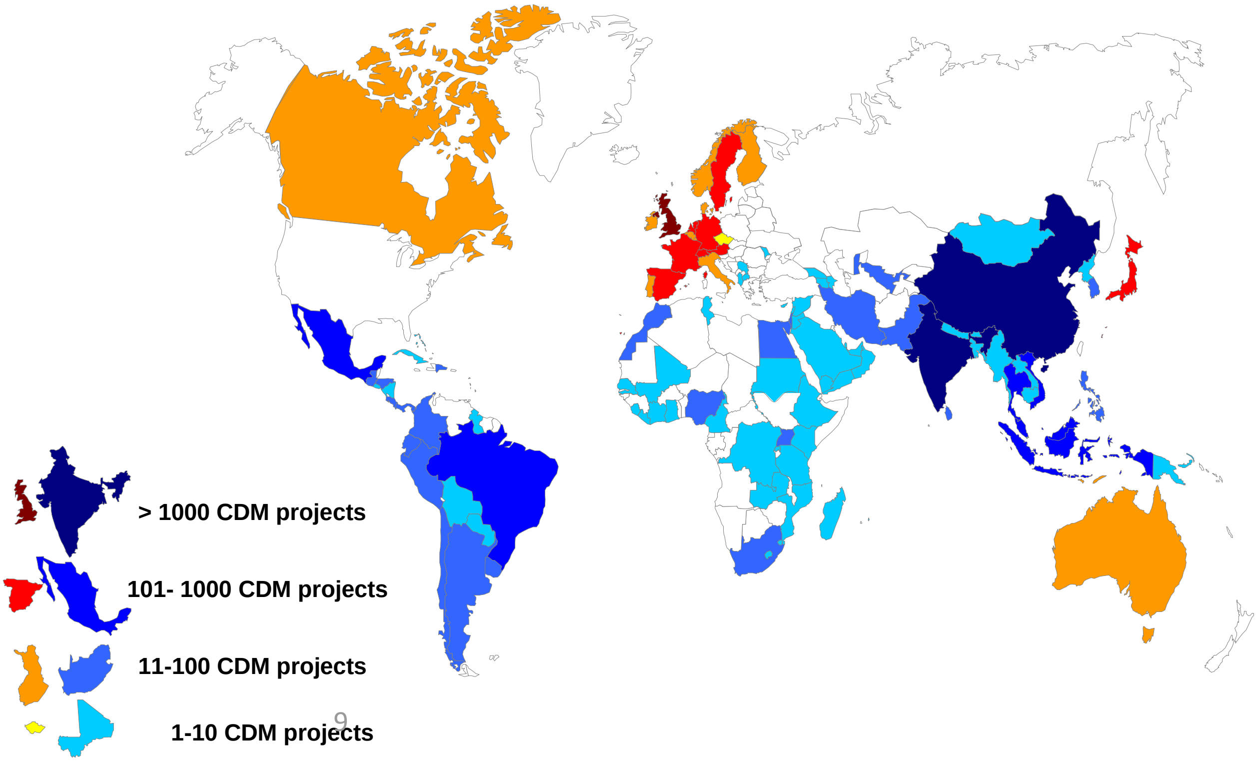



**Figure 14.38.** Regional distribution of CDM project hosts (blue) and primary CDM credit buyers (red) Data source: (UNEP Riso Centre 2013)

The reasons for the skewed regional concentration of CDM projects have been thoroughly researched. (Jung, 2006) assessed host country attractiveness through a cluster analysis 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; 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, coming to similar conclusions. (Castro and Michaelowa, 2010) assess the 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 et al. 2009) discussed how technology transfer could contribute to a more equitable distribution of projects.

For CDM programmes (PoAs) that allow bundling an unlimited number of projects, the distribution differs markedly from standard CDM projects. According to (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 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.

Obviously, numbers of projects may be distributed differently from total emission credit volumes and revenue / finance flows. Figure 14.39 shows changes of regional distributions of expected credit volumes for annual cohorts of newly submitted CDM projects; Asia dominates except for the year 2004.

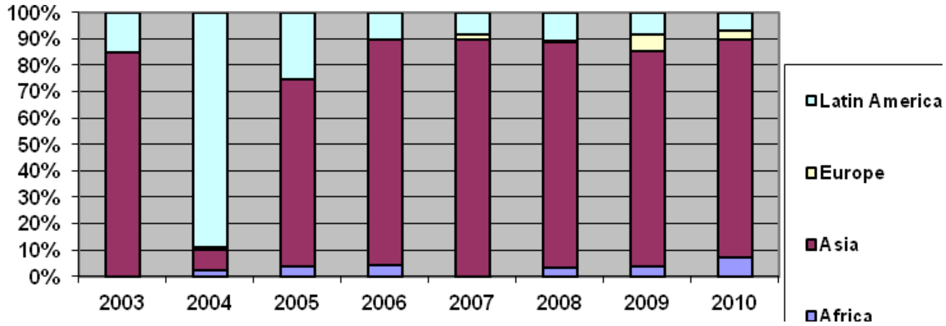



**Figure 14.39**. Regional distribution of pre-2013 credit volumes for annual CDM project cohorts Data Source: (UNEP Riso Centre 2013)

Figure 14.40 shows the regional distribution of 880 climate change projects (including mitigation and adaptation) of the GEF with a total finance volume of 3.1 billion $. The regional distribution is much more balanced than in the case of the CDM when looking at project numbers, but project volumes are skewed in favour of Asia. Academic literature has so far 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.

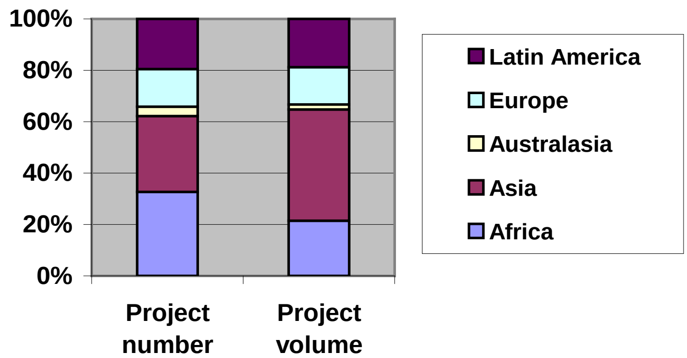



**Figure 14.40**. GEF climate change project distribution
Data source: (Global Environment Facility, 2013)

While the general direction of bilateral climate finance flows from the North to the South is obvious, regional specificities have only partially been addressed by the literature. (Atteridge et al., 2009) assessed the 2008 climate finance flows from France, Germany and Japan as well as the European Investment Bank and found 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. While the Rio Markers of the OECD could theoretically be used to assess the regional distribution of bilateral flows, the quality of the data is uneven due to simple coding errors as well as political incentives to overcode projects as being related to climate mitigation (Michaelowa and Michaelowa, 2011). There is no recent peer-reviewed literature discussing flows from MDBs.

### Regional Distribution of Policy Instruments Operating at National Levels

With the exception of the cases of emissions trading and feed in tariffs in Europe and renewable portfolio standards in the US, diffusion of climate policies across regions has not been focus of the research literature. In the US case, (Matisoff, 2008) sees a limited role for policy diffusion and argues that internal factors in each administrative unit are a stronger determinant of policy choice. For the European case of renewable energy policies, (Ringel, 2006) finds clear evidence that the concept of feed in tariffs diffused from Germany and substituted the system of renewable portfolio standards, but that the EU played a key role in that diffusion. (Carrapatoso, 2011) argues that policy dialogues between the EU and China contributed to the implementation of feed in tariffs and emissions trading systems in China.

A number of countries have officially submitted NAMAs to the UNFCCC. Table 14.7 provides an overview of the countries, which currently submitted NAMAs according to the NAMA type.

**Table 14.7**: Overview of NAMAs submitted to UNFCCC. Source: (Roser et al., 2011)

| Type | | Unilateral NAMAs | Supported NAMAS | Not available |
|---|---|---|---|---|
| Emission targets | Climate neutrality | Maldives | Bhutan, Costa Rica, Papua New Guinea | |
| | Below business as usual | Indonesia, Israel, Korea, Republic of, Singapore | Brazil, Chile, Mexico, Papua New Guinea, South Africa | |
| | Below base year | Republic of Moldova | Antigua and Barbuda, Marshall Islands | |
| | Emissions per GDP | China, India | | |
| Strategies and plans | | | Afghanistan, Georgia, Madagascar, Maldives, Mauritius, Mexico, Sierra Leone | Algeria, Cote d'Ivoire (Ivory Coast), Eritrea, Israel, Sierra Leone, Togo |
| Policies and programmes | | Argentina, Bostwana, Colombia, Ghana | Argentina, Bostwana, Brazil, Central African Republic, Chad, Chile, Colombia, Ghana, Jordan, Madagascar, Sierra Leone, Tunisia, Mexico, Peru, South Africa | Armenia, Benin, Cameroon, Congo, Cote d'Ivoire (Ivory Coast), Eritrea, Gabon, Indonesia, Macedonia, the former Yugoslav Republic, Mauritania, Mongolia, Morocco, Peru, San Marino, Sierra Leone, Tajikistan, Togo |
| Projects | | Ghana, Ethiopia | Central African Republic, Chad, Congo, Ethiopia, Ghana, Jordan, Madagascar, Sierra Leone, Tunisia, Mexico, Peru | Benin, Cambodia, Cameroon, Congo, Gabon, Macedonia, the former Yugoslav Republic, Mongolia, Morocco, Sierra Leone |

As can be seen from the distribution of NAMAs, most submissions relate to strategy development, policies and programmes and projects. A number of countries also submitted national targets, mainly reduction targets below business as usual projections. Most NAMAs also fall in the category of supported NAMAs although many countries have not specified whether, and for which NAMAs, support would be required (Roser et al., 2011).

The emerging lists of NAMAs (Nationally Appropriate Mitigation Actions) under the Cancun agreement allows to assess the regional distribution of policies across Non-Annex I countries as shown in Figure 14.41.

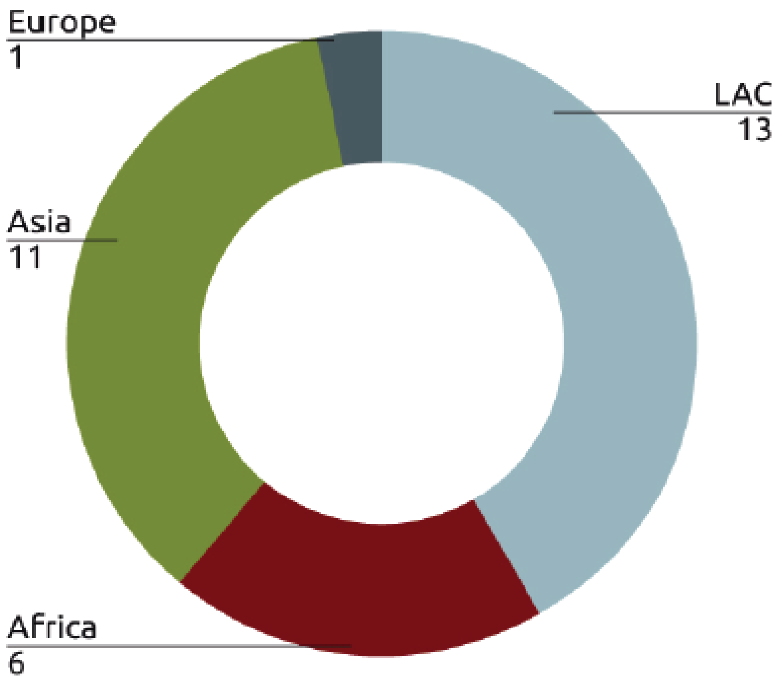



**Figure 14.41**. NAMAs according to regions
Data source: (Roser et al., 2011)

With regard to the sectoral distribution of NAMAs, at present most activities are developed within the transport sector as in Figure 14.42 This distinguishes current trends in NAMA development from the sectoral distribution of project activities under the CDM where only 0.6% of projects are related to transport (Roser et al., 2011). Other NAMA development activities are carried out within the following sectors: energy, waste, industry, buildings, forestry and agriculture.

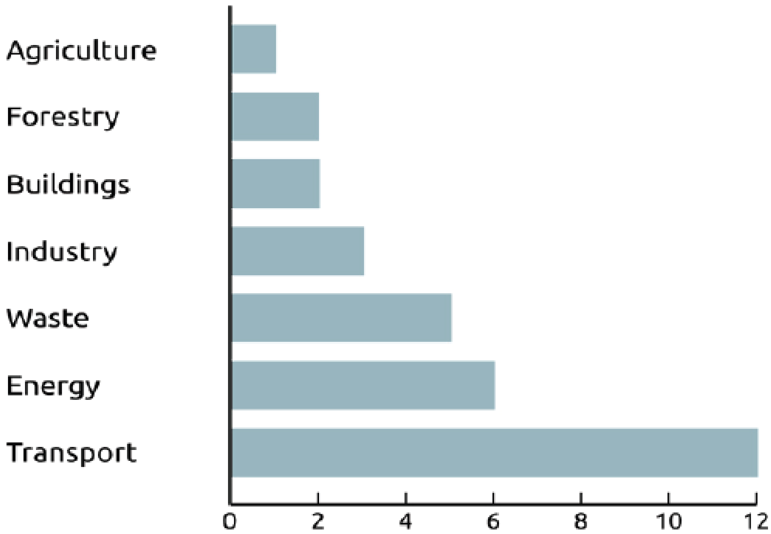



**Figure 14.42**. NAMAs according to types
Source: (Roser et al., 2011)

In terms of REDD, 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 14.43 provides a regional distribution of REDD projects.

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.

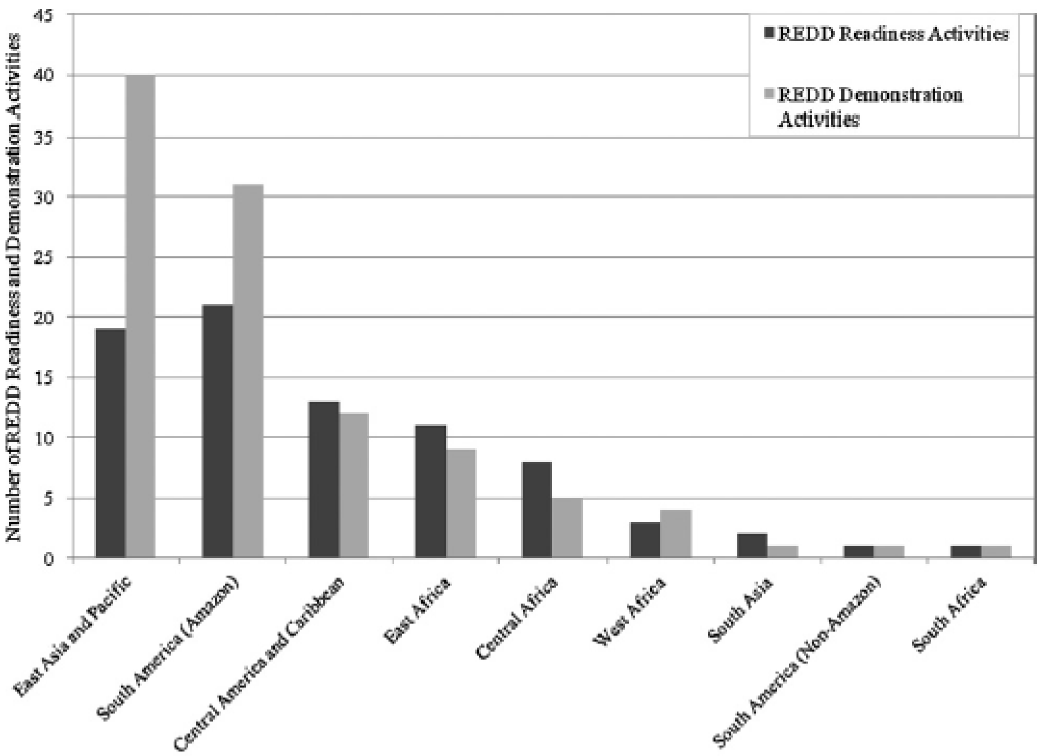



**Figure 14.43.** Regional distribution of REDD
Source: (Cerbu et al., 2011)

### 14.3.5 Conclusions for Low Carbon Development Options

The discussion has suggested that the challenges to adopt low-carbon development strategies differ greatly by regions. This pertains to the most important area of focus, where in poorer regions, ways to manage land use change and the development of low-carbon energy systems and less carbon-intensive urbanization patterns are of particular concern. In advanced economies, questions of reorienting energy systems, changing consumption patterns, and reforming transport systems will be particularly high on the agenda. All of these policy changes require technological development and transfer, access to finance, proper incentives, as well as local implementation capacity. Here the discussion has showed that there are great challenges in all these areas.

## 14.4 Regional Cooperation and Mitigation: Opportunities and Barriers

### 14.4.1 Regional Mechanisms: Conceptual

In the past few decades, countries have come together to cooperate on a variety of economic and political matters on the regional level. This chapter reviews these regional mechanisms in terms of what they have achieved in terms of mitigation, and what they might achieve in future. When considering these many regional mechanisms, we distinguish between climate-specific and climate-relevant activities; as the focus is on mitigation, we will also largely focus on initiatives that deal with mitigation issues. Climate-specific regional initiatives are forms of cooperation at the regional level that are specifically designed to address mitigation challenges. Conceptually, such climate-specific initiatives could be joint investment programs in low-carbon technologies, either to generate economies of scale or to ensure that such technologies are situated in locations within regions where the costs/emission avoided are lowest, joint regional policies to regulate emissions, regionally implemented regimes to tax emissions, or regional emissions trading schemes combined with a fixed upper limit of emissions consistent with an mitigation objective. Some but not all of these options for regional climate-specific approaches have indeed been tried in some regions (see below).

In addition, there is a large range of regional mechanisms that were designed with other objectives in mind, but with potentially important implications for mitigation at the regional level. We refer to them here as climate-relevant mechanisms. While of course any regional mechanism could have some mitigation implication, some are likely to have a more direct link to mitigation. In particular, four types of climate-relevant regional initiatives can play a role. The first one is related to regional trade agreements. Regional trade agreements, such as the EU, the NAFTA, or the MERCOSUR, promote trade within the group of member countries (so-called trade creation), albeit often at the expense of trade with third parties (trade diversion). As trade involves transport and as transport predominantly uses fossil fuels, this must have a climate impact. Moreover, the advancement of regional trade changes patterns of specialisation within and beyond regions. Thus, carbon-intensive industries may relocate within regions and third parties may be affected via trade diversion. A second type of climate-relevant activity is regional energy markets, power pools, and joint energy development projects. These activities are usually designed to ensure improved access and reliability of energy (particularly electricity) within a region and this has been a focus of a considerable amount of regional initiatives. These activities have clear mitigation implications that need to be investigated. A third type of climate-relevant mechanisms is regional transport and infrastructure initiatives (transport corridors and the like), which again are usually initiated to improve trade and movement of people. But depending on how they affect trade, transport, and urbanization, they clearly have mitigation relevance. Lastly, there is a range of regional initiatives, often initiated from the regional trading blocs and sometimes from regional development banks that are aimed to improve the coordination of policies in various sectors or fields, some of which can have mitigation implications that will need to be analysed.

When analysing these regional mechanisms, one clear question is to what extent the existing schemes have had an impact on mitigation. A second question, which may be more important, is to study to what extent these initiatives could be adjusted to have a greater mitigation potential in future. In fact, one of the key messages of the chapter is that such regional mechanisms could potentially become important platforms to organize regional initiatives for mitigation.

An important aspect of regional mechanisms is related to consistency and efficiency. As GHGs are global pollutants and their effect on global warming is by and large independent of the geographical location of the emission source, all emitters of a particular GHG should be charged the same (implicit or explicit) price. If this "law of one price" is violated, mitigation efforts will be inefficient. Moreover, the relative prices for different greenhouse gases should reflect their relative climate impacts. Regarding the issue of regional cooperation, this implies that regions should strive for *internal* and *external* consistency of prices for greenhouse gases. The law of one price should apply within regions and across regions. As regards internal consistency, regional markets for GHG emission permits achieve this goal. An example is the EU ETS, reviewed in detail elsewhere in this chapter. A problem with existing trading systems is that they cover only a part of GHG emissions. Usually, they address carbon emissions, but not other GHGs like methane or CFCs. And they cover only a part of carbon emissions. This may cause inefficient allocation of mitigation efforts. Additional problems arise if (implicit or explicit) prices for emissions differ across countries within a regional cooperation bloc. For example, differences in fuel prices induce cross-border shopping. See (Banfi et al., 2005). As cross-border shopping consumes energy, it contributes to global warming. Moreover, road freight transport is also affected and distorted by these price differentials. See (McKinnon, 2007)for the effects in the UK.

External consistency is linked to the problem of GHG leakage. GHG-intensive industries tend to locate in regions where GHG prices are low. Moreover, as fossil fuels are traded internationally, their demand tends to be shifted to regions in which prices are lower. See Chapter 15 of this report. First of all this leads to an inefficient allocation of resources since the climate-related component of social cost is the same in all regions. Second, leakage reduces a region's incentive to engage in mitigation since a share of its contribution vanishes via leakage. One answer to this problem is to use border-tax adjustments, which are discussed in Chapters 13 and 15. The other option is to link regional emission trading systems. See (Tuerk et al., 2009), but also (Flachsland et al., 2009a; b), who argue that – albeit welfare-enhancing on a global level – linking regional emission trading systems does not necessarily benefit all parties. There may be adverse terms-of-trade effects and regions lose discretion since they have to agree on a common climate policy.

Besides the efficiency issue, other criteria of evaluation of regional cooperation come into mind, such as well-being, equity, intra- and inter-generational justice. See Chapter 3. However, the following sections of this chapter will be devoted mainly to the mitigation potential of regional cooperation.

Are regional cooperation and global cooperation substitutes or complements? Will countries that cooperate on the regional level put less effort into global cooperation? There has been a debate on this in the literature on regional trade agreements (Baldwin, 2006), where regionalisation may slow down the process of global trade liberalisation. As regards climate agreements, (Asheim et al., 2006) and (Osmani & Tol 2010) use game theory to show that several regional agreements are better than a global agreement with limited (endogenous) participation.

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Box 14.1. Carbon Leakage, the Green Paradox, and Adjustment Measures

Regional climate policies may be partially or fully offset by Carbon Leakage. Carbon Leakage occurs whenever a country or a group of countries by reducing its carbon emissions induces increased carbon emissions in the rest of the world via changes in world-market prices of traded goods or factors of production. The main mechanisms underlying this phenomenon are threefold (Rauscher, 2005), (Burniaux and Oliveira Martins, 2012).

(1) Changes in prices of fossil fuels. Stricter climate policies reduce fossil-fuel prices and this induces additional use of these fuels elsewhere.

(2) Changes in prices for final goods. Stricter climate policies in a part of the world raise prices for carbon-intensive goods. This raises the production of these goods elsewhere and, therefore, carbon emissions as well.

(3) Changes in factor prices. Stricter climate policies reduce the remuneration of mobile factors, in particular capital. These factors move abroad and cause additional carbon emissions there.

There are additional effects arising from changes in market structure if international markets are non-competitive ((Barrett, 1994),(Kennedy, 1994)(Gürtzgen and Rauscher, 2000),) and from reactions by other countries if they respond to less climate change by increasing their own emission. As regards the magnitude of leakage effects, there is a wide range of estimates. Some papers argue that negative leakage is possible, at least theoretically ((Gürtzgen and Rauscher, 2000), (Copeland and Taylor, 2005), (Fullerton et al., 2011)). In contrast, (Sinn, 2008)employs an exhaustible-resources model by (Long and Sinn, 1985) and looks at a dynamic variant of mechanism (1) and predicts leakage exceeding 100%. He argues that exporters of fossil fuels will exhaust their deposits anyway. This implies 100% leakage or complete ineffectiveness of climate policies. If resource owners, expecting lower producer prices of fossil fuels due to stricter climate policies and lower demand in some countries, modify their extraction profiles such as to sell more oil as long as prices are still high. Thus, stricter climate policies by a subgroup of countries may actually aggravate rather than mitigate global warming. More recent papers (Eichner and Pethig, forthcoming; Gerlagh, 2010) modify Sinn's model and show that adding more complexity and realism, e.g. a cut-off price for fossil-fuels demand and stock-dependent extraction costs, to the model mitigates the leakage effect such that a green paradox is less likely to occur. Most empirical studies on leakage use computable general-equilibrium (CGE) models. The results are diverse. Leakage effects range from 20 to more than 100%, the majority of the estimates being in the 15 to 25% range (Felder and Rutherford, 1993)(Babiker, 2005)(Babiker and Rutherford, 2005), (Elliott et al., 2010)(Burniaux and Oliveira Martins, 2012).

As CGE models are calibrated models, the results depend on the assumptions underlying the calibration. E.g. most of them are constructed such that negative leakage and leakage exceeding 100% are impossible by assumption. This is a methodological shortcoming as the leakage figures derived depend on untested assumptions of the underlying model. A truly empirical model is due to (Aichele and Felbermayr, 2012). They show that ratification of the Kyoto protocol reduces a country' s carbon footprint of production, but not of consumption. Thus leakage is in the range of 100%. Summarizing, the evidence suggests that leakage figures are substantial although there is considerable disagreement about the exact magnitude, with some notable exceptions claiming that leakage is close to or even higher than 100%. Most of the models used are calibrated CGE models, which do not estimate leakage effects but merely simulate them under the proviso that underlying modeling assumptions are correct.

Measures to cope with leakage include border-tax adjustments, i.e. import tariffs on goods that have been produced carbon-intensively in non-compliant countries (Markusen, 1975)to cope with leakage through final-goods markets and taxation of own production of fossil fuels to cope with leakage through fossil-fuels markets (Hoel, 1994). Border-tax adjustments mitigate the comparative advantage of countries that do not employ mitigation policies. Some CGE studies show that border-tax adjustments can be effective to some extent (Elliott et al., 2010). As regards leakage through the market for fossil fuels, reducing own production of fossil fuels raises the world-market price and reduces demand. (Harstad, 2012) argues that countries or regions intending to mitigate $CO_2$

emissions should buy fossil-fuels deposits and preserve them. The use of taxes or other measures to reduce domestic production of fossil fuels to cope with leakage has not been addressed empirically. (Hoel, 1994) results suggest that the optimal tax rate should equal the emission tax times the leakage rate. Also the more recent research inspired by the green paradox (Sinn, 2008) suggests that the supply side of the market for fossil fuels deserves more attention if efficient mitigation strategies are sought.

It should be noted that policies coping with leakage are only second best. The first best is a global approach to mitigation with equal emission taxes or permit prices everywhere.

## 14.4.2 Existing Regional Cooperation Processes and their Mitigation Impacts

### *14.4.2.1 Climate Specific*

So far, regional climate policy initiatives have been rare; 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 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. While most supra-national climate policy initiatives specialize on certain technologies (see e.g. the Methane to Markets Initiative, the Climate Technology Initiative, the Carbon Sequestration Leadership Forum or the International Partnership for the Hydrogen Economy) are open for global membership (Bäckstrand, 2008) for a good summary of these initiatives, which are not assessed here further), in selected cases regional initiatives emerged. The Asia-Pacific Partnership for Climate Change is such a case; 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

Table 14.8 gives an overview on regional climate initiatives.

**Table 14.8**: Key features of the three regional climate policy initiatives EU ETS, WCI and APP

| Initiative<br>Characteristics | EU Emissions Trading Scheme | Western Climate Initiative | Asian-Pacific Partnership |
|---|---|---|---|
| Region | Europe | North America | Asia+North America |
| Year started | 2003 | 2007 | 2005 |
| Countries involved | 30 | 2 | 7 |
| Mandatory mitigation policy instrument | Yes (EU level) | Yes (state level) | No |
| Decision making level | Hybrid (EU/member countries), with increasing centralization | Decentralized (state level) | Centralized |
| Transparency[1] | High | High | Medium |
| Dedicated technology transfer component | No | No | Yes |
| Business participation | Yes | Yes | Yes |

[1] Evaluation of transparency by (Bäckstrand, 2008) for EU ETS and APP, by chapter authors for WCI.

*Analysis: Effectiveness for Mitigation, Institutional Framework, Lessons Learned*

The EU ETS is by far the largest emission trading in the world, covering over 12,000 installations belonging to over 4000 companies and over 2 billion t of $CO_2$ emissions. It has thus been thoroughly researched (Convery, 2009a) for an excellent review of the literature, and (Lohmann, 2011) for a general critique of the EU ETS). According to (Skjærseth and Wettestad, 2009), the "volte face" of the EU from being an opponent of market mechanisms in climate policy as late as 1997 to becoming a fervent supporter of a large-scale emissions trading system since 2000 was due to a rare window of opportunity. The Kyoto Protocol had increased the salience of climate policy. A change of staff in the Commission brought in young economists who saw emissions trading as alternative to the stalled carbon/energy tax requiring unanimity. According to EU rules, trading could be agreed through a qualified majority. The Commission acted swiftly and brought on board industry 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. Industry did not see that after the pilot phase 2005-7 the rules could be strengthened. The lukewarm reaction of several member states, especially Germany, which preferred a continuation of voluntary agreements as well as the UK which wanted to keep its own emissions trading system until 2008, was unable to derail the process, especially as the ETS was seen as cornerstone of the EU leadership after the US repudiation of the Kyoto Protocol. But the Commission had to accept a decentralized allocation system, which led to a "race to the bottom" by member states already then criticized by researchers (Betz and Sato, 2006). Nevertheless, allowance prices reached levels of almost 30 € totally unexpected by analysts, which triggered emission reductions estimated from 85 million t $CO_2$ (Ellerman and Buchner, 2008), whose analysis is extremely detailed) up to over 170 million t $CO_2$ (Anderson and Di Maria, 2011). (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 which showed an allowance surplus, 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 that 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 unexpected crash of industrial production due to the financial and economic crisis of 2008 led to an emissions decrease by 450 million t $CO_2$ and an allowance surplus for the entire 2008-2012 period. Now, 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; 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 their analysis for the cement sector (Demailly and Quirion, 2006) sees a stronger exposure, with significant production losses at 50% auctioning. (Grubb and Neuhoff, 2006; 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. Whether after the 2005 and 2009 crashes price levels of allowances have been sufficiently high to drive emissions reduction has been contested. 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 2005/6 (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. Surprisingly, 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 the 2005-2007 phase, companies covered by the EU ETS could import credits from the mechanisms without limit, but access to the mechanisms has been reduced massively 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; 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 is not generating price signals high enough to mobilize renewable energy and energy efficiency investments and 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.

Competitiveness implications of mandatory cap and trade schemes can be theoretically softened by border tax adjustments. (Oberndorfer and Rennings, 2007) define competitiveness and review the early studies on competitiveness impacts. Border tax adjustments (BTA), which have been proposed to limit production losses and thus carbon leakage are assessed by (Kuik and Hofkes, 2010) and found not to be very effective. (Monjon and Quirion, 2010) propose that such adjustments should be built on benchmarks. Also other empirical studies have found that BTA would have small effects “on most traded goods, would reduce leakage of emissions reduction very modestly, and would do little to protect import-competing industries” in the United States and Europe (McKibbin et al., 2008). With benefits held to be too small, warnings are made as to the costs of implementing BTA in terms of their administrative complexity or the potentially damaging consequences for the global trading system. Explanations relate to the fact that most carbon emissions stem from domestic activities, such as electricity generation and local and regional transportation, which are largely non-traded and are little affected by international trade (McKibbin et al., 2008) as it is the case even in explicitly carbon-motivated regional trade agreements (Dong and Whalley, 2009). In this regard, emphasis is placed on achieving an ambitious international approach to address the climate change problem, with participation by all the major greenhouse-gas-emitting countries and sectors (McKibbin et al., 2008).

The WCI is a bottom-up initiative consisting of US and Canadian states (see Chapter 13.7.1.2 for a detailed review). It was initiated in 2007 and originally supposed to start trading in 2012. By 2008 it looked like it was set to be the second largest trading system in the world, behind only the EU-ETS, due to a rise of the relevance of mitigation policy under the Obama administration. 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; generally the WCI was to take the role as testing ground for a federal cap and trade system. However, by 2012 the situation had changed drastically. Federal cap and trade had been defeated in both the US and Canada, and only California and Quebec, as well as British Columbia remained remotely interested in trading which has yet to start.

Most researchers stress that the APP was purposefully set up by the US and Australia as an alternative to the Kyoto Protocol and UNFCCC process (Bäckstrand, 2008; Lawrence, 2009; Karlsson-Vinkhuyzen and Asselt, 2009; Taplin and McGee, 2010). (Kellow, 2010) sees it as a "promising non-binding sectoral approach" covering over 50% of global emissions, and as a stepping-stone towards workable alternatives to the Kyoto Protocol. The APP introduced task forces to cover aluminium production, buildings and appliances, cement, cleaner fossil energy, coal mining, power generation, renewable energy and distributed generation, and steel production. 170 projects had been approved by the Policy and Implementation Committee by mid-2009, but only 7 completed (Taplin and McGee, 2010), p. 18). This may be due to the fact that the total budget reached just 200 million $ (Taplin and McGee, 2010), p. 18). (Karlsson-Vinkhuyzen and Asselt, 2009) explain the willingness of Asian countries to participate by the wish to maintain good diplomatic relations with the US, and to generate revenues through transfers. Business found the APP attractive because it supported the exchange of specialists, the organization of workshops, and led to the analysis of sectoral mitigation opportunities from different angles. Particularly the development of best practice guides was seen to contribute to technology transfer. Business also liked that the APP did not set any emission targets, which led to an orientation of projects towards generic technological improvements, and not towards direct emission reduction. (Heggelund & Buan 2009) suggest that the APP for China was a complement to the Kyoto process that allowed benefiting from technology transfers. They conclude that APP membership did not lead to a decrease of willingness of the Chinese government to engage in the UNFCCC process. After Australia's ratification of the Kyoto Protocol, the Rudd government continued to view the APP as a valuable regional mechanism for facilitating technology development and transfer (Lawrence, 2009) but slashed the Australian contribution by 44 million $. (Taplin and McGee, 2010) p. 20) see the APP may well be "an emergent model for regional partnerships under Kyoto that brings industry into decision-making roles".

#### *Issues: Big Difference European ETS and Other Regional Initiatives*

The EU ETS is a mandatory policy which has evolved over a decade in strong interaction between the EU Commission, member state governments industry lobbies. It has gone through three phases, and shifted from a highly decentralized to a centralized system. It is thus not comparable with the other two initiatives, which are much smaller in scope and which have mobilized a limited volume of mitigation.

### Other Regional Initiatives

There are a number of regional initiatives mostly initiated by regional organizations or group of countries that focus on climate change mitigation. Table 14.9 provides list of few regional initiatives with the prime mandate of climate mitigation (sometimes combined with adaptation).

**Table 14.9:** Regional Climate Initiatives

| Regional initiatives | Climate change mandates | Geographical coverage | Source |
|---|---|---|---|
| ***Africa*** | | | |
| COMESA (Common Market for Eastern and Southern Africa) Climate Change Initiative | Initiative to address climate change within the context of its responsibilities and strategy for promotion of the Comprehensive Africa Agriculture Development Programme (CAADP). | **19 member states**, a population of over **389 million** | www.comesea.int |
| CCAFS (Climate Change Agriculture and Food Security) in West and East Africa (CGIAR) | The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) is a 10-year research initiative launched by the Consultative Group on International Agricultural Research and Earth System Science Partnership | East Africa, West Africa and Indo-Gangetic Plains. | http://ccafs.cgiar.org/ |
| Mediterranean Climate Change Initiative | The Mediterranean Climate Change Initiative is designed to be an autonomous political initiative as well as a projects-based initiative eligible for Union for the Mediterranean (UfM) branding. It aims to accelerate the region's responses to the impacts of climate change and lead by example | Albania<br>Bulgaria<br>Croatia<br>Cyprus<br>Egypt<br>Former Yugoslav Republic of | http://www.medclimatechangeinitiative.org/ |

| | | | |
|---|---|---|---|
| | the transition to a low carbon development model. | Macedonia<br>France<br>Hellenic Republic<br>Israel<br>Italy<br>Malta<br>Mauritania<br>Montenegro<br>Palestinian National Authority<br>Romania<br>Serbia<br>Slovenia<br>Turkey | |
| ***Asia*** | | | |
| ACRI (Arab Climate Resilience Initiative) (UNDP Regional Bureau for Arab States) | ACRI, an initiative of the Regional Bureau for Arab States of the United Nations Development Programme, is to support and build resolve among national partners and regional stakeholders to formulate integrated, cross-sectoral and regional responses to the challenges of climate change and to facilitate practical and cooperative adaptation to ongoing and future impacts, whilst furthering gains in human development in the Arab countries. | Syria, Egypt, Bahrain, Morocco | http://www.arabclimateinitiative.org/ |
| AFCC (ASEAN Multi-Sectoral Framework on Climate Change) | The overall goal of the AFCC is to contribute to food security through sustainable, efficient and effective use of land, forest, water and aquatic resources by minimising the risks and impact of and the contributions to climate change. To achieve this goal, two major objectives have been identified: (i) coordination on the development of adaptation and mitigation strategies; and (ii) cooperation on the implementation of integrated adaptation and mitigation measures. | Member states of Association of South East Asian Nations Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam | http://www.aseansec.org/24802.htm |
| CCCI-AP (Cities and Climate Change Initiative in Asia-Pacific Region) | At the local level UN-HABITAT strives to help cities in developing countries to address climate change and, at the national, regional and global levels, to raise awareness and to help counterparts to build the capacities needed to enable cities and local governments to address climate change effectively. UN-Habitat's Cities and Climate Change Initiative (CCCI) seeks to enhance the preparedness and mitigation activities of cities in developing and least developed countries. | Developing and least developed countries. | http://www.unhabitat.org/categories.asp?catid=550 |
| MRC-CCAI (Mekong River Commission Climate Change and Adaptation Initiative) | Climate Change and Adaptation Initiative (CCAI) is a collaborative effort among MRC Member Countries—Cambodia, Lao PDR, Thailand and Viet Nam, to demonstrate and share adaptation strategies. With its emphasis on a basin-wide approach, the Initiative ensures that climate change adaptation is harmonised with effective strategies, plans at various levels and is applied at priority locations throughout the basin. | MRC Member Countries—Cambodia, Lao PDR, Thailand and Viet Nam | http://www.mrcmekong.org/about-the-mrc/programmes/climate-change-and-adaptation-initiative/ |
| ***Australasia*** | | | |
| ICCAI (International Climate Change Adaptation Initiative) | Australia invested $150 million over three years from 2008–09 to meet high priority climate change adaptation needs in vulnerable countries in our region. Over the next two years this assistance will be scaled up by $178.2 million to help the most vulnerable countries adapt to the impacts of climate change. The primary geographic emphasis of the AusAID–DCCEE jointly–managed International Climate Change Adaptation Initiative (ICCAI) is on Australia's neighbouring island countries. Nevertheless, targeted policy and technical assistance is also being made available for other countries in the region and, most recently, the Caribbean and | Australia's neighbouring island countries, the Caribbean and Africa | http://www.ausaid.gov.au/aidissues/climatechange/Pages/adaptation_initiative.aspx |

| | | | |
|---|---|---|---|
| | Africa.<br>The initiative comprises four interrelated components, which in combination will deliver a coordinated package of development assistance. Improved scientific information and understanding; Strategic planning and vulnerability assessments; Implementing, financing and coordinating adaptation measures;<br>Multilateral support for climate change adaptation | | |
| PCCSP (Pacific Climate Change Science Program) | The Pacific Climate Change Science Program is a A$20 million science program to help Australia's neighbouring island countries gain a better understanding of how climate change will impact the region | Australia's neighbouring island countries | http://www.csiro.au/partnerships/Pacific-Climate-Change-Science-Program |
| Joint Pacific-EU Initiative on Climate Change | | | http://www.forumsec.org/pages.cfm/newsroom/press-statements/2010/joint-pacific-eu-initiative-on-climate-change.html |
| APEC Climate Change | APEC is the premier Asia-Pacific economic forum. Our primary goal is to support sustainable economic growth and prosperity in the Asia-Pacific region. APEC has launched initiatives, primarily through the Energy Working Group (EWG), to more broadly promote clean and efficient energy production and use. | 21 member economies | www.apec.org |
| ***Latin America*** | | | |
| | | | |

Note: All information is sourced from the initiatives internet pages. No assessment is peer-reviewed literature is available while drafting this section.

### The Global Climate Change Alliance (GCCA) Initiative of the European Union

An example of an inter-regional climate-specific cooperation mechanism is the Global Climate Change Alliance (GCCA), an initiative created by the European Union in 2007 (European Commission, 2007, 2008b). The GCCA was created by the EU as part of its strategy for cooperation with developing countries most vulnerable to climate change.

The GCCA is an instrument to provide technical and financial support to developing countries to integrate climate change into their development policies and to implement adaptation and mitigation measures (Grijp van der and Etty, 2010; European Union, 2011a; b; Global Climate Change Alliance (GCCA), 2011). The GCCA implements national and regional programmes in about 25 countries in Africa, Asia, the Caribbean and the Pacific. The focus is on developing countries that are most vulnerable to climate change effects, in particular the least developed countries (LDCs) and small island developing states (SIDS), which are recipients of aid.

Areas of work of the GCCA include adaptation strategies in agriculture and water, clean energy, forestry, CDM implementation, disaster risk reduction and inclusion of climate change into development strategies. As part of the programmes, regional cooperation is encouraged on cross-border climate related issues, mainly through partnerships with existing regional organisations. The GCCA has established a platform for exchange of experience, regional dialogue, capacity building, technical and financial assistance (Global Climate Change Alliance (GCCA), 2011).

As part of its activities, the GCCA conducts regional policy dialogues with the different regions in which it is active. These policy dialogues have led to joint declarations on climate change between the EU and several regions or groups of countries. The joint declarations have emphasized the need for further cooperation between the EU and its partners on climate change and have been part of an effort by the European Union to find common ground with the target countries and regions on specific climate policy aspects. In these declarations, the GCCA has been portrayed by the parties as a complement to regional mechanisms for fostering political dialogue and cooperation on climate change.

The Global Climate Change Alliance is an example of an interregional cooperation mechanism on mitigation and adaptation and one of several instruments created to mainstream climate change in development cooperation (Peskett et al., 2009; Grijp van der and Etty, 2010). As such, it faces the challenge of demonstrating it's value-added against a number of other instruments in the EU and in the international development cooperation and climate change contexts and attracting sufficient funding for a meaningful impact. Still, it illustrates the possibilities for interregional cooperation to support national and regional implementation of climate-related measures.

#### *14.4.2.2 Climate Relevant Regional Cooperation Processes and Their Mitigation Impacts*

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 of particular relevance as mitigation and adaption policies often depend upon trade policy (Cottier et al., 2009; Aerni et al., 2010; Hufbauer et al., 2010)). Based upon the disciplines of multilateral trade under the rules of the WTO, 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. They increasingly transgress regional relations and encompass transcontinental preferential trade agreements (PTAs).

PTAs (including RTAs) provide trade preferences to participating parties. They basically require in goods to abolish tariffs and quantitative restrictions in substantially all the trade, and the granting of national treatment in services, respectively, and do not allow increasing trade barriers vis-à-vis third countries. Increasingly, they show regulatory convergence. They either represent a bilateral (among two countries) or plurilateral (in a group of countries) layer of privileged trade relations. The formation of PTAs is influenced by a number of factors. First, the competitive disadvantage of those staying outside preferential arrangements and, consequently, competition among countries for trade preferences in export markets create a so-called domino effect, whereby every additional agreement pushes other trading partners to join it or create their own PTAs (Baldwin, 2006). Second, countries entering PTAs expect obtaining more concessions in different sectors than would have been possible in multilateral trade relations on an MFN basis. As a result, the trend to enter into PTAs has intensified over the last decade and the tendency towards regionalisation of trade as well as economic and geopolitical relations is likely to prevail in coming years (WTO, 2011a).

As of November 2011, the WTO acknowledged 313 notifications of PTAs to be in force. Out of this, 211 (67.4%) are self-standing agreements (WTO statistics on PTAs are based on notification requirements rather than on physical number of PTAs; thus, for an PTA that includes both goods and services, WTO counts two notifications: one for goods and the other for services) (WTO, 2011b). Altogether, by region, North America participates in 32 PTAs; Central America in 22; South America in 34; Caribbean in 6; Europe in 85; Commonwealth of Independent States in 32; Africa in 26; Middle East in 25; West Asia in 21; East Asia in 53; and Oceania in 17 (WTO, 2011b). There are nine multilateral preferential trade agreements, amongst which the best known are: the European Union (a customs union not addressed here due to much deeper cooperation and integration among Member States), the European Free Trade Association (EFTA), the North American Free Trade Agreement (NAFTA), the Southern Common Market (MERCOSUR), the Association of Southeast Asian Nations (ASEAN), the ASEAN Free Trade Area (AFTA), and the Common Market of Eastern and Southern Africa (COMESA).

Given that the multilateral process of trade liberalisation is slow and the current Doha Development Agenda of the WTO stalling, PTAs are primarily aimed to accelerate liberalisation of trade in regions. However, in parallel to the economic goals achieved through elimination of tariff and non-tariff barriers to trade, the new generation of PTAs contain so called WTO-X provisions, which promote policy objectives that are not discussed at the multilateral trade negotiations (Horn et al., 2010).

Trade policy, such as multilateral trade liberalization or PTAs, can have influence mitigation through the change in production structures of participants and non-participants. According to the terminology introduced by (Grossman and Krueger, 1991), trade liberalisation can affect the environment through three effects: scale (increased output and energy use harming the environment), composition (changes in the sectoral structure of the economy may raise or lower emissions comparative advantage), and technique (using less carbon-intensive technologies which is beneficial to the environment). In economic theory, the overall effect is ambiguous (Siebert, 1977; Copeland and Taylor, 1994). The decomposition of data into scale, composition and technique effects has been used to address the impact of trade liberalisation on the environment empirically. (Antweiler et al., 2001). Different approaches, based on gravity models, have been chosen by (Frankel and Rose, 2005) and (Kellenberg, 2008). On the whole, there is some evidence that freer trade is slightly beneficial to the environment.

According to the economic theory of international trade, regional trade agreements foster trade within regions and amongst member countries and (trade creation) they are detrimental to trade with third parties since trade with non-member countries is replace by intraregional trade (trade diversion). Trade diversion can lead to inefficiencies in the allocation of resources across the sectors of the economy. Although the impacts of trade creation and trade diversion have not been analysed theoretically with respect to their environmental impacts, conclusion by analogy implies ambiguity. Both pollution intensive industries 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 find weak evidence that the demand for dirty imports declined slightly.

Liberalizing trade in environmental goods and services can help to meet the challenge of global warming (WTO, 2011a). There are benefits of this in terms of the development and transfer of climate-friendly technologies and renewable energy, as well as in the trade of goods and services, spill over to the regional trade agreements (RTAs), which are negotiated within its framework (WTO, 2009). In addition to regulatory measures, national, regional or multilateral initiatives to deal with climate change involve the adoption by governments of price-based measures such as taxes and tariffs, market-based mechanisms as well as other measures, including subsidies subject to WTO rules and procedures (WTO, 2011c).

While tax mechanisms are contentious (see box on carbon leakage), trade liberalization in major trade regions has fostered processes that are relevant to climate change mitigation via the development of cooperation on climate issues. In this regard, (Dong and Whalley, 2010) and (Dong and Whalley, 2011) look at environmentally motivated trade agreements, but they find that their impacts, albeit positive, are very small.

On the other hand, an issue that is increasingly addressed in PTAs is the environment, which complements general provisions applicable to environmental measures taken. 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). A study shows that the impact of PTAs on environment is indirect rather than direct. This means that environmental benefits are not so much due to environmental provisions in PTAs as they are due as a result of trade liberalisation and its positive effects on investment and economic growth (Ghosh and Yamarik, 2006). Nevertheless, provisions contained in environmental chapters of PTAs have a positive impact on domestic environmental protection stimulating parties to accomplish environmental policies, enforce environmental laws and keep up high environmental standards (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).

There is a potential to expand PTA environmental provisions to specifically cover issues of climate policy concerns. General provisions may accommodate the need to address climate change mitigation. Environmental chapters of PTAs may include provisions on cooperation and capacity building under the UNFCCC, the Kyoto Protocol or a future international climate agreement. However, these potentials have not yet been sufficiently explored (Cottier et al., 2009). One of the few existing examples of enhanced bilateral cooperation relates to the promotion of capacity building for the purposes of implementation of the Clean Development Mechanism under the Kyoto Protocol provided for in Article 147 of Japan-Mexico Agreement for the Strengthening of the Economic Partnership. Similarly, PTAs could in the future include provisions on establishment of emissions trading schemes (ETSs) with mutual recognition of emissions allowances (to link national ETSs in a region) and carbon-related standards in general by PTA parties (Holmes et al., 2011). Climate policy-related provisions could also be a subject of PTA chapters on energy, investment, government procurement, as well as horizontal crosscutting issues related to bilateral/regional trade in goods and services. The latter include provisions on liberalisation of trade in environmental goods and services, carbon tariffs on exceptionally polluting products, border measures applied to processes and production methods (PPMs) linked to the carbon content of traded products and services, climate-policy related technical regulations and standards, as well as subsidies related to the promotion of climate-friendly products and technologies. Liberalisation of regional trade will follow a climate-friendly pattern if based on the regulatory differentiation among traded products linked to the processes and production methods (PPMs). Liberalization and regulation in environmental goods and services can help to meet the challenge of global warming providing benefits in terms of the development and transfer of climate-friendly know-how, technologies and renewable energy (WTO, 2009). 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 PPM-based tariff distinctions (Cosbey, 2004). The use of carbon tariffs and carbon-related border tax adjustments (BTAs) will address competitiveness and carbon leakage concerns of parties with emissions reduction systems (e.g. EU ETS) in place and stimulate parties without emissions reduction commitments to reduce greenhouse gas emissions. The implementation of carbon tariffs and BTAs in PTAs may require the use of benchmark methods to tracing emissions in final products (e.g. best available technology or predominant production methods), as well as designing adequate preferential rules of origin and tariff levels to avoid trade deflection effects (Holzer and Shariff, 2012). In promoting climate mitigation and adaptation goals, PTAs thus can go beyond climate policy cooperation provisions in environmental chapters.

The use of carbon trade restrictions in bilateral and plurilateral arrangements has a definite advantage over unilateral application, as it makes the risk of retaliations smaller (Holzer, 2010; Hufbauer et al., 2010). Measures taken under PTAs, however, have to be in compliance with obligations under the WTO Agreement. While PTAs constitute their own regulatory system of trade relations, the conclusion of PTAs and the choice of their forms, including a required level of trade liberalisation (e.g. "substantially all the trade" and substantial sectoral coverage requirements), are subject to WTO rules (Cottier and Foltea, 2006). As unilateral PPMs is a contentious issue in the WTO due to their infringement on sovereignty rights and the costs they inflict on developing countries and subject to the specific requirements of exceptions (Bernasconi-Osterwalder, 2006; Conrad, 2011), their use under PTAs is challenging from a WTO law perspective. The bilateral or plurilateral PTA approach, however, allows linkages with technology transfer. It provides greater flexibility in terms of the MFN requirement and reduces the likelihood of challenge of a measure in the WTO dispute settlement (Holzer and Shariff, 2012).

Overall, evaluations of the relationship between trade and climate change have raised concerns about the effect of trade policies on climate change mitigation (Weber and Peters, 2009; Nielsen, 2010). Yet, it is recognized that PTAs could play a useful role in providing a supplementary forum for bringing together a number of key players (Lawrence, 2008) and foster bilateral, regional and trans-regional environmental cooperation (Carrapatoso, 2008). With the current complexities of the UNFCCC negotiations and the unwillingness of countries to bring trade-related issues of climate policy to the WTO, 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).

In addition to PTAs, other instruments and institutions, both international and regional in character could contribute to mitigating and adapting to climate change. Among these are environment-focused institutions (i.e. UNEP), sectorially focused institutions (International Atomic Energy Agency, IAEA), energy-related institutions (International Energy Agency, IEA), and development-focused institutions (through multilateral development banks and other development institutions) (Michonski and Levi, 2010). However, cooperation on non-climate issues faces the challenge of meeting climate change demands with limited financing and a non-binding nature of agreements.

Finally, informal leader-level fora (Group of Twenty, G20) and international associations may exert an important role in processes leading to climate change mitigation. The Asia Pacific Economic Forum (APEC), which gathers the 21 leading economies in the Asia Pacific region, and produce 60% of global output in GHG, has established actions and initiatives on climate change, energy security and clean development. In 2007, APEC's Sydney Declaration on Climate and Energy, and the creation of the Asia-Pacific Partnership (APP) put technology development and transfer as central elements to their efforts. Yet, both initiatives rely on a voluntary non-legally binding approach and their significant impact on climate change mitigation efforts have been questioned (Lawrence, 2008).

### Regional Cooperation on Energy

Given the centrality of the energy sector for mitigation, regional cooperation in the energy sector could be of particular relevance. There are regional cooperation mechanisms on renewable energy sources (RES) and energy efficiency (EE) in different world regions that have relevance for mitigation of greenhouse gases, access to energy services and sustainable development.

Regional cooperation has the potential of effectively moving forward the process of diffusion of renewable energy and energy efficient technologies in situations where, for instance, stand-alone countries do not have the capacity to implement the necessary measures on their own in order to overcome barriers. They are also useful when coordination, harmonisation, experience exchange are required and/or common approaches in the context of a regional market bring benefits.

Regional cooperation on RES and EE typically emerges from more general regional and/or interregional agreements for cooperation at economic, policy and legislative levels. 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 and if they do, there is a lack of systematic implementation, adequate financial support and monitoring of those initiatives. Nonetheless, some initiatives have materialized and are making progress.

Regional cooperation mechanisms already implemented or currently being implemented have taken different forms depending, among others, on the degree of political cohesion in the region and the strength of economic ties between the participating countries. Thus, cooperation mechanisms range from the adoption of overarching common energy policies, strategies and targets to the establishment of institutions with regional focus, promoting and supporting the use of RES and EE potentials and the development of common regional policies or at least some degree of coordination and harmonisation of policies, strategies and actions. Some forms of interregional cooperation are also emerging, with industrialized countries supporting initiatives targeted at specific regions in the developing world.

Activities developed through regional cooperation encompass capacity building, development of investment projects, harmonisation of legislation and regulatory instruments, creation of regional support mechanisms for technology demonstration and deployment, best-practice exchange and know-how transfer as well as joint activities for the achievement of regional targets for RES and/or EE, among others.

Regional initiatives that aim at tapping opportunities in renewable energy sources and energy efficiency can contribute to low-carbon development in the regional energy systems, while providing for ancillary benefits in terms of security of energy supply, job creation, improving access to modern energy services, bringing environmental and economic benefits, etc. However, a number of barriers to regional and interregional cooperation in renewable energy and energy efficiency remain to be solved. Overcoming these barriers in order to achieve an effective implementation of regional cooperation in RES and EE requires efforts in a wide number of areas, such as:

- Garnering sustained political support for energy efficiency and renewable energy in the national governments and in the framework of broader regional cooperation agreements dealing with a plethora of issues requires long-term efforts and substantial political skills.
- Building and strengthening institutions capable of conceiving and implementing policies and programmes at the national and regional levels is a long-term process that needs to be tailored to specific circumstances in a given region,
- Developing legislative and regulatory frameworks that are compatible across countries
- Education and training of the necessary human capital

In what follows, some examples of existing regional cooperation mechanisms will be briefly examined, namely the implementation of directives on renewable energy resources in the European Union (European Commission, 2001, 2003, 2009b), and in South East Europe under the Energy Community Treaty (Energy Community 2005; 2008; 2010), the cooperation on renewable energy and energy efficiency in West Africa (ECOWAS, 2003; ECOWAS/UEMOA, 2005, 2006; ECREEE, 2010)and cooperation in EE and RES in South East Asia (ASEAN, 1999, 2004, 2010). The first, involved the most intense form of regional cooperation, will be discussed in some detail, while the others are covered in boxes.

### Regional Cooperation on Renewable Energy in the European Union

The legislative framework for renewable energy in the European Union (EU) has been set up through several directives of the European Commission adopted by EU Member States (European Commission, 2001, 2003, 2009b). The implementation of these directives has taken place as part of the process of integration of the EU member states, regarding the adoption of common policies on renewable energy. 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:

- DIRECTIVE 2001/77/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market (European Commission, 2001)

- DIRECTIVE 2003/30/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport (European Commission, 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 harmonisation of a number of legal and regulatory aspects and required actions by EU member states to improve the growth, development and access of renewable energy (e.g. R. Haas u. a. 2006; Reinhard Haas u. a. 2011; Harmelink u. a. 2006). While there was progress towards the targets in member states, this progress did not occur at the required pace (Rowlands, 2005; Patlitzianas et al., 2005; European Commission, 2009a; Ragwitz et al., 2012). Therefore, the European Commission decided to introduce a more rigorous and comprehensive legal framework for renewable energy including binding targets.

This led to the introduction of the "DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC" (European Commission, 2009b). In this directive, EU Member States have agreed to meet binding targets for the share of RES in their gross final energy consumption by the year 2020. The overall target set by the RES directive for the European Union is 20% of EU gross final energy consumption to come from renewable resources by the year 2020. The EU RES directive builds upon its two predecessors in the areas of renewable electricity and biofuels.

The RES Directive 2009/28/EC is part of the EU climate and energy package. This EU climate and energy package was agreed by the European Parliament and Council in December 2008 and became law in June 2009 (European Commission, 2008). The package comprises several binding legislative instruments to implement the so-called "20-20-20" targets as follows:

- A reduction in EU greenhouse gas emissions of at least 20% below 1990 levels
- 20% of EU gross final energy consumption to come from renewable resources
- A 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency.

Increasing the share of renewable energy sources in the gross final energy consumption of the European Union is one of the pillars of the EU climate policy to reduce greenhouse gases. 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 in comparison to a baseline scenario (Capros et al., 2010).

The RES directive includes the so-called cooperation mechanisms with the aim of fostering cooperation on the development of renewable energy sources between the member states in a cost-effective manner. The types of cooperation mechanisms foreseen by the RES directive are as follows (European Commission, 2009b; Klessmann, 2009, 2012; Ruokonen et al., 2010; Jansen et al., 2010; Klessmann et al., 2010):

- **Statistical transfers between Member States:** Statistical transfers refer to the possibility of one member state to transfer a specified amount of renewable energy to another member state. The transfer should not affect the achievement of the national target of the EU member state making the transfer.
- **Joint projects between Member States:** Two or more member states may cooperate in the realization of joint projects for the production of renewable electricity, heating and cooling.

- **Joint projects between Member States and third countries:** One or more member states may cooperate with a country outside the European Union in the realization of joint projects for the production of renewable electricity. In this case, it is required that the electricity is physically imported into the European Union. In addition, the third country should not provide any kind of support to the RES production, other than an investment grant.
- **Joint support schemes:** Two or more Member States can decide to jointly or partly co-ordinate their national support schemes for RES production. In such case, a certain amount of energy from renewable sources produced in the territory of one participating Member State can be counted towards the target of another participating country. The first joint support scheme between Sweden and Norway has entered into operation in January 2012. The two countries agreed to launch a common certificate-based support scheme for renewable electricity (Swedish Energy Agency (SEA), 2010; Jansen, 2011).

If developed and implemented, the cooperation mechanisms foreseen by the RES directive 2009/28/EC could foster a more optimal use of RES across the EU, with resulting benefits in terms of the economic efficiency of policies (Ragwitz et al., 2012; European Commission, 2012e).

The implementation of the EU directives for renewable energy and the achievement of the national targets in the member states have required considerable efforts and faced, and still faces, barriers in a number of areas (Held et al., 2006; Haas et al., 2011; Patlitzianas and Karagounis, 2011; Arasto et al., 2012). Still, progress has been made and the implementation of EU directives for renewable energy has contributed to advance the introduction of renewable energy technologies in the EU member states by setting national targets and providing a common legislative framework at the EU level (Cardoso Marques and Fuinhas, 2012). This comprehensive framework has also facilitated coordinated efforts across member states in a number of areas, while encouraging best-practice and know-how exchange and development of joint initiatives.

This regional cooperation in the field of renewable energy has taken place in the framework of a well-developed EU integration at the political, legal, policy, economic and industrial level. Only in the context of this close integration ties it has been possible to advance with the implementation of complex EU directives for renewable energy.

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Box 14.2. 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, on the one hand, and the Contracting Parties, namely, 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 discussed above (on electricity produced from renewable energy sources and on biofuels)

As a result, contracting parties to the energy community treaty have made some progress in the development of policy, legal, regulatory and institutional frameworks for the promotion of renewable energy sources (Energy Community, 2008; Mihajlov, 2010). Being acceding countries, candidate countries or potential candidate countries for accession to the European Union have strong incentives to promote renewable energy and energy efficiency in their territory.

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 progress in developing and implementing these enabling frameworks has been dissimilar across Contracting Parties. Although potentials for renewable energies appear sizeable, barriers to their development still abound. Thus, contracting parties still need to implement concrete strategies and support measures before renewables can make an important contribution to the regional energy supply and security (Mihajlov, 2010; Karakosta et al., 2011; Tešić et al., 2011; Lalic et al., 2011). Several analyses (EIHP, 2007; IEA, 2008; Energy Community, 2010a; Mihajlov, 2010; Lalic et al., 2011) have recommended the introduction of a stable and comprehensive legislative framework as a key element for a solid promotion of renewable energy sources in the Contracting Parties.

As a further development, in May 2009, the Energy Community started a Task Force on Renewable Energy (RE TF) with participation of the contracting parties. The RE task force investigates and proposes the modalities for a possible adoption of the EU renewable energy directive 2009/28/EC within the Energy Community Treaty. The potential adoption of the RES directive implies adaptation, reformulation and extension of a number of legislative and regulatory provisions by the Contracting Parties (Energy Community, 2010a; b).

An additional element has to do with the potential use of the cooperation mechanisms established by the RES directive by the Contracting Parties. The EU RES Directive (European Commission, 2009b, 2011b) states that in case the contracting parties to the EnCT adopt the directive, they would be able to make use of the cooperation mechanisms foreseen in the directive in the same conditions as the EU Member States. This paragraph opens possibilities for cooperation between contracting parties and EU member states in the development of RES investment projects. However, the precise legal conditions for the implementation of this passage of the RES directive remain to be determined.

Additional incentives for the use of renewable energy in the Contracting parties were provided by their accession to the Kyoto Protocol. The Energy Community Treaty (Article 13) envisaged accession to the Kyoto Protocol as a “soft-law” obligation. Nonetheless, all Contracting Parties, except the United Nations Interim Administration Mission in Kosovo (UMMIK), ratified the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol. With the exemption of Croatia, the Contracting Parties are non-Annex I Parties to the UNFCCC and non-Annex B Parties to Kyoto (Energy Community, 2008). (Montini, 2010) has examined the institutional, administrative and legislative characteristics for the implementation of the Kyoto protocol and, in particular, of the Clean Development Mechanism (CDM) in four selected Western Balkan countries (Albania, Macedonia, Montenegro and Serbia), which are contracting parties to the Energy Community Treaty. While a number of challenges remain, progress has been made in terms of institutional and legislative frameworks as well as regarding capacity building for the implementation of mitigation projects. With these developments, renewable energy projects in the Contracting Parties can also qualify as CDM projects.

The implementation of EU directives for renewable energy has provided a framework for the penetration of renewable energy in the Contracting Parties to the Energy Community Treaty (Renner, 2009, p. 20). In this case, the development of economic and political ties between this region and the European Union and the prospect of contracting parties of becoming EU member states in the future have contributed to a harmonisation of legal, policy and regulatory elements for the promotion of renewable energy. One of the main driving forces for the implementation of legislative frameworks for the promotion of renewable energy sources in these countries has been the potential prospect of a future admission into the European Union.

This is an example of regional cooperation in the context of a legally binding treaty of energy and environment. By means of the Energy Community Treaty, the European Union has exported its legislative frameworks on energy and environment to a neighbouring).

Box 14.3. Regional cooperation on energy access, renewable energy sources and energy efficiency in West Africa

The Economic Community of West African States (ECOWAS) was created in May 1975 by the Treaty of Lagos promoting economic integration. Member countries are Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, the Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo. The majority of these countries have a very low access to modern energy services and substantial levels of poverty (ECOWAS/UEMOA 2006).

The ECOWAS regional energy programme is part of the integration and economic development policy. The main objectives of the program are to strengthen regional integration and to boost growth through market development in order to fight poverty (ECOWAS, 2003, 2006). The energy protocol signed by member states provided a framework to strengthen regional cooperation on energy issues. (ECOWAS, 2003). Specifically, the energy protocol included provisions for member states to establish energy efficiency policies, legal and regulatory frameworks and to develop renewable energy sources and cleaner fuels. The protocol also encouraged ECOWAS member states to assist each other in this process.

In 2006, ECOWAS and the West African Economic and Monetary Union (UEMOA) adopted the white paper on access to energy services in rural and peri-urban areas (ECOWAS/UEMOA, 2005). The white paper formulated goals on energy access for ECOWAS, with the aim to ensure access to modern energy services to at least half the population living in rural and peri-urban areas by 2015. Other specific objectives were to strengthen regional integration with a view to fostering development and building capacities, to help harmonise political and institutional frameworks, and to develop coherent energy policies based on reducing poverty in rural and peri-urban areas and achieving the UN Millennium Development Goals (MDGs).

In the context of the white paper, renewable energy sources and energy efficiency were recognised as valuable instruments to achieve and enhance access to modern energy (ECOWAS/UEMOA, 2005). This role has also been explored by a number of other studies in West Africa (GTZ, 2009) and other regions as well (IEA, 2010a; Kuik et al., 2011; Rowlands, 2011; Pachauri et al., 2012; Bazilian et al., 2012).

The white paper also expressed the need for a regional agency for energy access that could support the achievement of the targets, among others by giving support to regional and national efforts on promoting the deployment of renewable energy and energy efficiency technologies (Brew-Hammond et al., 2006). In the process of the white paper implementation, ECOWAS member states established in 2010 the Regional Centre for Renewable Energy and Energy Efficiency (ECREEE). ECREEE is a specialized ECOWAS agency with the objective of creating framework conditions and an enabling environment for renewable energy and energy efficiency markets by reducing barriers in the ECOWAS region (ECREEE, 2010). Among others, ECREEE provides support to national activities, implements capacity building and awareness raising programmes, promotes investment in these areas and coordinates the development of regional energy efficiency and renewable energy policies.

The ECOWAS regional policies have move forward the integration of energy access, renewable energy and energy efficiency into the strategic-development framework of the region. Still, a number of barriers at the institutional, technology, policy, public acceptance and finance, among others, need to be overcome for technologies to be deployed. The introduction of sustainable uses of renewable energy and energy efficiency in West Africa support the implementation of mitigation and adaptation strategies by making development compatible with climate change challenges (Gupta and Ivanova, 2009; UN AGECC, 2010; Moomaw et al., 2011; Rowlands, 2011). In addition, their contribution to development helps increasing the capacity of these countries to adapt to climate change (Davidson et al., 2003; Klein et al., 2007). At this stage, it is hard, however, to tell whether this initiative will eventually realize its potential and contribute to coordinated activities in the energy sector to promote mitigation.

Box 14.4. Regional Cooperation in RES and EE in South East Asia

ASEAN, founded in 1956, currently includes Indonesia, Malaysia, the Philippines, Singapore, Thailand, Brunei Darussalam, Vietnam, Laos, Myanmar and Cambodia. Regional cooperation on energy started in 1975 after the oil shocks in 1973 and concentrated initially on oil. Thereafter, ASEAN expanded its energy cooperation through a number of bi-lateral and regional agreements, protocols and organizational instruments (Kneeland et al., 2005). Regional cooperation on energy issues has also been extended to other countries and economic blocks outside the region, for instance to the ASEAN +3 group, covering the ASEAN member countries, China, Japan and the republic of Korea (Cabalu et al., 2010).

As part of the regional energy cooperation, the ASEAN-EC Energy Management Training and Research Center (AEEMTRC) 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). ASEAN's Center on Energy (ACE), the current denomitation, was created in 1999, following its predecessor the AEEMTRC. The ACE plays the role of facilitator, coordinator and information clearinghouse to enable the implementation of policy of the ASEAN Ministers on Energy Meeting (AMEM) and Senior Officials on Energy Meeting (SOME). As part of its activities, the ACE is involved in the preparation of ASEAN Plans of Action for Energy Cooperation-APAEC (ASEAN, 1995, 1999, 2004, 2010), which encompasses the actions that ASEAN undertakes in a number of areas of energy cooperation. Among other activities, ACE coordinates regional networks on energy efficiency and renewable energy. However, the ACE has mainly an advisory role and no clear mandate to implement actual energy projects (Poocharoen and Sovacool, 2012).

Regional cooperation on energy efficiency and renewable energy 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, 2010b; c). These cooperation activities take place in the context of an active regional cooperation on energy encompassing, among others, oil security, transnational natural gas pipelines and electricity interconnections (ASEAN, 1995, 1999, 2004, 2010; Sovacool, 2009). Therefore, cooperation on renewables and energy efficiency plays a comparatively more marginal role.

Cooperation encompasses a variety of activities such as capacity building, creation of networks for exchange of experience and best practice, technology transfer, development and implementation of legislative and regulatory frameworks and implementation of policy programmes and measures. Some specific activities undertaken in the framework of the APAEC plans are as follows (ASEAN, 2004, 2010):

- Energy labelling program for energy efficient products under the ASEAN Standards and Labelling Program for magnetic ballasts, refrigerators, air-conditioners, and motors.
- Promotion of renewable energy through projects on small hydropower, co-generation, information networking for promotion of renewable energy sources, the green independent power producers network and ASEAN small-scale renewable energy program, among others.

Potentials for renewable energy and energy efficiency are sizeable in the ASEAN region (Lidula et al., 2007; IEA, 2010c). Their development has been dissimilar across member states with a number of barriers still to be surmounted (USAID, 2007; Sovacool, 2009; IEA, 2010c). Nonetheless, the regional cooperation on renewable energy and energy efficiency in the ASEAN region has shown continuity and member states have remained committed over the last decades (Yu, 2003; Karki et al., 2005; Kneeland et al., 2005; Carlos and Ba Khang, 2008). Regional networks have grown and consolidated and joint projects have been pursued with a long-term perspective. 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 and the region has made progress in the penetration of renewable energy and energy efficient technologies (Kneeland et al., 2005; Sovacool, 2009; IEA, 2010c). For instance, during the APAEC 2004-2009, the regional 10% target to increase the installed renewable energy based capacities for electricity generation was met (ASEAN, 2010).

Despite these developments, support for renewable energy and energy efficiency differs substantially across member states and some of them do not have sufficient support measures in place. The governance of the regional cooperation process and implementation of support policies needs to be advanced and/or substantially improved (Sovacool, 2010; Poocharoen and Sovacool, 2012). Regulatory frameworks and policies require harmonisation across countries and coordination of a wide network of stakeholders and the effectiveness of support policies, and especially financial support mechanisms must be improved (Lidula et al., 2007; Sovacool, 2010).

Moreover, the ASEAN region is still heavily reliant on oil and coal to supply energy needs. The use of renewable energy sources and energy efficiency would need to be scaled up substantially in the future, in order to make a sizeable contribution to greenhouse gases (GHG) mitigation and strengthening regional cooperation would support technology deployment (Vithayasrichareon et al. 2012). Greenhouse gas emissions from the energy sector have been growing at a fast pace in the last decades and are expected to continue a dynamic growth as the region´s demand for energy grows (ADB, 2009; IEA, 2010c; ACE et al., 2011). $CO_2$ emissions from energy, specifically, are growing from low initial levels but at a very rapid pace (Luukkanen and Kaivo-oja, 2002).

According to e.g. (ADB, 2009) and (Das and Ahlgren, 2010), mitigation potentials through the sustainable use of renewable energy sources and energy efficiency appear substantial in the region. (ACE et al., 2011) developed scenarios for the ASEAN energy system until the year 2030. According to their calculations, a business-as-usual scenario with substantial growth of coal, oil and gas but also growth of renewables would lead to $CO_2$ emissions of about 895 million tons of Carbon equivalent (Mt-C) in 2030, compared to approximately 250 million tons of Carbon equivalent (Mt-C) in 2007. An alternative scenario with some additional use of renewables and nuclear power and including substantial energy efficiency measures would lead to about 679 million tons of Carbon equivalent (Mt-C) in 2030, 24% lower than that of the business-as-usual scenario.

### 14.4.2.3 Regional Examples of Synergies and Trade-Offs Between Adaptation and Mitigation

Integrated approaches to mitigation and adaptation can indeed provide very promising options, which can be primarily identified in those 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”). (Locatelli et al., 2011), (Vignola et al., 2009)

The examples contained in boxes 14.1 and 14.2 below indicate the need for specific national, regional and international policies and actions to achieve the benefits resulting from possible mitigation and adaptation synergies and to avoid trade-offs in the forestry sector. The examples also reflect the need to strengthen local, national and regional capacities. In relation to international climate policies the UNFCCC plays a key role. The COP 16 of the UNFCCC, in Cancun, agreed guidance and safeguards for REED+ implementation. They stipulate that REDD+ activities should be implemented, *inter alia, “*in the context of sustainable development and reducing poverty, while responding to climate change", and "to be consistent with the national adaptation needs of the country" (UNFCCC, 2011).

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Box 14.5. 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 (Somorin et al., 2011). These countries have a population of 122 800 000 inhabitants. Congo Basin carbon stocks are large, representing 8.7 per cent of forest carbon stocks of the world. This large amount of carbon creates opportunities to REDD+, as potential mitigation option. 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 of persons that directly depend from forests. (FAO and ITTO, 2011)

(Ghazoul et al., 2010) have argued that it is important to recognize and appropriately compensate the full range of economics, social and political costs of REDD+. Non-timber forest products, such food, water, energy and health, including the market of some of them, normally serve as safety nets for forest communities, and have implications for climate change livelihood adaptation in the Congo (Nkem et al., 2010). These authors argue that REDD+ and other market mechanisms should be considered with caution. They do not necessarily guarantee to enhance adaptation and substitute the community dependence on forests that currently serve as traditional safety nets, resulting from the inseparable role of forests for healthcare, nutritional base and economic wellbeing of people.

(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 to independent mitigation and adaptation policies and others to integrated policies. The authors concluded that the Congo Basin policy community has the task 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 not to be based solely in reducing carbon emissions. The authors also suggested 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.

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Box **14.6**. **Forest activities in Latin America**

Several forest mitigation and adaptation projects in Latin America were assessed to study the interrelationship between mitigation and adaptation. (Locatelli et al., 2011) concluded that mitigation and adaptation have been treated separately. Similar studies were conducted in many projects and activities in tropical forests, including from other regions, by (Reyer et al., 2009) and (Guariguata et al., 2008). They found that consideration of adaptation in forest mitigation projects is insufficient. All these authors and (Ravindranath, 2007) argued on the need to jointly include adaptation and mitigation in forest projects.

To date, carbon sequestration and forest conservation projects in Latin America have mixed results so far, causing indirect social benefits, such as diversifying income among participants, but also negative outcomes, such as reducing livelihood options and impacting biodiversity. These findings were identified by (Bailis, 2006) after the assessment of multiple on-going projects aimed to avoid deforestation and to afforestate/reforestate. The insufficiency of existing financing mechanisms was also identified as a problem to be addressed. The author suggested incorporating payments for additional benefits that can accrue from successful projects, including the provision of environmental services like biodiversity conservation and watershed management, as well as other social goods. Measures to mainstream adaptation and mitigation actions into forest projects also were suggested through specific national and international policies, development of social and environmental standards to be included in guidelines for both adaptation and mitigation forest projects, increased knowledge and research on possible synergies and trade offs for the forestry sector at all levels (Locatelli et al., 2011) , (Guariguata et al., 2008).

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

Box 14.7. The Great Green Wall of the Sahara and the Sahel Initiative (GGWSSI)

Fifteen km wide and stretching 8000 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. And perhaps most importantly, it will foster political stability through cooperation at all scales from the international to the community

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The GGWSSI is a priority action of the Africa – EU Partnership on Climate (European Union, 2011) and is proposed to catalyse “sustainable development and poverty reduction in the desert margins north and south of the Sahara” (African Union 2002) 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 firstly to adaptation and secondly to mitigation to climate change through SLM practices.

SLM 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),(FAO, 2008), thus will contribute to maintaining and enhancing productivity. The techniques which increase soil organic carbon content (SOC) are critically important (including the use of composts, mulch, zaï, low / zero tillage, conservation agriculture, rotations and crop diversification; holistic rangeland management; agroforestry and silvopastoralism), as restoration of SOC improves soil structure and consequently functioning, increasing rainfall infiltration and its capacity to store both plant nutrients and rainwater (Woodfine and Sperling, 2008). Trees contribute to adaptation, as they provide vital shade (for crops, livestock and people), fruit, fodder, forage, fuel and can reduce storm damage. Mitigation refers to a human intervention to reduce the "sources" of greenhouse gases or enhance the "sinks" that remove carbon dioxide from the atmosphere. SLM practices contribute to mitigating climate change, particularly through sequestering carbon (in trees, other above ground biomass and also, of particular importance in drylands, in soils), reducing emissions of carbon dioxide (protecting existing above ground biomass and reducing soil degradation), methane (improved livestock productivity, increased off-take) and nitrous oxide (biological nitrogen fixation using leguminous plants and trees, avoiding need for fertilizers); also reducing use of fuel (low / zero tillage and conservation agriculture) and agrochemicals.

### 14.4.3 Technology-Focused Agreements and Cooperation Within and Across Regions

While knowledge-sharing and joint RD&D agreements are possible in bilateral, regional, and larger multilateral frameworks (de Coninck et al., 2008), regional approaches to technology cooperation for climate mitigation may evolve for a variety of reasons. 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 surrounding a particular regionally appropriate technology. Other regional agreements, however, frequently do not conform to traditional geographically defined regions, but rather may be motivated by a desire to transfer technological experience. 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 European Union, typically include countries from the North sharing such experience with countries from the South, it is increasingly common for such 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.There has been limited assessment of the efficacy of regional agreements; such assessments when available are reviewed below.

#### *14.4.3.1 Regional Technology-Focused Agreements*

Few regional technology-focused agreements conform to traditional geographically-defined regions, however the Energy and Climate Partnership of the Americas (ECPA), initiated by the United States, 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 including advanced power sector integration and cross border trade in electricity, advancing renewable energy, and the establishment of an Energy Innovation Center to serve as a regional incubator for implementation and financing of sustainable energy innovation (ECPA, 2012). 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).

Within the EU region, there are several agreements that aim to promote low carbon technology, including the EU Renewables Directive and the EU Directive on the geological storage of carbon dioxide (European Commission, 2009a; b). 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 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).

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)..

Asia-Pacific Economic Cooperation (APEC) has an Energy Working Group (EWG), launched in 1990 that 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: one on Biofuels and the other on Energy Trade and Investment (ETITF) (APEC Secretariat).

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), 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).

#### *14.4.3.2 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 come together because they shared a specific geography but rather because of their common interests surrounding various climate mitigation technologies, as well as perhaps 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; Lawrence, 2009; Karlsson-Vinkhuyzen and Asselt, 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 April 5, 2011, though some projects have reportedly been continued under other governmental agreements(US Department of State, 2011).

Another technology agreement that brings together clean energy technology experience from different regions is the Clean Energy Ministerial (CEM). First announced by the US Department of Energy at the Copenhagen climate negotiations in 2009, 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 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 greenhouse gas 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, 2011a).

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's 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, and includes 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).

#### *14.4.3.3 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, 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, and this report does not provide an include list 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 cooperation 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 includes 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); and an Energy Dialogue Forum with South Africa with a focus on cooperation on coal, clean coal and CO2 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 greenhouse gas emitters, and such talks can help to promote US-China understanding and help to 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).

#### *14.4.3.4 South-South Technology Cooperation Agreements*

There are increasingly 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, and 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 China Science and Technology Exchange Centre (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, funded by China's Ministry of Science and Technology, initiated in April 2012 (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 least developed countries. 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).

### 14.4.4 Regional Mechanisms for Investments and Finance

#### *14.4.4.1 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 which will be for developing countries, roughly evenly distributed between the large emerging economies and the remaining developing countries (International Energy Agency, 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 to less than 450 ppm CO2e (International Energy Agency 2009). The UNFCCC estimates that 80% of the capital needed to address climate change issues will come from the private sector — both businesses and consumers (UNFCCC, 2007; UNDP, 2011).

At a regional level, 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, for example, 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).

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 14.10). It also found that regional cooperation provides the greatest opportunity for analysing and understanding the problems of, and designing strategies for coping with, the impact of climate change and variability (United Nations 2010).

**Table 14.10:** Regional composition of actual MBD climate change financing

| Geographic | ACTUAL 2006 | ACTUAL 2007 | ACTUAL 2008 | ACTUAL 2009 | TOTAL 2006-2009 | Shares 2006-2009 |
|---|---|---|---|---|---|---|
| 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). http://www.un.org/wcm/webdav/site/climatechange/shared/Documents/AGF_reports/Work_Stream_4_International%20Financial%20Institutions.pdf

## 14.5 Taking Stock and Options for the Future

The discussion above has suggested that a regional approach to the issue of 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:

a) The mitigation challenge is dramatically different by region. The chapter has brought out that one possibility is to group countries into three regional groupings. On the one hand, there are advanced industrial countries with very high per capita emissions, high institutional and technological capacity, and moderate growth prospects. Effective mitigation at the global level will require this group of countries to drastically reduce per capita emissions by drastically reorienting 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 of countries 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 this group of countries is going to be critical, particularly since the current development paths will lead to rapidly rising emissions in a business-as-usual scenario. The opportunities for re-orienting the economies towards less carbon-intensive growth are there but becoming increasingly costly as carbon-intensive technologies, settlement and consumption patterns are locked in, while the capacity to re-orient the economic structure is also growing but not everywhere very strong. 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; but weak institutional, technological, and financial capacities will make it very different for these countries to embark on such a low-emissions growth strategy unless such a strategy receives strong international institutional, technological, and financial support. Clearly, this suggests that no region will have it particularly easy to address the mitigation challenge. This suggestions two ways to investigate this further. First, it is particularly fruitful to investigate how countries within a region have been able to differ greatly in addressing these challenges. Understanding this 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 different challenges discussed above.

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, which despite its flaws represents the most advanced approach to addressing the mitigation challenge at the regional level, initiatives in other regions have been much less ambitious and also much less 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 regional mechanisms investigated.

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 engaging regional bodies more in international agreements that deal with mitigation such as technological transfer and finance for mitigation. Successes in such ventures will likely depend; however, on greatly strengthen the capacity and decision-making power of regional mechanisms to take on such an enhanced role.

## 14.6 Gaps in knowledge and data

[Note from TSU: Section to be completed for the Second Order Draft]

## 14.7 Frequently Asked Questions

[Note from TSU: FAQs will be presented in boxes throughout the text in the Second Order Draft]

**FAQ 14.1** How are regions defined in the AR5?

For the purposes of this chapter, only supra-national (i.e. in between the national and global level) regions are considered. Sub-national regions are addressed in chapter 15. 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), Japan, Aus, NZ, (JPAUNZ), 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 IAMs (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 as defined by the United Nations.

**FAQ 14.2** Why is the regional level important for analyzing and achieving mitigation objectives? (14.1, 14.2)

Thinking about mitigation issues 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, level of economic development, patterns of urbanization and industrialization, access to finance and technology, and more broadly capacity to develop and implement various mitigation options.

There is a second reason why regions matter. For many decades, regional integration has been a powerful force in the global economy and politics. From loose free trade areas in many developing areas to deep integration involving monetary union in parts of the EU, these regional integration initiatives have built up platforms of cooperation between countries that could become the central institutional forces to undertake regionally coordinated mitigation activities (within the framework of a global agreement or outside of one). Some regional integration initiatives, most notably the EU, have already used deep cooperation to promote a carbon trading scheme and to devise regional policies on renewable energy and biofuels; others have focused largely on trade integration which might similarly have repercussions for the mitigation challenge; many regional initiatives have also been supported by regional development and aid initiatives. It will be critical to analyse to what extent these regional activities have been able to effectively promote mitigation activities and what options exist to build on these platforms of regional cooperation to implement further mitigation actions.

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

Opportunities and barriers for mitigation differ greatly by region. On average, it is the case that those regions with the greatest opportunities to leapfrog to low-carbon development (such as countries in Sub Saharan Africa) are facing particularly strong institutional and financial constraints to undertake the necessary investments; often they also lack access to the required technologies or the ability to implement them effectively. Conversely, those regions with the greatest technological, financial and capacity advantages face much reduced opportunities for low-cost strategies to move towards low-carbon development.

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

Apart from the European Union (with its Emissions Trading Scheme and its energy policies), regional cooperation has, to date, not played an important role in further a mitigation agenda. While many regional groupings have developed initiatives to promote mitigation at the regional level directly, and many regional cooperation agreements in other areas (such as trade, energy, and infrastructure) influence mitigation indirectly, the influence of these initiatives and policies is currently small. But regional cooperation could play an enhanced role in promoting mitigation in future, particularly if explicitly incorporates mitigation objectives in trade, infrastructure, and energy policies and it promotes direct mitigation action at the regional level. In this sense, 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).

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